ASSESSMENT OF NEWFOUNDLAND AND LABRADOR SNOW CRAB

Image : Snow Crab

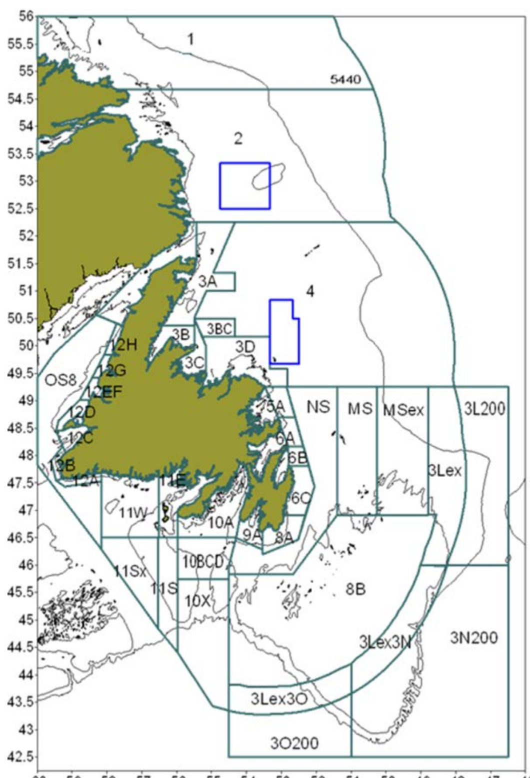

Figure 1. Newfoundland and Labrador Snow Crab Management Areas (CMAs). Blue boxes show trawling and gill-netting closures.

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 2,800 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 Div. 2HJ3KLNOP4R, DFO inshore trap surveys in Div. 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 18-20, 2014 on Newfoundland and Labrador Snow Crab Assessment in St. John's, NL. Participants included DFO scientists, fisheries managers, and representatives from industry, the Provincial and Nunatsiavut governments, Aboriginal interests, and academia. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Total landings have remained at 50,000–53,000 t since 2007. However, Div. 3LNO has accounted for a steadily increasing percentage in recent years, from about half in 2009 to two-thirds in the past two years.
- The overall exploitable biomass has changed little since the mid-2000's. However, both the trap and trawl surveys indicate that Div. 3LNO has accounted for an increased percentage in recent years, from about 40 % in 2008 to 75 % in 2013.
- Overall, recruitment is expected to decline in the short term (2-3 years).
- A recent warm oceanographic regime suggests weak recruitment in the long term.

Divisions 2HJ

- **Landings** decreased by 45 % since 2008, to 1,380 t. The TAC has not been taken in the past 3 years.
- **CPUE** declined steadily by half from 2008 to 2011, was unchanged in 2012, and increased in 2013.
- The **exploitable biomass**, as indicated by the post-season trawl survey, declined steadily from 2006 to 2011 and has changed little since.
- **Recruitment** declined from 2006 to 2011 and changed little since; prospects are uncertain in the short term (2-3 years). The post-season trawl survey pre-recruit index has changed little since 2005.
- A recent warm oceanographic regime suggests weak **recruitment** in the **long term.**
- The **exploitation rate index** increased steadily from 2007 to 2012 before decreasing in 2013.
- The **pre-recruit fishing mortality rate index** was at its highest level since 2004 during 2011 and 2012 but decreased by more than half in 2013. The **percentage of the catch handled and released** in the fishery decreased from 35 % in 2012 to 20 % in 2013, implying a decrease in pre-recruit mortality.
- Maintaining the current level of fishery removals would likely have little effect on the **exploitation rate** in 2014.

Division 3K Offshore

- **Landings** most recently peaked at 13,300 t in 2009 but declined by 51 % to 6,500 t in 2012 before increasing to 6,600 t in 2013. **Effort** most recently peaked in 2009 and has since declined by 33 %.
- **CPUE** declined by half from 2008 to 2011 and increased slightly since 2012.
- The **exploitable biomass**, as indicated by the post-season trap and trawl surveys, declined by more than two thirds since 2008.
- **Recruitment** declined after 2008 and prospects remain poor in the short term (2-3 years). Post-season pre-recruit biomass indices from both trap and trawl surveys have decreased by about 70 % since 2008.
- A recent warm oceanographic regime suggests weak **recruitment** in the **long term.**

- The trawl survey-based **exploitation rate index** was at its highest level since 2004 in 2010-2011. It decreased in 2012 before increasing again in 2013.
- The **pre-recruit fishing mortality rate index** increased from 2007 to 2011 but decreased in 2012 before increasing again in 2013. The **percentage of the catch handled and released** in the fishery decreased from about 20 % in 2012 to about 10 % in 2013, implying a decrease in pre-recruit mortality.
- Maintaining the current level of fishery removals would likely result in an increase in the **exploitation rate** in 2014.

Division 3K Inshore

- **Landings** declined by 34 % from 2,900 t in 2009 to 1,900 t in 2012 and 2013. **Effort** increased by 70 % from 2008 to 2011 before declining by 40 % to 2013.
- **CPUE** declined by more than half from 2008 to 2011, and increased over the past two years.
- The **exploitable biomass**, as indicated by the post-season trap survey, decreased from 2007 to 2009 and has since fluctuated.
- **Recruitment** prospects are poor in the short term (2-3 years). The post-season trap survey pre-recruit biomass index decreased by more than half in 2013, to its lowest level in the time series.
- The post-season trap survey-based **exploitation rate index** has changed little throughout the time series.
- Data are insufficient to estimate **the pre-recruit fishing mortality rate index**.
- Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2014.

Divisions 3LNO Offshore

- **Landings** decreased by 11 % from 24,500 t in 2006 to 21,900 t in 2009 and then increased by 20 % to 26,300 t in 2013. Effort increased by 83 % from 2000 to 2008 and has since declined by 32 %.
- VMS-based **CPUE** declined to its lowest level in 2008, and has since increased steadily to its highest level in the time series.
- 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. However both indices have since increased slightly.
- Biological data from several sources indicate that **recruitment** will likely decrease in the short term.
- A recent warm oceanographic regime suggests weak **recruitment** in the **long term**.
- The **exploitation rate index** decreased marginally in 2013.
- The **pre-recruit fishing mortality rate** index decreased from 2008 to 2011, increased in 2012 and changed little in 2013. The percentage of the catch handled and released in the fishery decreased from about 20 % in 2008 to 9 % in 2013, implying a decrease in pre-recruit mortality.

- Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2014.

Division 3L Inshore

- **Landings** increased by 19 % from 6,100 t in 2005 to 7,300 t in 2010, and have since changed little, at 7,600 t in 2013. **Effort** increased from 2008 to 2010 and has since declined steadily.
- **CPUE** increased sharply since 2011 to its highest level.
- The post-season trap survey index suggests that the **exploitable biomass** increased steadily since 2008 to its highest level in the time series, with considerable variability among management areas.
- **Recruitment** has declined slightly since 2010, although there is considerable variability among management areas, and is expected to decline further in the short-term (2-3 years). The post-season trap survey pre-recruit biomass index decreased in 2013.
- 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 rate index**.
- Maintaining the current level of fishery removals would likely result in little change in the exploitation rate in 2014.

Subdivision 3Ps Offshore

- **Landings** almost doubled from 2,300 t in 2006 to a peak of 4,200 t in 2011, before declining by 16 % to 3,500 t in 2013. **Effort** increased by 76 % from 2008 to a record high level in 2013.
- **CPUE** increased from 2005 to 2009 and has steadily declined since, to about its previous lowest level.
- The **exploitable biomass**, as indicated by both the spring trawl survey and the post-season trap survey indices, increased steadily from 2006 to 2009 before declining rapidly to its lowest level in 2013.
- **Recruitment** has recently declined and is expected to decline further in the short term (2-3 years). Pre-recruit biomass indices from both trap and trawl surveys declined rapidly from 2009 to their lowest levels in 2013.
- A recent warm oceanographic regime suggests weak **recruitment** in the **long term**.
- The spring trawl survey-based **exploitation rate index** more than doubled from 2009-2012, before doubling again in 2013.
- The **pre-recruit fishing mortality rate index** has increased steadily since 2009 to about its previous highest level.
- Maintaining the current level of fishery removals would increase the **exploitation rate** in 2014.

Subdivision 3Ps Inshore

- **Landings** more than tripled from 700 t in 2005 to 2,500 t in 2011 and remained at that level since. **Effort** declined substantially in 2005 and has since varied without trend.
- **CPUE** increased steadily from 2005 to 2010, changed little in 2011–2012, then decreased slightly in 2013.
- The **exploitable biomass,** as indicated by the post-season trap survey index, increased substantially between 2006 and 2010, changed little in 2011-2012, then decreased by half in 2013.
- **Recruitment** decreased substantially in 2013 and is expected to remain low in the short term (2-3 years). The **pre-recruit biomass** has been declining since 2007.
- The post-season trap survey-based **exploitation rate index** has changed little in the past six years.
- Data are insufficient to estimate a **pre-recruit fishing mortality rate index.**
- Maintaining the current level of fishery removals would increase the **exploitation rate** in 2014.

Division 4R Offshore

- **Landings** declined by 83% from 190 t in 2007 to a historical low of 30 t in 2010, and increased to 300 t in 2013. **Effort** increased by almost a factor of 7 since 2010. The TAC has not been taken since 2002.
- VMS-based **CPUE** declined from 2004 to its lowest level in 2009 before increasing to its highest value in the time series in 2013.
- The **exploitable biomass** remains low relative to other areas.
- **Recruitment** prospects are uncertain in the short term (2-3 years).
- A recent warm oceanographic regime suggests weak **recruitment** in the **long term**.
- Data are insufficient to calculate the **exploitation rate** and **pre-recruit fishing mortality rate indices.**
- The effect of maintaining the current level of removals on the **exploitation rate** in 2014 is unknown.

Division 4R Inshore

- **Landings** declined by 80% from 930 t in 2003 to a historical low of 160 t in 2010 and have since more than tripled to 600 t in 2013. **Effort** declined by 69% from 2004 to 2010 and doubled in 2011 before declining by 34% to 2013. The TAC has not been taken since 2002.
- **CPUE** increased sharply since 2010 to a record high level in 2013.
- The **exploitable biomass**, as indicated by the post-season trap survey index, fluctuated from 2006 to 2010, was three times as large in 2011, and changed little in 2012 before decreasing in 2013.

- **Recruitment** prospects are unfavourable in the short term (2-3 years). The trap survey **pre-recruit biomass index** more than doubled in 2009 and changed little until it decreased substantially to remain below pre-2009 level during 2012-2013.
- The post-season trap survey-based **exploitation rate index** decreased in 2012 and changed little in 2013.
- Data are insufficient to estimate a **pre-recruit fishing mortality rate index**.
- Maintaining the current level of fishery removals would increase the **exploitation rate** in 2014.

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 (Div. 2J3K4R) and at slightly older ages in cold areas (Subdiv. 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 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 (Crab Management Area 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 Div. 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 Div. 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.

Licenses supplemental to ground fishing 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 2,800 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 VMS was fully implemented in offshore fleets in 2004, to ensure compliance with regulations regarding area fished.

Landings for Div. 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 where the TAC was not taken. Total landings have remained at 50,000–53,000 t since 2007. However, Div. 3LNO has accounted for a steadily increasing percentage in recent years, from about half in 2009 to two-thirds in the past two years.

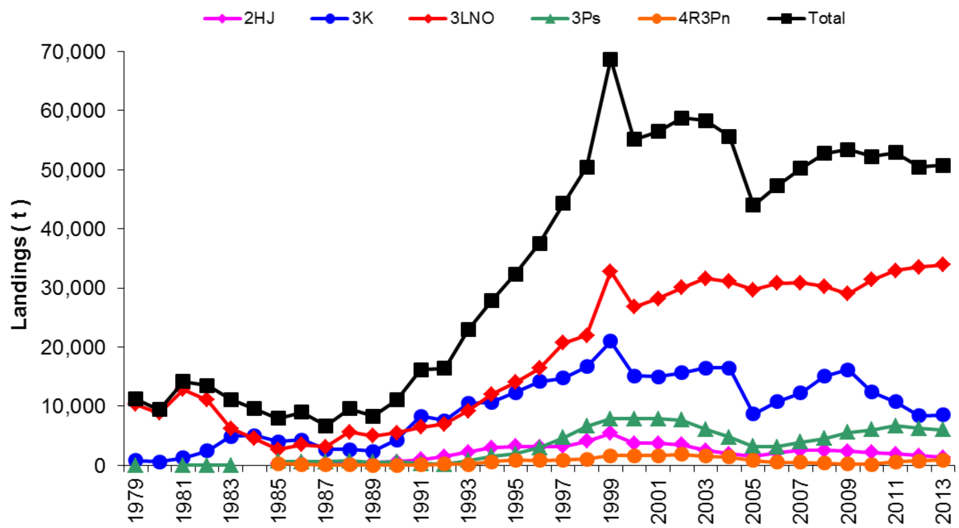

Figure 2. Trends in landings (t) by NAFO Division and in total.

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 (Div. 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.

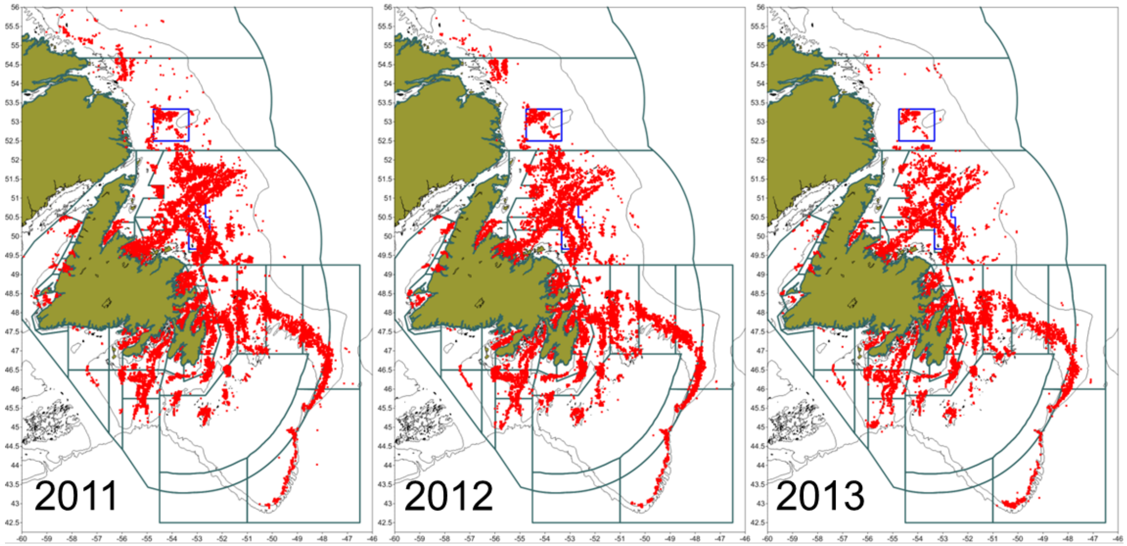

Figure 3. Spatial distribution of commercial fishing effort during 2011-13.

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 Div. 2HJ3KLNO, during spring in Subdiv. 3Ps, and during summer in Div. 4R. A Campelen shrimp trawl has been used in these multi-species surveys beginning in 1995 (Div. 2HJ3KLNOPs) or 2004 (Div. 4R). Spring trawl surveys are considered to be 'pre-fishery' surveys, although they overlap with much of the Subdiv. 3Ps fishery in recent years. These spring surveys are thought to be less reliable than fall (post-fishery) surveys because some population components are relatively poorly sampled during spring when mating and molting take place. 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 Div. 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 Div. 2HJ) and little element of human error. Bottom temperature data from DFO 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 (Div. 3KLPs4R); there is no distinction between inshore and offshore areas in Div. 2HJ (Fig. 1). Div. 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 pre-season (Subdiv. 3Ps), summer post-season (Div. 4R), and fall post-season (Div. 2HJ3KLNO) bottom trawl surveys provide data that are used to predict changes in biomass and recruitment for the upcoming fishery in the same year (Subdiv. 3Ps) or the following year (Div. 2HJ3KLNO4R). 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) from the spring and fall surveys, but is based on all legal-sized crabs from the Div. 4R summer survey (where chela height is not measured). This index 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 (Div. 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, but is based on all males 76-94 mm CW from the Div. 4R summer survey. 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. However, there is little evidence of annual progression of smallest males (<40 mm CW) to successively larger sizes from spring or fall multi-species survey size frequency data. Longer-term (i.e., >3 years) recruitment prospects are inferred based on effects of ocean climate variation on early survival (Dawe et al., 2008, Marcello et al., 2013), as reflected in the relationship of biomass indices (CPUE and survey exploitable biomass indices) with ocean climate indices from 6-10 years earlier. Two thermal indices are used in each offshore area. A mean bottom temperature index is derived using fall (Div. 2J and 3K) or spring (Subdiv. 3Ps) survey data from shallow-water small crab habitat on the banks and in nearshore areas for Div. 2J (<200 m), 3K (<300 m), and 3Ps (<100 m). The temperature index for Div. 3LNO is the January-June mean bottom temperature at 176 m, from Station 27 oceanographic monitoring station, located within the inshore branch of the Labrador Current, 10 nautical miles (na. mi.) off Cape Spear, NL. The second index is a small crab habitat index, represented by the percentage of the bottom area covered by cold water. This index is derived using data from fall surveys based on temperatures <2°C in the deep warm northern areas (Div. 2J and 3K), whereas they are derived using data from spring surveys in the shallower colder southern areas, based on temperatures <1°C (Div. 3LNOPs). Best relationships were found at lags of 6-8 years in all areas except Div. 3LNO where a lag of 10 years gave the best fit for one relationship. Relationships were found to be consistent between CPUE and survey biomass indices, so they are shown here using only the longer time series of CPUE indices.

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 the previous assessment, 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 (ERI) which is defined as:

ERI=Landings/EBI

Where;

EBI is the exploitable biomass index from the most recent trap or trawl survey.

Trends in fishery-induced mortality on pre-recruits are inferred from changes in the pre-recruit fishing mortality rate index (PFMI). This index reflects an unknown mortality on released pre-recruits and is defined as:

PFMI=S(Cr/TBI)

Where;

Cr is the estimated catch of undersized (<94 mm CW) males (adolescents and adults) caught and released in the fishery, based on observer at-sea sampling

And;

TBI is the total biomass index of pre-recruits (>76 mm CW adolescents) plus undersized (76-94 mm CW) adults from the most recent trawl survey

And;

S is a scaling factor to account for low observer coverage, defined as;

S=Total Landings/Total catch of exploitable crabs kept from observer at-sea sampling

Pre-recruit fishing mortality rate indices were not estimated for inshore areas due to inadequate observer coverage.

The percentage (by weight) of the total catch handled and released, as estimated from observer data, is interpreted as an index of wastage of pre-recruits. Mortalities on pre-recruits, including wastage, will impact short-term (about 1-3 years) recruitment. Also, mortality on small (<95 mm CW) males may adversely affect insemination of females, especially when abundance of larger males is low. The percent handled and released (discarded) is not estimated for inshore areas due to inadequate observer coverage.

The mortality indicators described above refer, in a sense, to mortality as it happens. Another approach to inferring mortality can be based on the pattern it leaves in the shell-age composition of survivors. If one considers only terminally molted (adult) crabs, the age distribution of shells of a given size indicates the mortality rate at that size. Fishing mortality on snow crab would be expected to result in a lower proportion of intermediate and old-shelled adult males within the legal size range than at smaller sizes.

Overall Resource Status, Divisions 2HJ3KLNOP4R

Multi-species trawl surveys indicate that the exploitable biomass was highest at the start of the survey series (1995-1998, Fig. 4). It declined from the late 1990s to 2003 and then increased. The overall exploitable biomass has changed little since the mid-2000's. However, both the trap and trawl surveys indicate that Div. 3LNO has accounted for a steadily increasing percentage in recent years, from about 40 % in 2008 to 75 % in 2013.

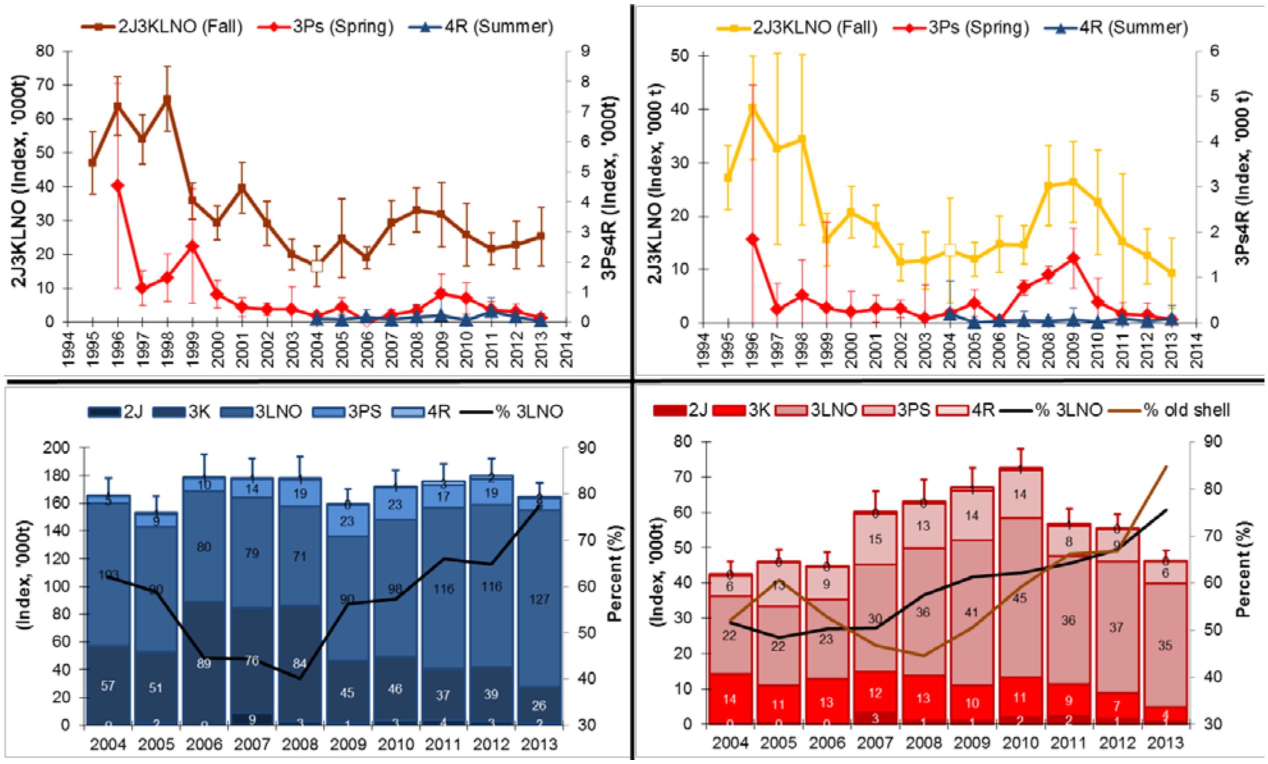

Figure 4. Trends in exploitable biomass indices (left) and pre-recruit biomass indices (right) from multi-species offshore surveys during fall (Division 2HJ3KLNO), spring (Subdivision 3Ps), and summer (Div. 4R) (above) and from fall post-season trap surveys throughout inshore and offshore Div. 2J3KLNOPs4R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

Overall **recruitment** is expected to decline in the short term (2-3 years). Trap and trawl survey biomass indices of pre-recruits (Fig. 4) increased from 2006-2007 to 2009-2010 due to increases in the South (Div. 3LNOPs). Both the trap and trawl surveys indicate that Div. 3LNO has accounted for an increased percentage in recent years. Survey biomass indices of pre-recruits have recently declined in all areas except Div. 2HJ. A recent warm oceanographic regime suggests weak **recruitment** in the **long** 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.

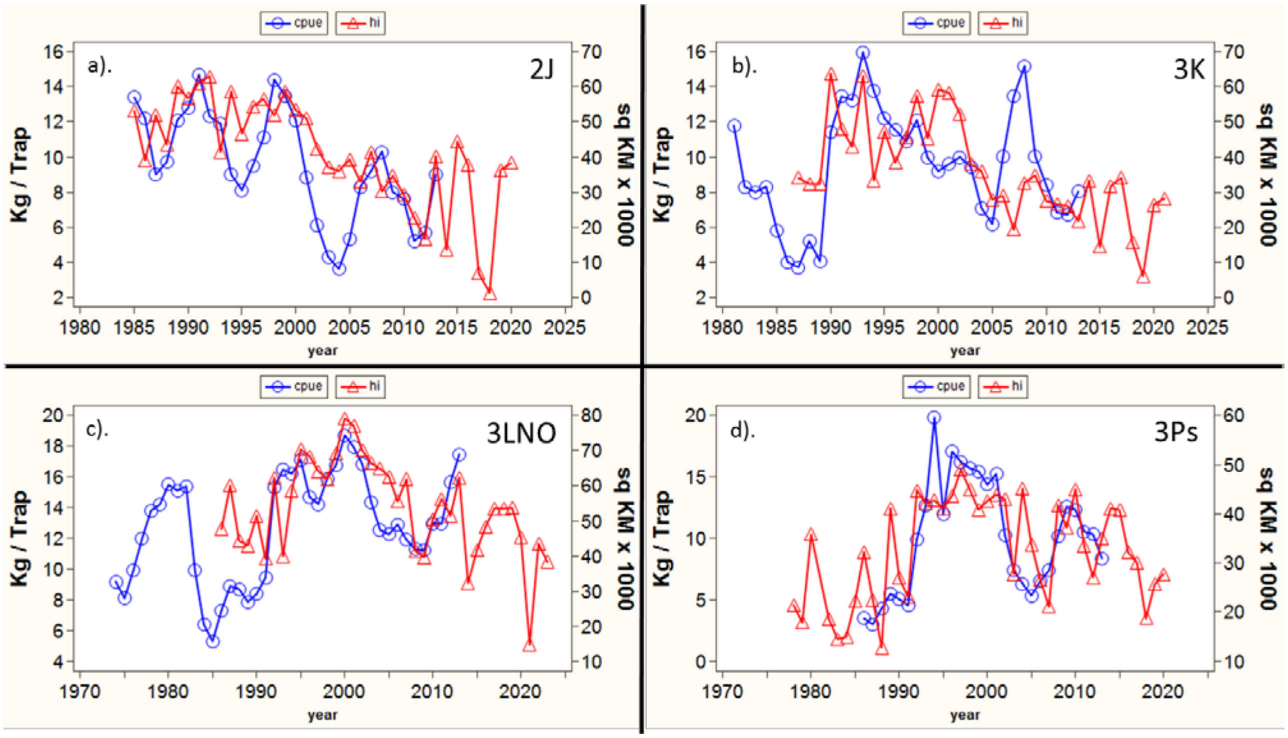

Figure 5. Relationship of CPUE with habitat indices (HI) for Divisions 2J3KLNOPs at delays of 6-8 years for Div.2J3KPs and 10 years for Div. 3LNO. Delay of best fit was determined by pairwise correlation analysis.

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 decreased by 45 % since 2008, to 1,380 t. The TAC has not been taken in the past three years due to shortfalls in the northernmost areas. Meanwhile effort increased by 55 % to 2011 before decreasing by 23 % in 2012. Total effort in 2013 is unknown as only about half of the logbooks were returned. The 2013 fishery was concentrated in Hawke Channel, while the Cartwright channel in northern Div. 2J was virtually abandoned.

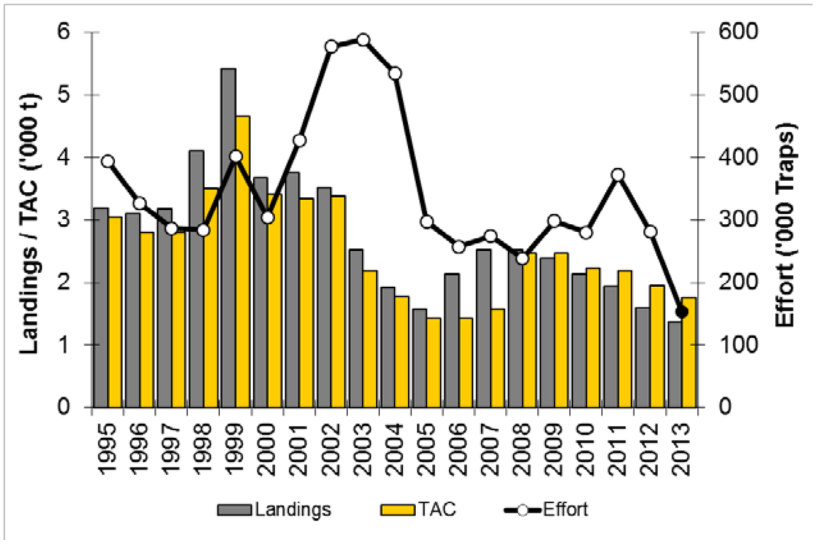

Figure 6. Trends in TAC, landings, and fishing effort in Division 2HJ. The most recent estimate of effort is preliminary due to incomplete logbook data.

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), initially decreasing from 1991 to 1995, and increasing to a peak in 1998. It declined steadily from 1998 to a record low level in 2004 and then increased to a peak in 2008. **CPUE** declined steadily by half from 2008 to 2011, was unchanged in 2012, and increased in 2013. However the magnitude of the 2013 increase is uncertain because both the VMS and logbook indices are based on data from only about half of the fishery and observer coverage was low.

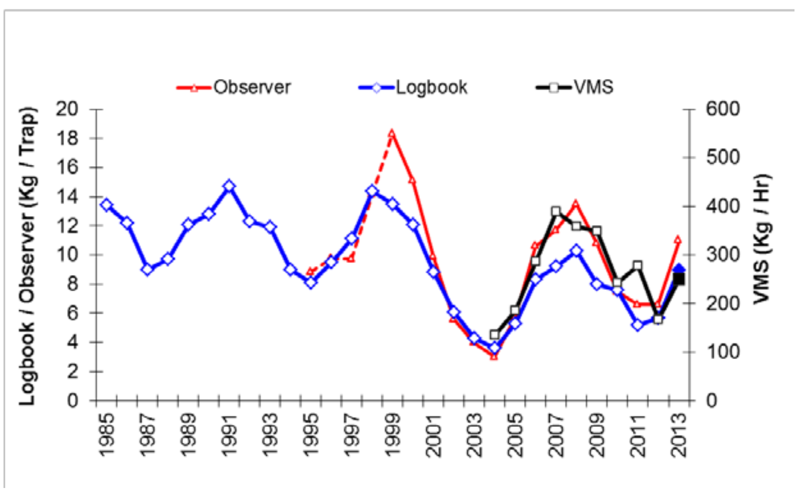

Figure 7. Trends in Division 2HJ commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line). The most recent logbook and VMS estimates are preliminary due to incomplete data.

Biomass

The post-season trawl survey exploitable biomass index decreased steadily by 92 %, from 1998 to 2002 (Fig. 8). It increased from 2002 to peak in 2006 but remained below pre-2002 levels. The **exploitable biomass**, as indicated by the post-season trawl survey, declined steadily from

2006 to 2011 and has changed little since. The post-season trap survey index decreased since 2011, but this index is considered less reliable than the trawl survey index because of limited spatial coverage by the trap survey in this area. The trap survey was incomplete in 2008 and 2009. The trawl survey indicates that the exploitable biomass has contracted southward in recent years with virtually none of the exploitable biomass in Div. 2H since 2011.

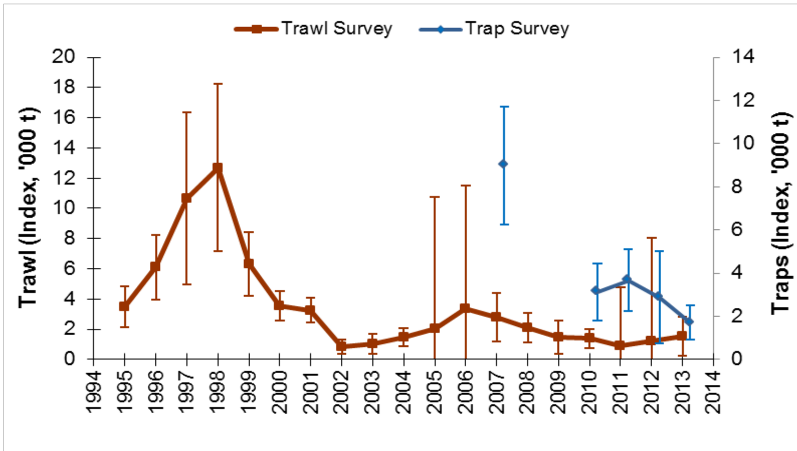

Figure 8. Trends in the Division 2HJ exploitable biomass indices based on post season trawl and trap surveys. The trap survey was conducted only in the southern portion of the Division (Hawke Channel) in 2008 and 2009. Error bars are 95 % confidence intervals.

Recruitment

Recruitment declined from 2006 to 2011 and changed little since; prospects are uncertain in the short term (2-3 years). The post-season trawl survey pre-recruit index has changed little since 2005 (Fig. 9). The post-season trap survey index has declined since 2011.

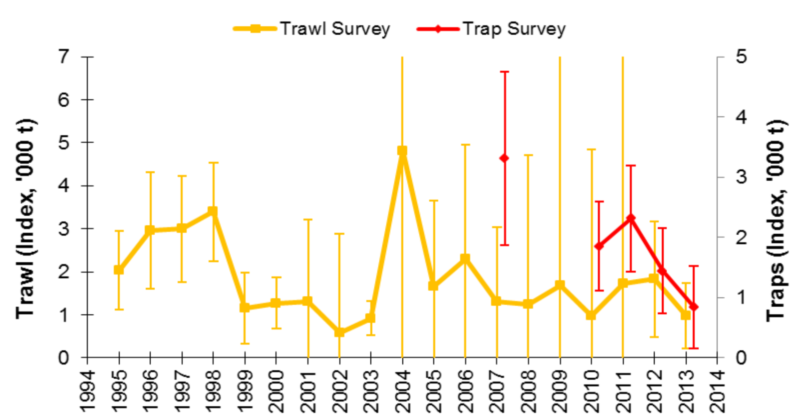

Figure 9. Trends in Division 2HJ pre-recruit biomass indices from the post-season trawl survey and the CPS trap survey. The trap survey was conducted only in the southern portion of the Division (Hawke Channel) in 2008 and 2009. Error bars are 95 % confidence intervals.

A recent warm oceanographic regime suggests weak **recruitment** in the **long term**.

The ocean climate indices have varied considerably over the past 8 years (Fig. 5a), introducing uncertainty beyond the short term. However, the overall trend is warming, with record warm conditions in 2010 and 2011.

Mortality

The **exploitation rate index** declined from 2003 to 2007 and then increased steadily from 2007 to 2012 before decreasing in 2013 (Fig. 10). The **pre-recruit fishing mortality rate index** was at its highest level since 2004 during 2011 and 2012 but decreased by more than half in 2013. The **percentage of the catch handled and released** in the fishery decreased from 35 % in 2012 to 20 % in 2013, implying a decrease in pre-recruit mortality.

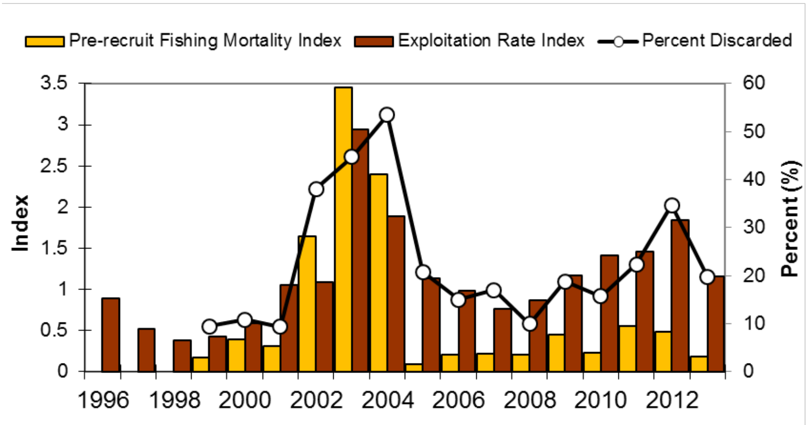

Figure 10. Trends in the Division 2HJ exploitation rate and pre-recruit fishing mortality rate indices and percentage of the catch discarded in the fishery.

The mortality indicated by the shell-type distribution of adult crabs in the autumn survey showed no suggestion of extra, fishery-induced mortality on adults of legal size.

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

Commercial Fishery

Landings most recently peaked at 13,300 t in 2009 but declined by 51 % to 6,500 t in 2012 before increasing to 6,600 t in 2013. The TAC was fully subscribed in 2013, for the first time since 2009. **Effort** most recently peaked in 2009 and has since declined by 33 % (Fig. 11).

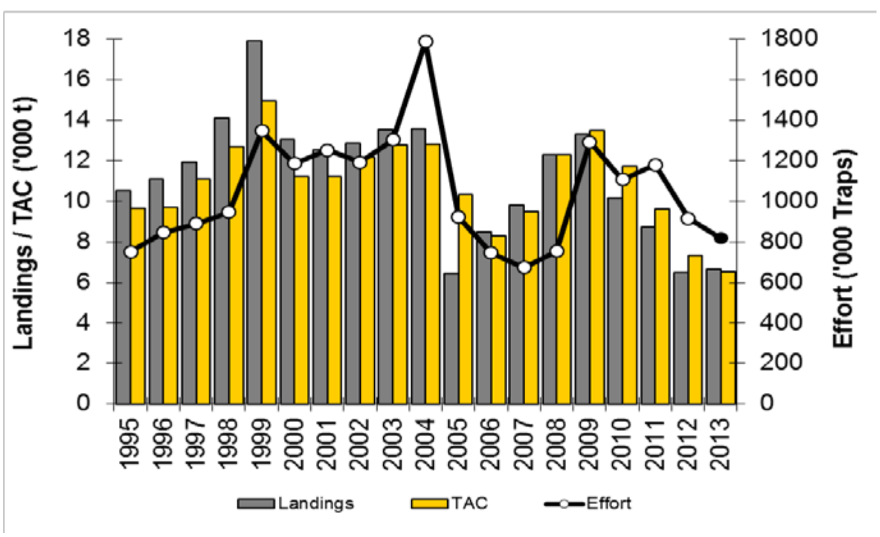

Figure 11. Trends in TAC, landings, and fishing effort in Division 3K offshore. The most recent estimate of effort is preliminary due to incomplete logbook data.

Commercial **CPUE** (Fig. 12) indicates substantial deterioration of fishery performance in recent years. It declined by half from 2008 to 2011 and increased slightly since 2012.

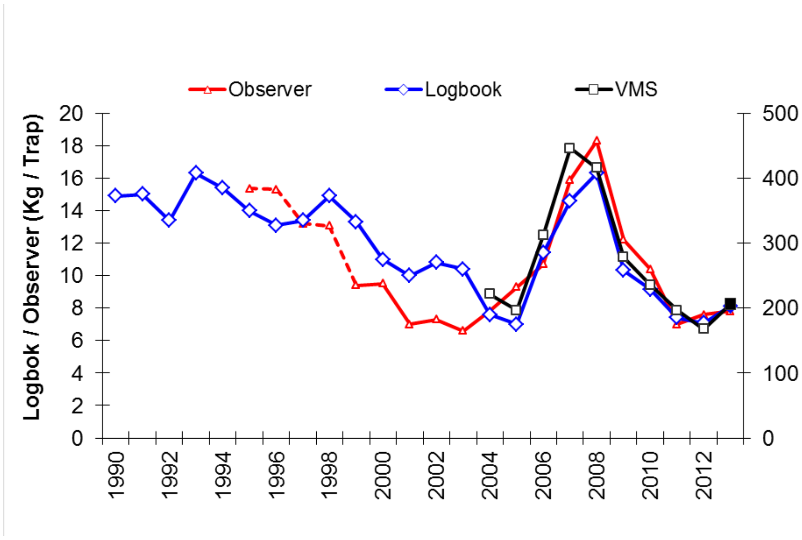

Figure 12. Trends in Division 3K offshore commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line). The most recent logbook and VMS estimates are preliminary due to incomplete data.

Biomass

The post-season trawl survey exploitable biomass index decreased from its highest level in the late 1990s to its lowest in 2003, before increasing to 2007 (Fig. 13). The post-season trap survey exploitable biomass index increased in 2006. Both indices remained high to 2008. The **exploitable biomass**, as indicated by the post-season trap and trawl surveys, declined by more than two thirds since 2008.

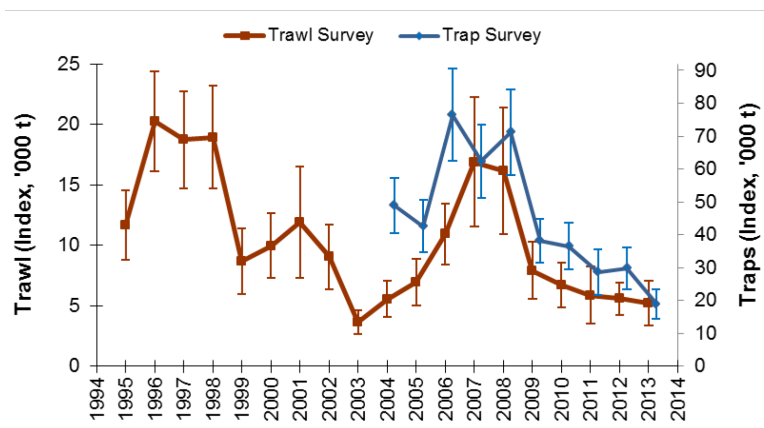

Figure 13. Trends in the Division 3K offshore exploitable biomass indices based on post-season trawl and trap surveys. Error bars are 95 % confidence intervals.

Recruitment

Recruitment declined after 2008 and prospects remain poor in the short term (2-3 years). Post-season pre-recruit biomass indices from both trap and trawl surveys have decreased by about 70 % since 2008 (Fig. 14).

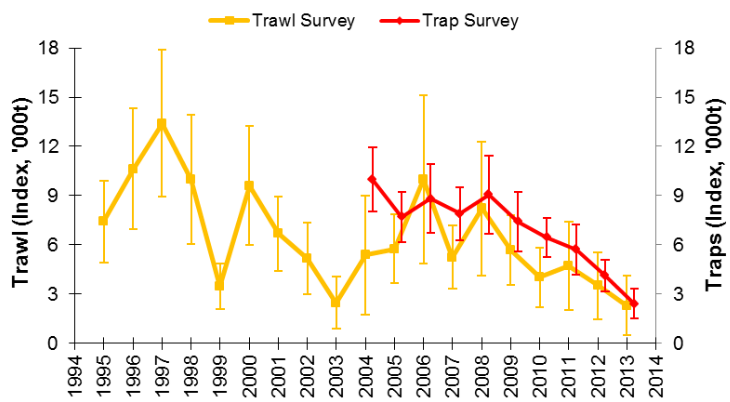

Figure 14. Trends in Division 3K offshore pre-recruit biomass indices based on post-season trawl and trap surveys. Error bars are 95 % confidence intervals.

The recent decrease in recruitment was likely exacerbated by a high handling mortality on soft-shelled immediate pre-recruits in the fishery during recent years. However, in 2013 there was little soft-shelled crab in the fishery, despite low catch rates, implying especially poor recruitment prospects for 2014.

A recent warm oceanographic regime suggests weak **recruitment** in the **long term.** The ocean climate indices have varied considerably over the past decade (Fig. 5b), introducing uncertainty beyond the short term. However, the overall trend is warming, with record warm conditions in 2011.

Mortality

The trawl survey-based **exploitation rate index** was at its highest level since 2004 in 2010-2011 (Fig. 15). It decreased in 2012 before increasing again in 2013. The **pre-recruit fishing mortality rate index** increased from 2007 to 2011 but decreased in 2012 before increasing again in 2013. The **percentage of the catch handled and released** in the fishery decreased from about 20 % in 2012 to about 10 % in 2013, implying a decrease in pre-recruit mortality.

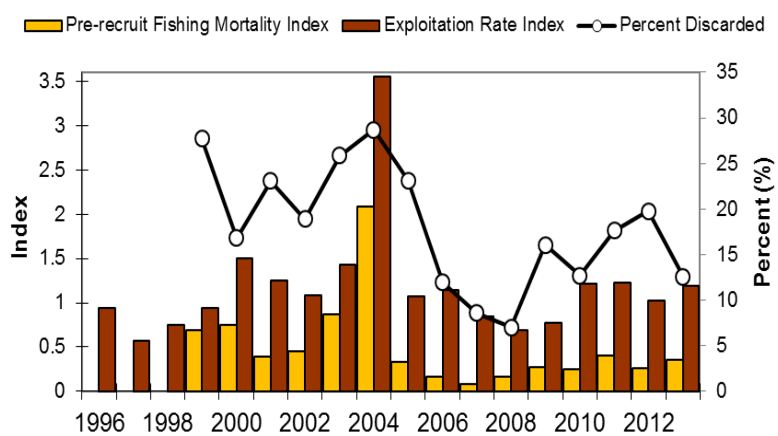

Figure 15. Trends in the Division 3K offshore exploitation rate and pre-recruit fishing mortality rate indices and percentage of the catch discarded in the fishery.

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

Commercial Fishery

Landings (Fig. 16) have oscillated since 1995 with recent peaks in 2003 and 2009. They increased from 2,200 t in 2005 to 2,900 t in 2009. They declined by 34 % from 2,900 t in 2009 to 1,900 t in 2012 and 2013**.** The TAC was fully subscribed in 2013, for the first time since 2009. **Effort** increased by 70 % from 2008 to 2011 before declining by 40 % to 2013.

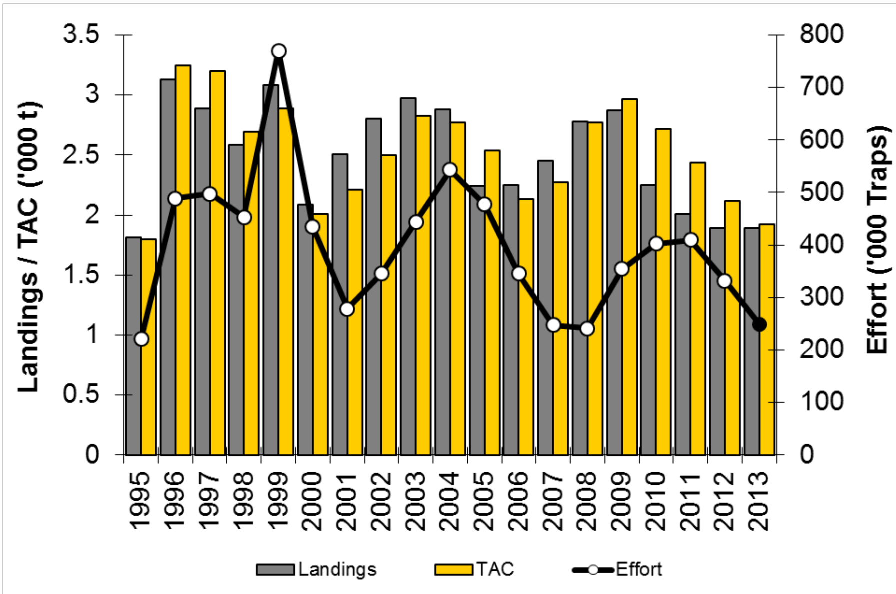

Figure 16. Trends in TAC, landings, and fishing effort in Division 3K inshore. The most recent estimate of effort is preliminary due to incomplete logbook data.

Commercial **CPUE** (Fig. 17) increased sharply from 2005 to a record high level in 2008, it declined by more than half from 2008 to 2011, and increased over the past two years.

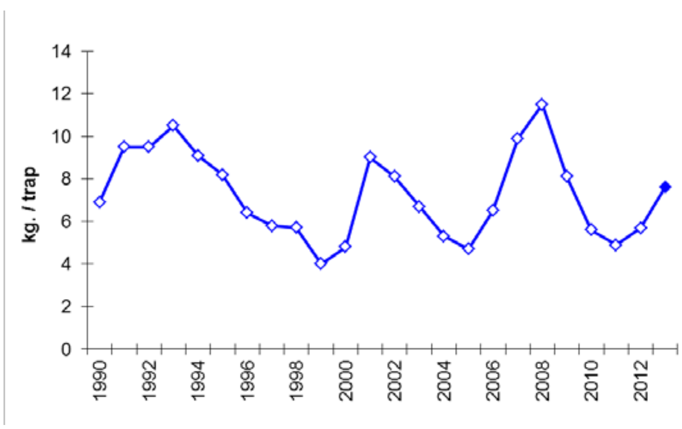

Figure 17. Trend in Division 3K inshore commercial logbook CPUE. The most recent logbook and VMS estimates are preliminary due to incomplete data.

Biomass

The **exploitable biomass**, as indicated by the post-season trap survey, decreased from 2007 to 2009 and has since fluctuated (Fig. 18).

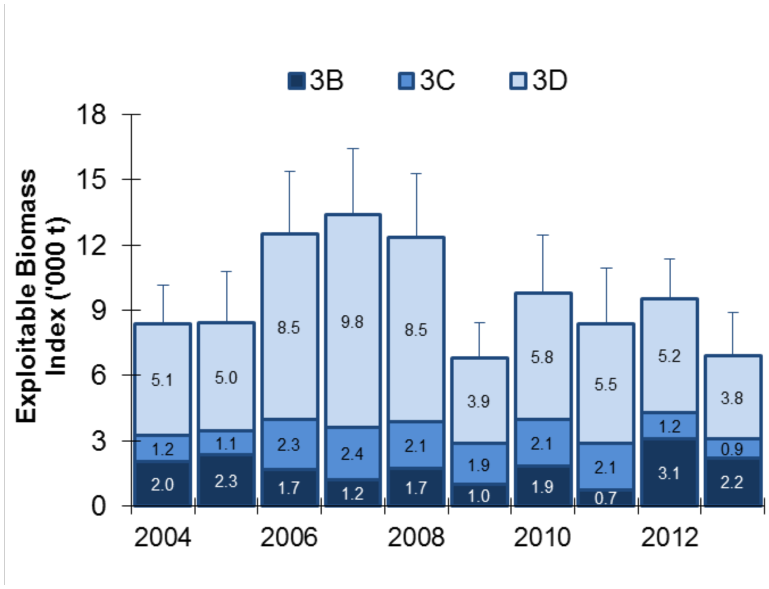

Figure 18. Exploitable biomass index based on the post-season trap survey in inshore Division 3K. Error bars are upper 97.5 % confidence bounds.

Recruitment

Recruitment prospects are poor in the short term (2-3 years). The post-season trap survey pre-recruit biomass index decreased by more than half in 2013, to its lowest level in the time series (Fig. 19). The percentage of sub-legal sized crabs that are old-shelled, and therefore probably terminally molted, has changed little in the past four years.

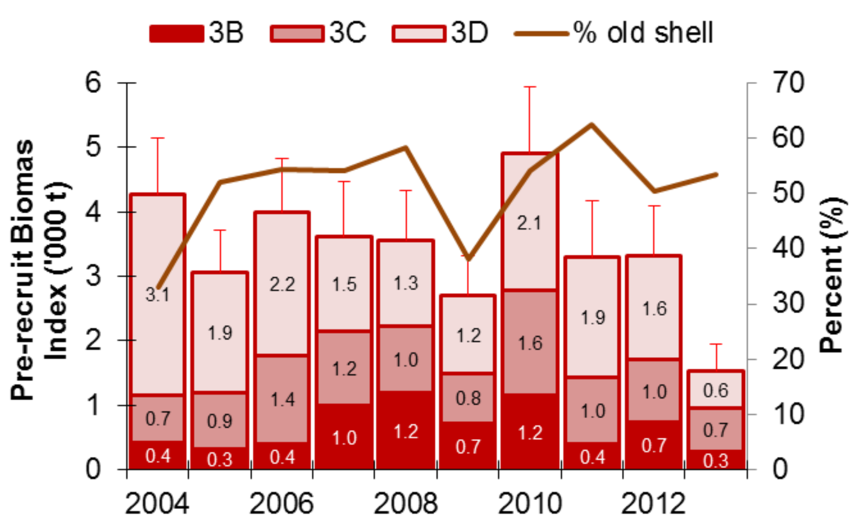

Figure 19. Pre-recruit biomass index from the post-season trap survey in inshore Division 3K with percentage of pre-recruit-sized crabs that are old-shelled. Error bars are upper 97.5 % confidence bounds.

Mortality

The post-season trap survey-based **exploitation rate index** has changed little throughout the time series (Fig. 20). However, there was considerable variability among management areas, with the index decreasing sharply in one area while increasing in another in 2013. The unusually high value in White Bay (CMA 3B) in 2012 was a function of the anomalously low 2011 exploitable biomass index. Data are insufficient to estimate the **pre-recruit fishing mortality rate index.**

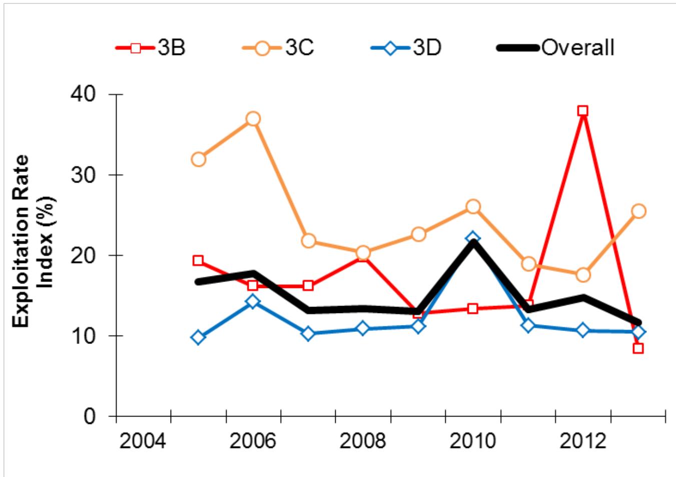

Figure 20. Exploitation rate index from the post-season trap survey in inshore Division 3K.

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

Commercial Fishery

Landings decreased by 11 % from 24,500 t in 2006 to 21,900 t in 2009 and then increased by 20 % to 26,300 t in 2013 (Fig. 21). **Effort** increased by 83 % from 2000 to 2008 and has since declined by 32 %.

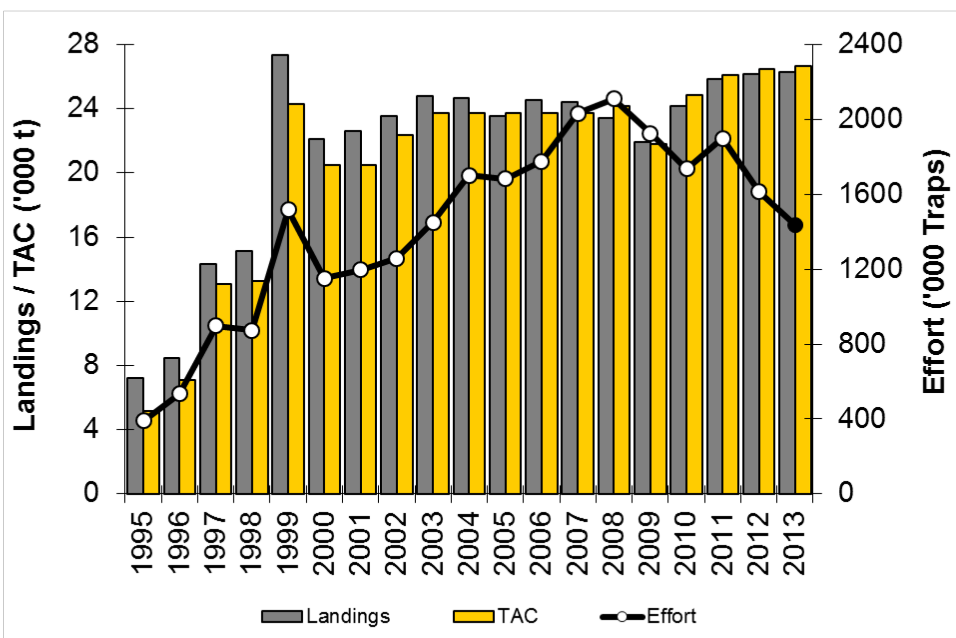

Figure 21. Trends in TAC, landings, and fishing effort in Division 3LNO offshore. The most recent estimate of effort is preliminary due to incomplete logbook data.

VMS-based **CPUE** declined to its lowest level in 2008, and has since increased steadily to its highest level in the time series (Fig. 22).

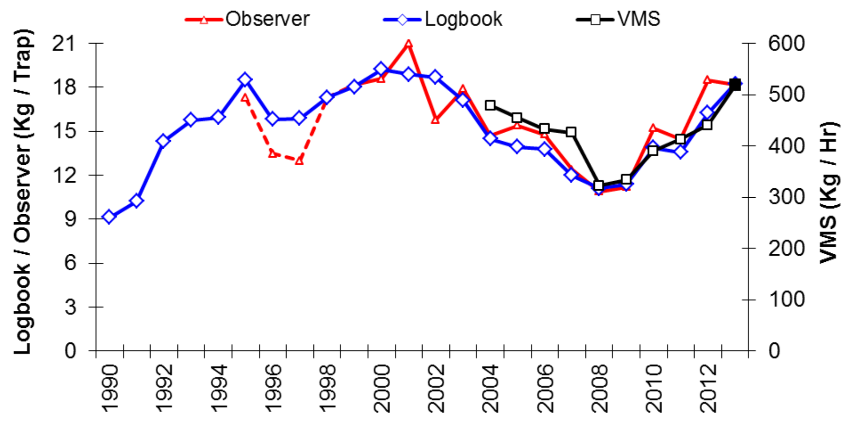

Figure 22. Trends in Division 3LNO offshore commercial CPUE. The observer index is based on at-sea sampling since 1998 (solid line) and catch estimates in earlier years (dashed line). The most recent logbook and VMS estimates are preliminary due to incomplete data.

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). However both indices have since increased slightly. It is believed that the trend in the trap survey index better reflects the trend in the exploitable biomass because it is supported by the increasing fishery performance during that time (Fig. 22). The trawl survey index (Fig. 23) may have been inflated during 2008-2010 by increased survey trawl efficiency.

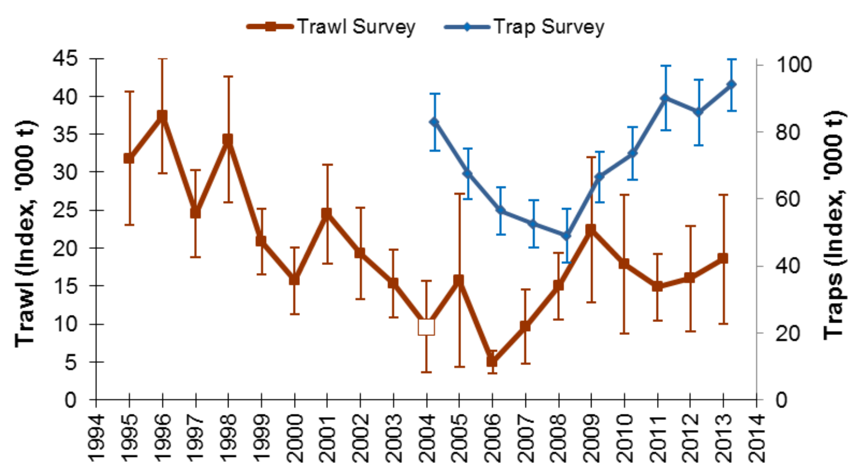

Figure 23. Trends in the Division 3LNO offshore exploitable biomass indices based on post-season trawl and trap surveys; the trawl survey was incomplete in 2004. Error bars are 95 % confidence intervals.

Recruitment

Biological data from several sources indicate that **recruitment** will likely decrease in the short term. Size distributions from the post-season trawl survey indicate that a recent recruitment pulse (modal group of adolescents), reflected in a 2009-2010 peak in pre-recruit biomass indices from both surveys (Fig. 24), has now fully recruited to the exploitable biomass. There is no evidence of any increase in the pre-recruit biomass indices in the past three years (Fig. 24), or of very small (<40 mm CW) males that last peaked in 2001-2003 representing the most recent recruitment pulse. There has also been no evidence of another incoming recruitment pulse in small-meshed trap size distributions that clearly showed progression of the most recent recruitment pulse. This is supported by data from observer at-sea sampling that showed a decline in the percentage of the catch discarded since 2008.

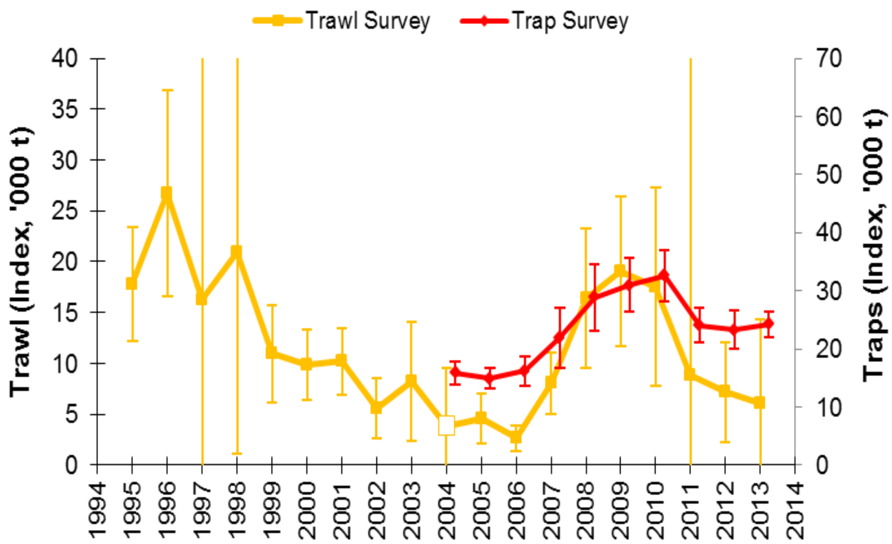

Figure 24. Trends in Division 3LNO offshore pre-recruit biomass indices based on post-season trawl and trap surveys; the trawl survey was incomplete in 2004. Error bars are 95 % confidence intervals.

A recent warm oceanographic regime suggests weak **recruitment** in the **long term**. The ocean climate indices have been highly variable in recent years (Fig. 5c). It is unknown how this variability will affect incoming recruitment.

Mortality

The **exploitation rate index** decreased marginally in 2013 (Fig. 25).

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

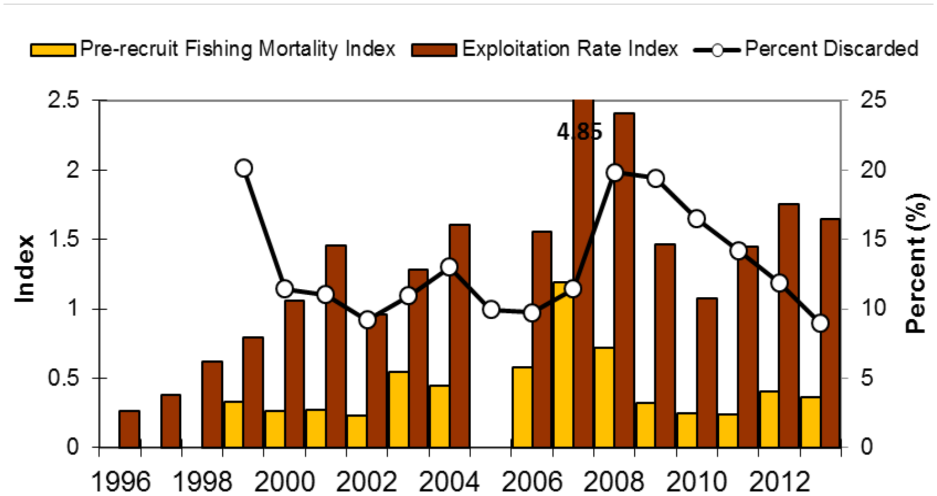

Figure 25. Trends in the Division 3LNO offshore exploitation rate and pre-recruit fishing mortality rate indices and percentage of the catch discarded in the fishery. Mortality indices were not calculated for 2005 because the survey was incomplete in 2004.

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

Commercial Fishery

Landings increased by 19 % from 6,100 t in 2005 to 7,300 t in 2010, and have since changed little, at 7,600 t in 2013 (Fig. 26). **Effort** increased from 2008 to 2010 and has since declined steadily.

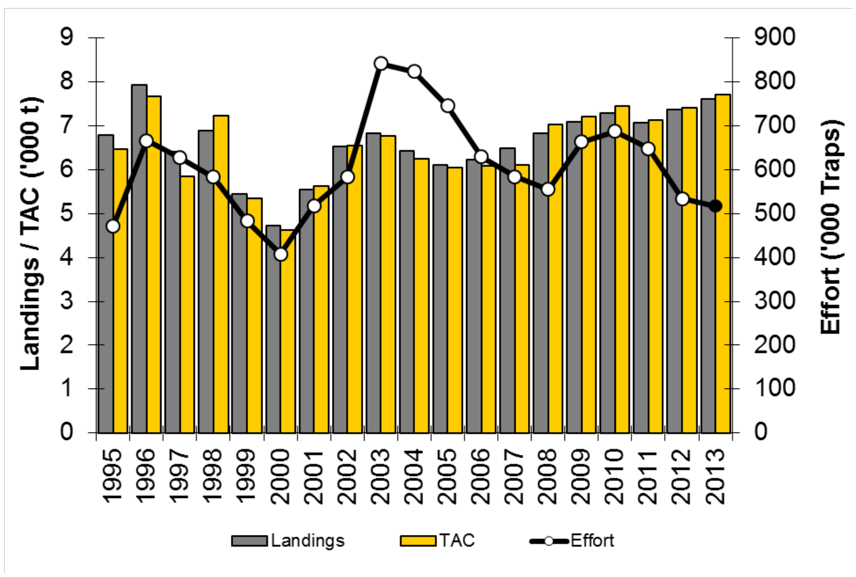

Figure 26. Trends in TAC, landings, and fishing effort in Division 3L inshore. The most recent estimate of effort is preliminary due to incomplete logbook data.

CPUE increased sharply since 2011 to its highest level, after varying about the long term average for the previous 5 years (Fig. 27).

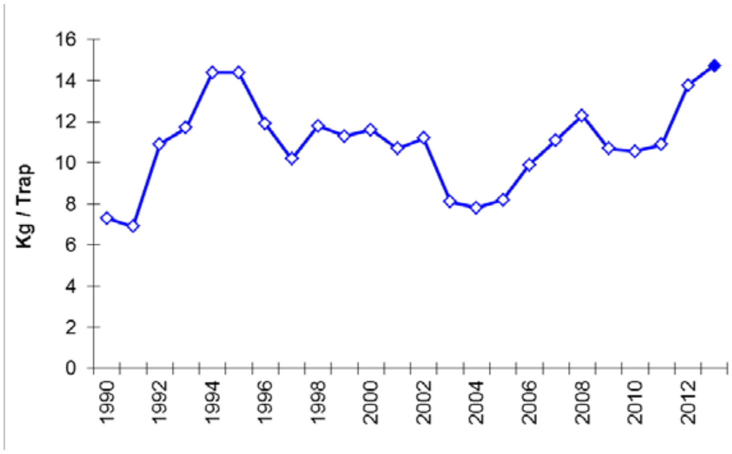

Figure 27. Trends in Division 3L inshore commercial logbook CPUE. The most recent estimate is preliminary due to incomplete data.

Biomass

The post-season trap survey index suggests that the **exploitable biomass** increased steadily since 2008 to its highest level in the time series, with considerable variability among management areas (Fig. 28).

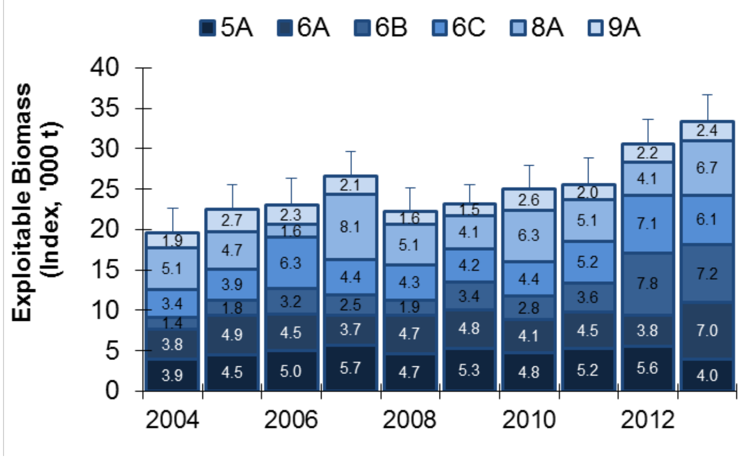

Figure 28. Exploitable biomass index based on the post-season trap survey in inshore Division 3L. Error bars are upper 97.5 % confidence bounds.

Recruitment

Recruitment has declined slightly since 2010, although there is considerable variability among management areas, and is expected to decline further in the short-term (2-3 years). The post-season trap survey pre-recruit biomass index decreased in 2013 (Fig. 29). The **pre-recruit biomass index** in this area is dominated by old-shelled crabs and their proportion has increased in recent years, particularly in 2012-2013 (Fig. 29). It is believed that most of those are terminally-molted and will never contribute to the exploitable biomass.

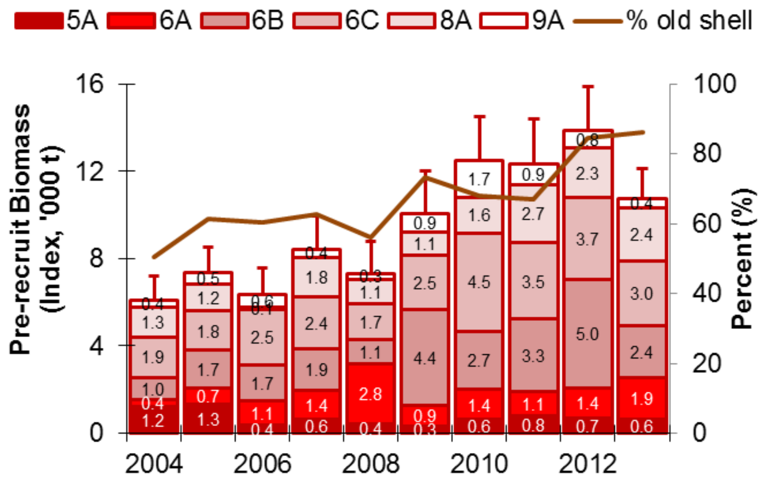

Figure 29. Pre-recruit biomass index of under-sized crabs from the post-season trap survey in inshore Division 3L with percentage of sub-legal sized males that are old-shelled. Error bars are upper 97.5 % confidence bounds.

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 rate index**.

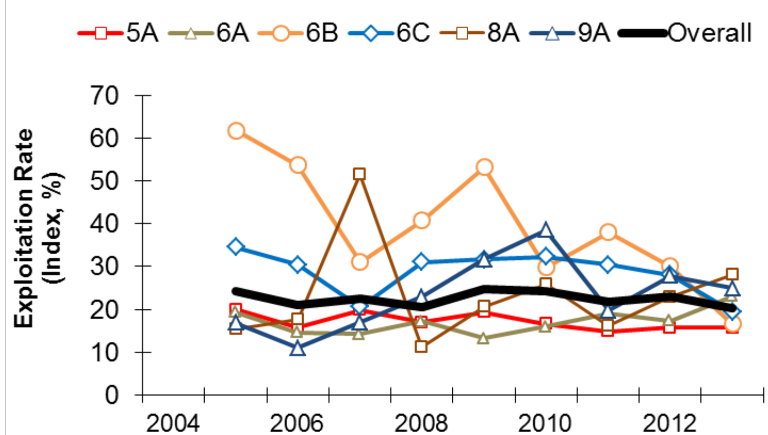

Figure 30. Exploitation rate index from the post-season trap survey in inshore Division 3L.

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

Commercial Fishery

Landings almost doubled from 2,300 t in 2006 to a peak of 4,200 t in 2011, before declining by 16 % to 3,500 t in 2013 (Fig. 31). **Effort** increased by 76 % from 2008 to a record high level in 2013.

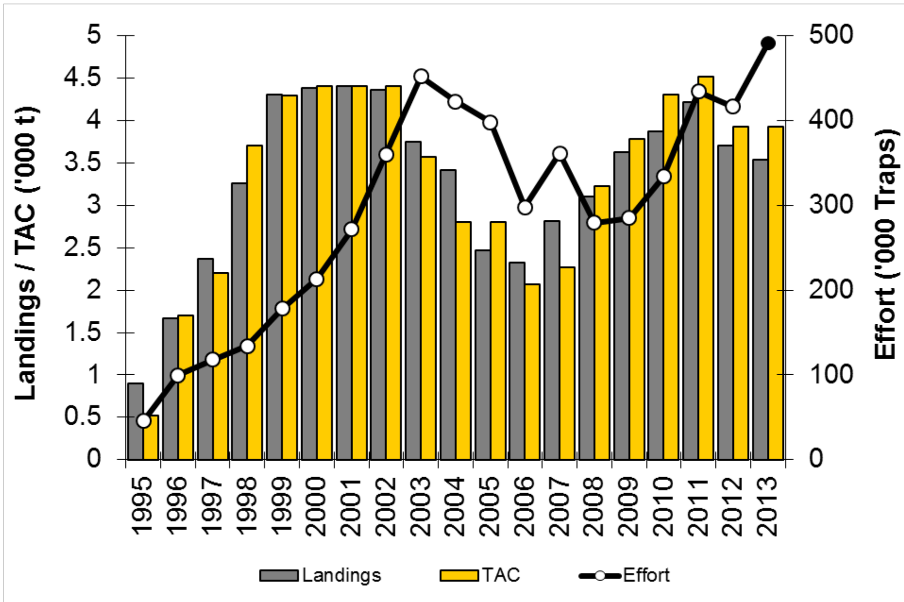

Figure 31. Trends in TAC, landings, and fishing effort in Subdivision 3Ps offshore. The most recent estimate of effort is preliminary due to incomplete logbook data.

CPUE increased from 2005 to 2009 and has steadily declined since, to about its previous lowest level (Fig. 32).

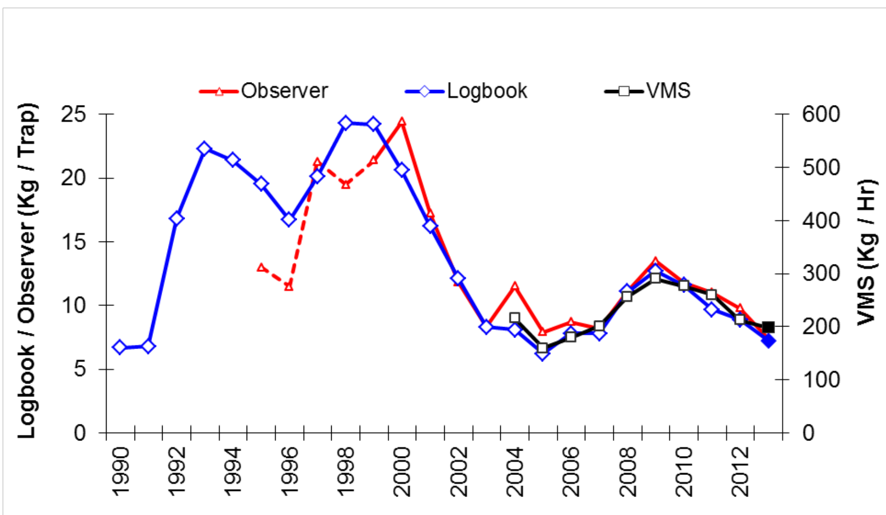

Figure 32. Trends in Subdiv. 3Ps offshore commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line). The most recent logbook and VMS estimates are preliminary due to incomplete data.

Biomass

The **exploitable biomass**, as indicated by both the spring trawl survey and the post-season trap survey indices, increased steadily from 2006 to 2009 before declining rapidly to its lowest level in 2013 (Fig. 33).

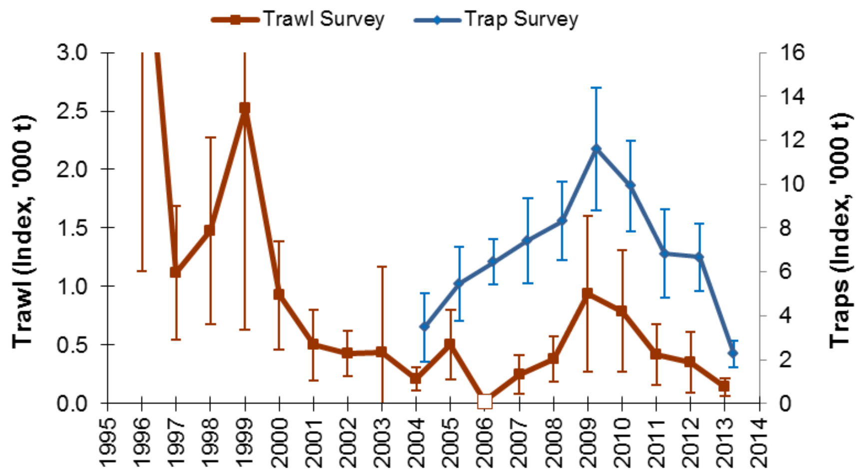

Figure 33. Trends in the Subdivision 3Ps offshore exploitable biomass indices from the pre-season trawl survey and the post-season trap survey; the trawl survey was incomplete in 2006. Error bars are 95 % confidence intervals.

Recruitment

Recruitment has recently declined and is expected to decline further in the short term (2-3 years). Pre-recruit biomass indices from both trap and trawl surveys declined rapidly from 2009 to their lowest levels in 2013 (Fig. 34).

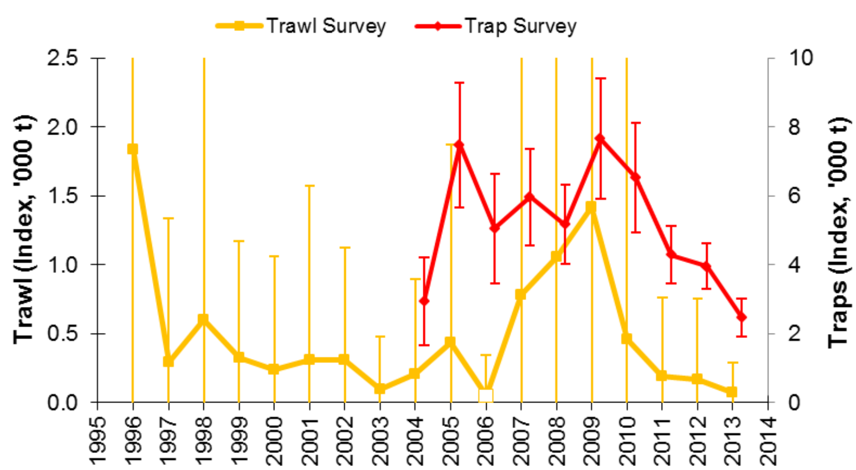

Figure 34. Trends in the pre-recruit biomass indices from the pre-season trawl survey and the post-season trap survey in Subdivision 3Ps offshore; the trawl survey was incomplete in 2006. Error bars are 95 % confidence intervals.

A recent warm oceanographic regime suggests weak **recruitment** in the **long term**. The temperature indices imply some variability in recruitment beyond the short term (Fig. 5d). However, the overall trend is warming, with near record warm conditions in 2011.

Mortality

The spring trawl survey-based **exploitation rate index** more than doubled from 2009-2012, before doubling again in 2013. The **pre-recruit fishing mortality rate index** has increased steadily since 2009 to about its previous highest level (Fig. 35). The **percentage of the catch handled and released** in the fishery declined from about 45 % in 2005 to 20 % in 2013 (Fig. 35), implying a decline in pre-recruit mortality.

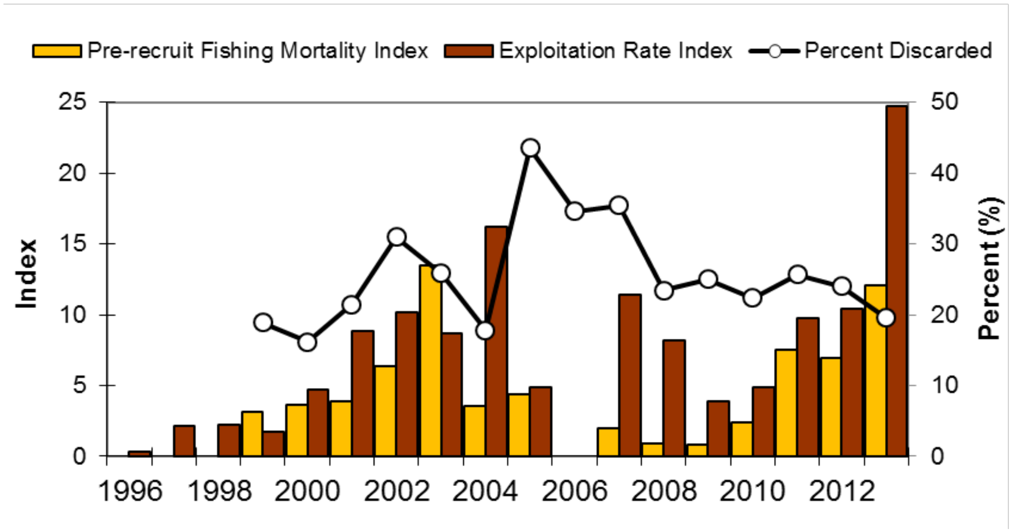

Figure 35. Trends in the Subdivision 3Ps offshore exploitation rate and pre-recruit fishing mortality indices and percentage of the catch discarded in the fishery. Mortality indices were not calculated for 2006 because the survey was incomplete in that year.

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

Commercial Fishery

Landings peaked at 3,500 t in 1999 and then declined to 2005 (Fig. 36). They more than tripled from 700 t in 2005 to 2,500 t in 2011 and remained at that level since. **Effort** declined substantially in 2005 and has since varied without trend.

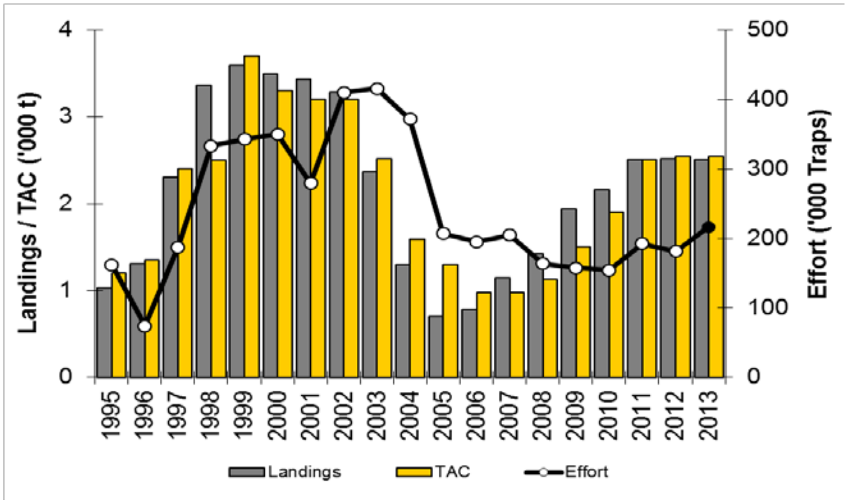

Figure 36. Trends in TAC, landings, and fishing effort in Subdivision 3Ps inshore. The most recent estimate of effort is preliminary due to incomplete logbook data.

CPUE increased steadily from 2005 to 2010, changed little in 2011-2012, and then decreased slightly in 2013 (Fig. 37).

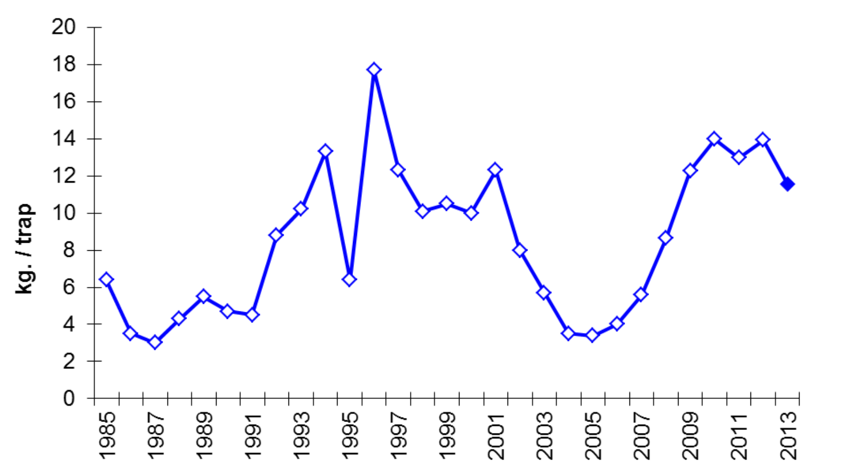

Figure 37. Trends in Subdivision 3Ps inshore commercial logbook CPUE. The most recent estimate is preliminary due to incomplete data.

Biomass

The **exploitable biomass,** as indicated by the post-season trap survey index, increased substantially between 2006 and 2010, changed little in 2011-2012, then decreased by half in 2013 (Fig. 38). Most of the biomass is in Placentia Bay (CMA 10A).

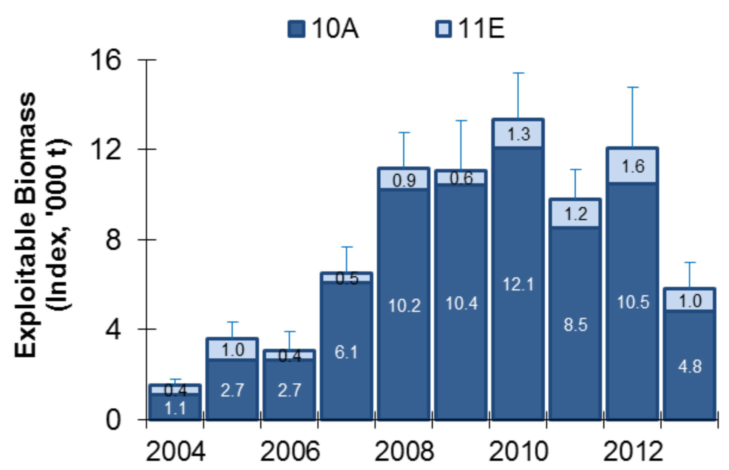

Figure 38. Exploitable biomass index based on the post-season trap survey in inshore Subdivision 3Ps. Error bars are upper 97.5 % confidence bounds.

Recruitment

Recruitment decreased substantially in 2013 and is expected to remain low in the short term (2-3 years). The **pre-recruit biomass** has been declining since 2007 (Fig. 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.

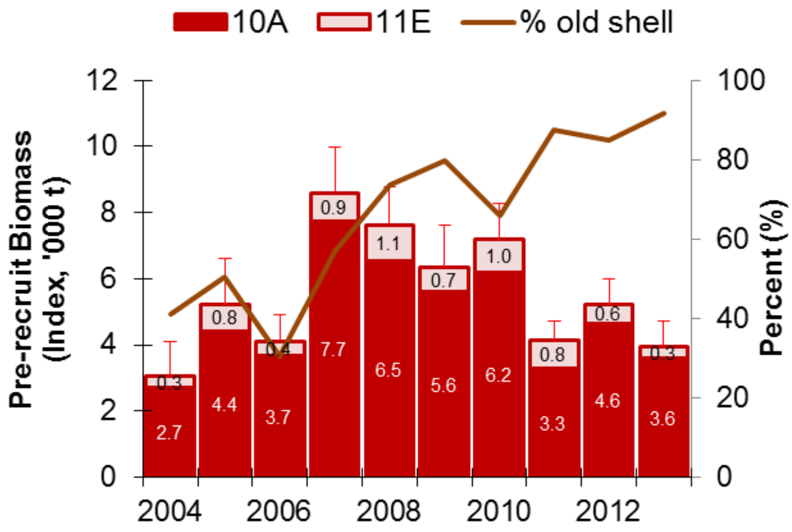

Figure 39. Pre-recruit biomass index of under-sized crabs from the post-season trap survey in inshore Subdivision 3Ps with percentage of sub-legal-sized crabs that were old-shelled. Error bars are upper 97.5 % confidence bounds.

Mortality

The post-season trap survey-based **exploitation rate index** has changed little in the past six years (Fig. 40). Data are insufficient to estimate a **pre-recruit fishing mortality rate index**.

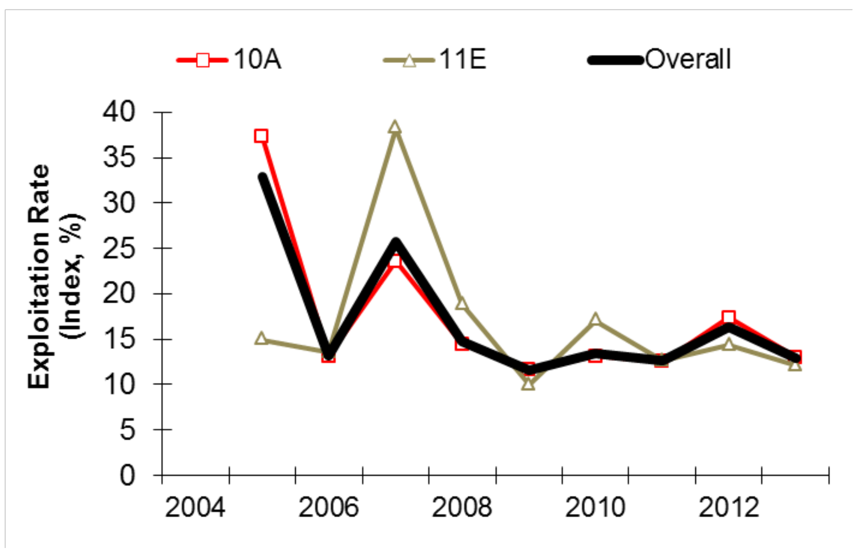

Figure 40. Exploitation rate index from the post-season trap survey in inshore Subdivision 3Ps.

Resource Status, Division 4R Offshore (CMA OS8)

Commercial Fishery

Landings declined substantially from 580 t in 2004 to 80 t in 2006 before more than doubling in 2007 (Fig. 41). **Landings** declined by 83 % from 190 t in 2007 to a historical low of 30 t in 2010, and increased to 300 t in 2013. **Effort** increased by almost a factor of 7 since 2010. The TAC has not been taken since 2002.

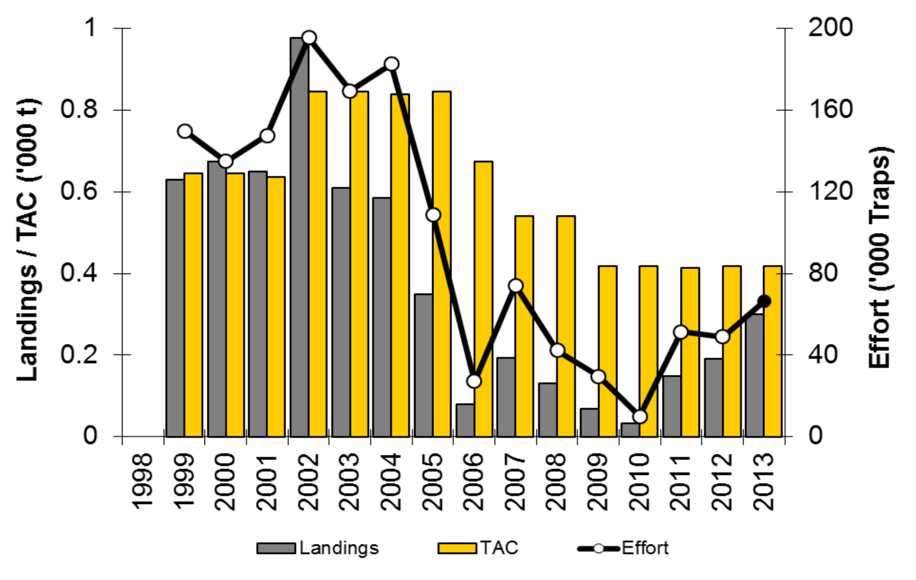

Figure 41. Trends in TAC, landings, and fishing effort in Division 4R. The most recent estimate of effort is preliminary due to incomplete logbook data.

VMS-based **CPUE** declined from 2004 to its lowest level in 2009 before increasing to its highest value in the time series in 2013 (Fig. 42). **CPUE** has consistently been low relative to other divisions.

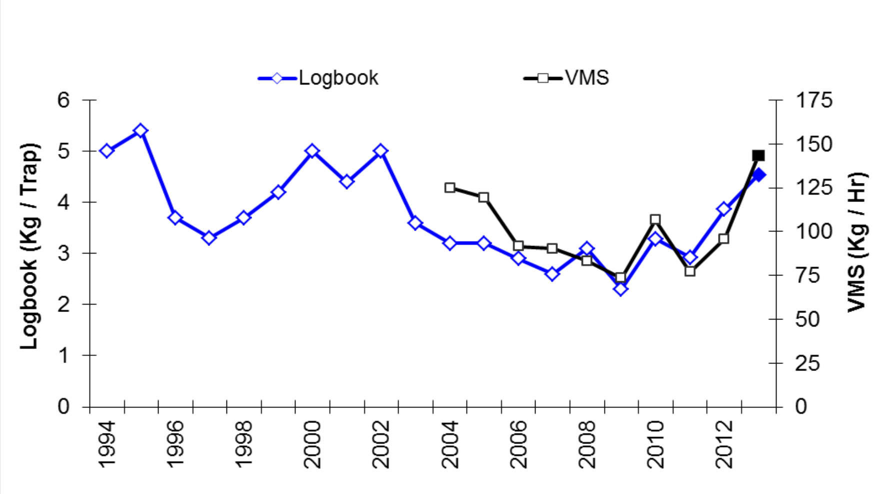

Figure 42. Trends in Division 4R offshore commercial CPUE. The most recent estimates are preliminary due to incomplete data.

Biomass

The **exploitable biomass** remains low relative to other areas. Trawl survey catches are few and localized in the northern portion of the area. In both surveys the variation among catches is high compared to the mean (Fig. 43). This introduces high uncertainty in interpreting annual changes. The trap survey was incomplete in 2013.

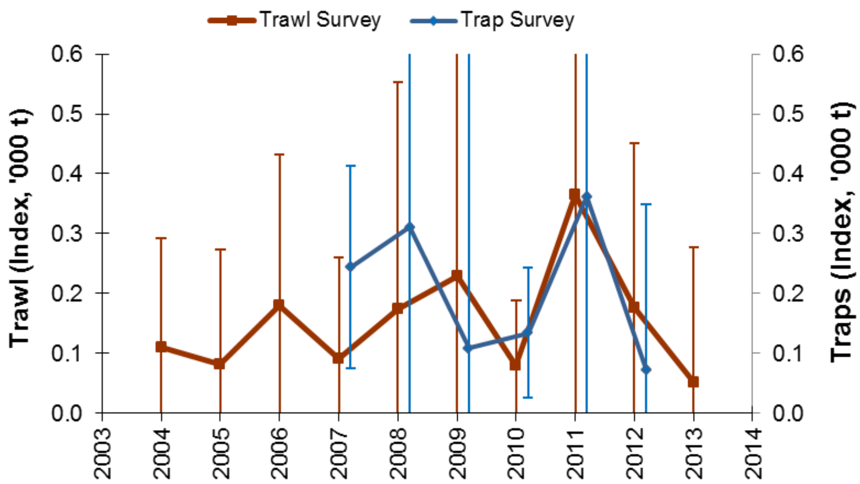

Figure 43. Trends in the Division 4R offshore exploitable biomass indices from the post-season trawl and trap surveys. Error bars are 95 % confidence intervals. The trap survey was incomplete in 2013.

Recruitment

Recruitment prospects are uncertain in the short term (2-3 years). Trawl survey catches are few and localized in the northern portion of the area. In both surveys the variation among catches is high compared to the mean (Fig. 44). This introduces high uncertainty in interpreting annual changes.

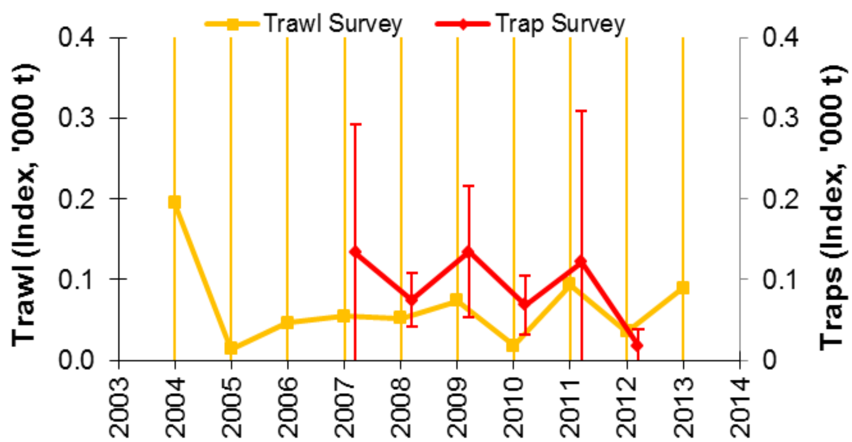

Figure 44. Trends in the pre-recruit biomass indices from the pre-season trawl survey and the post-season trap survey in Division 4R offshore. Error bars are 95 % confidence intervals. The trap survey was incomplete in 2013.

A recent warm oceanographic regime suggests weak **recruitment** in the **long term**. CPUE in this, the warmest, area is inversely related to shallow water bottom temperature five years earlier based on a 1989-2009 temperature series (Fig. 45). A more recent temperature series from a nearby oceanographic station trends similarly and shows steady warming since 2008.

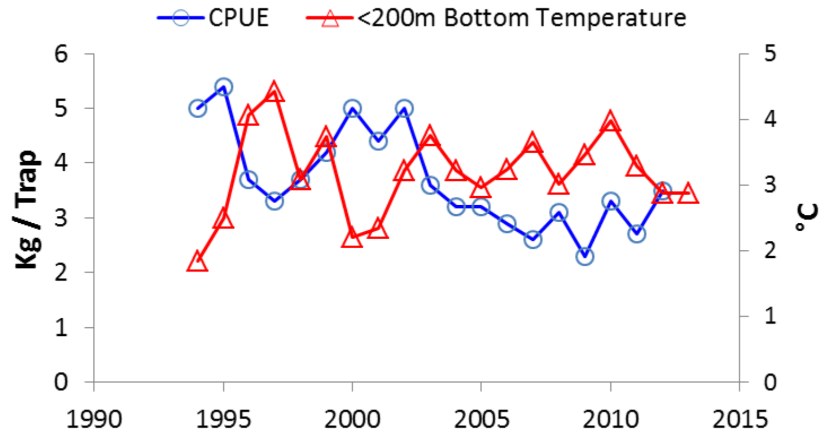

Figure 45. Relationship of offshore Div. 4R CPUE with bottom temperature (BT) 5 years earlier.

Mortality

Data are insufficient to calculate **exploitation rate** and **pre-recruit fishing mortality rate indices**.

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

Commercial Fishery

Landings declined by 80 % from 930 t in 2003 to a historical low of 160 t in 2010 and have since more than tripled to 600 t in 2013 (Fig. 46). **Effort** declined by 69 % from 2004 to 2010 and doubled in 2011 before declining by 34 % to 2013. The TAC has not been taken since 2002.

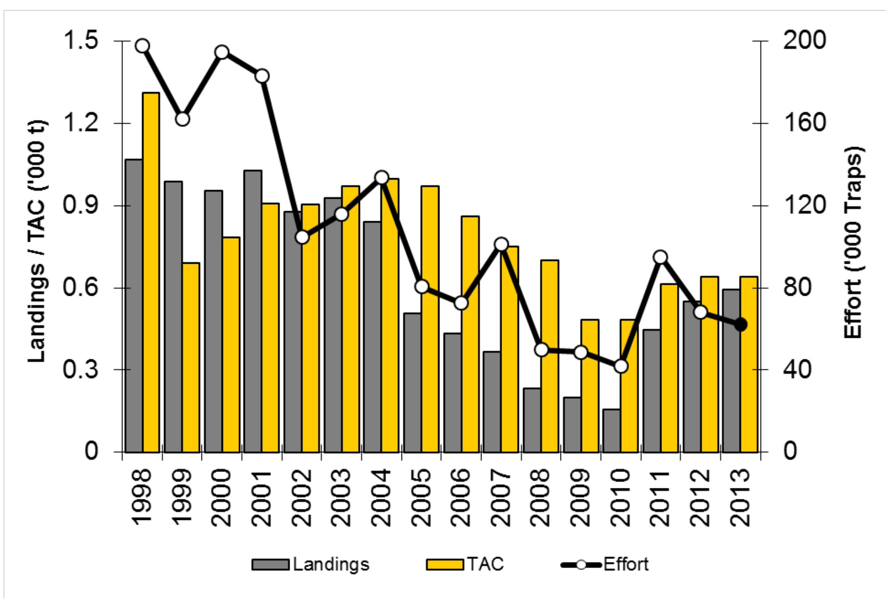

Figure 46. Trends in TAC, landings, and fishing effort in Division 4R inshore. The most recent estimate of effort is preliminary due to incomplete logbook data.

CPUE declined by more than half from 2002 to 2007 and changed little to 2010 (Fig. 47). It increased sharply since 2010 to a record high level in 2013.

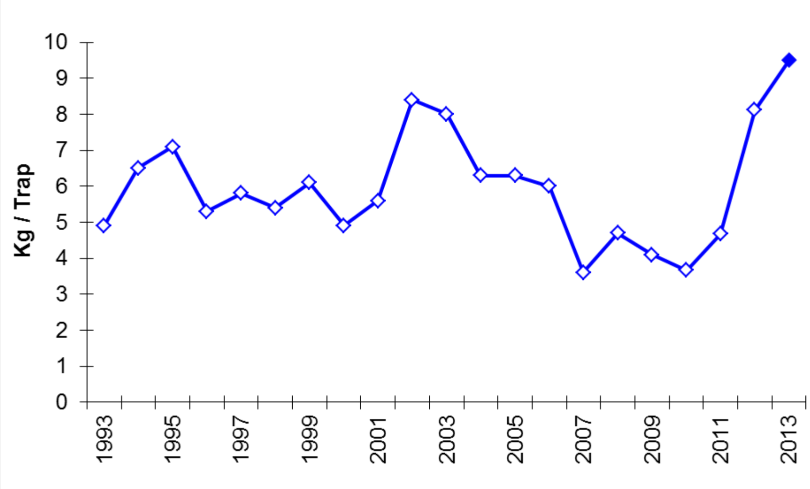

Figure 47. Trends in Division 4R inshore commercial logbook CPUE. The most recent estimate is preliminary due to incomplete data.

The **exploitable biomass**, as indicated by the post-season trap survey index, fluctuated from 2006 to 2010,was three times as large in 2011, and changed little in 2012 before decreasing in 2013 (Fig. 48).

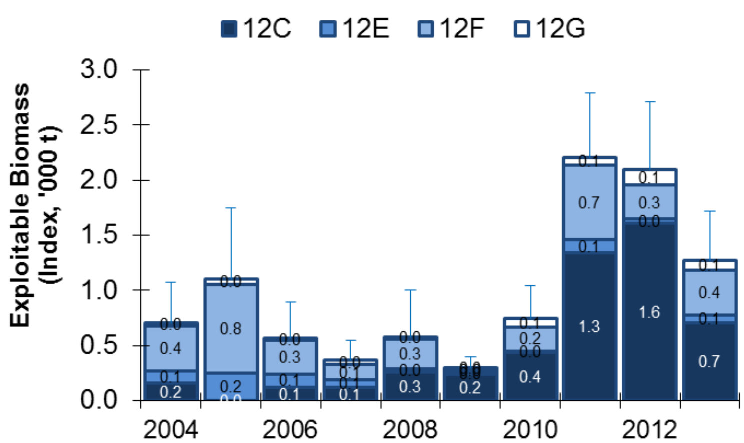

Figure 48. Exploitable biomass index based on the post-season trap survey in inshore Div. 4R. Error bars are upper 97.5 % confidence bounds.

Recruitment

Recruitment prospects are unfavourable in the short term (2-3 years). The trap survey **pre-recruit biomass index** more than doubled in 2009 and changed little until it decreased substantially to remain below pre-2009 level during 2012-2013 (Fig. 49). The percentage of sub-legal sized crabs that are old-shelled, and therefore probably terminally molted, has changed little in the past four years.

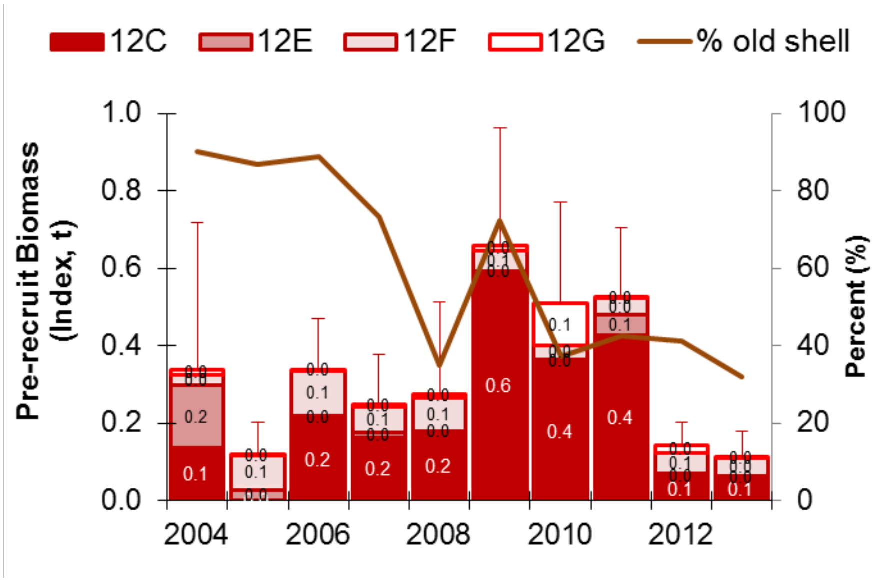

Figure 49. Trends in the pre-recruit biomass index from the post-season trap survey in inshore Div. 4R, with percentage of sub-legal-sized crabs that are old-shelled. Error bars are upper 97.5 % confidence bounds.

Mortality

The post-season trap survey-based **exploitation rate index** decreased in 2012 and changed little in 2013 (Fig. 50). However there has been considerable variation among management areas. Data are insufficient to estimate a **pre-recruit fishing mortality rate index**.

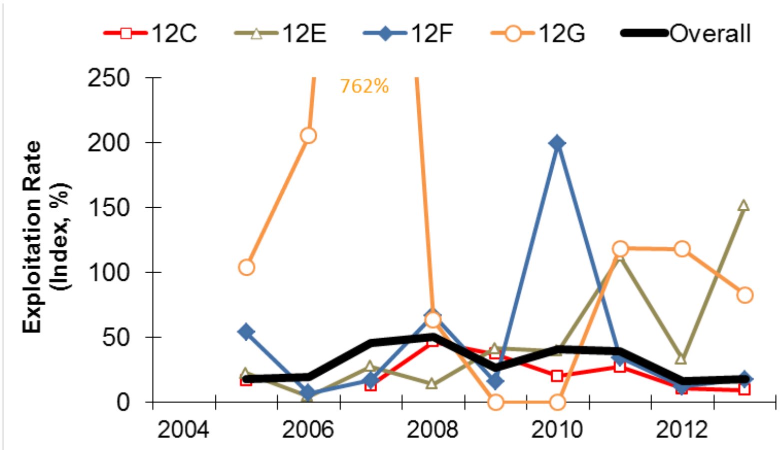

Figure 50. Exploitation rate index from the post-season trap survey in inshore Div. 4R.

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.

Indices from the spring trawl survey in Subdiv. 3Ps are more uncertain than those from the fall surveys because they occur after a variable fraction of fishery removals. The exploitable biomass index from the summer Div. 4R survey is considered unreliable because variation among catches is high compared to the mean. Uncertainty is especially high in interpreting recruitment prospects based on the pre-recruit biomass index from this survey. Chelae are not measured so that the pre-recruit biomass index includes an unknown portion of under-sized adults (terminally molted) that will never recruit to the fishery.

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. As with the Div. 4R trawl survey uncertainty is especially high in interpreting recruitment prospects based on the pre-recruit biomass index from this survey because terminal-molt status (adult versus adolescent) is not determined. This is of concern in Div. 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. Div. 3LNOPs) than under warm regimes (eg. Div. 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 temperature indices. For example, bottom temperature and habitat indices imply that biomass may increase in the very near future in the northern areas (Div. 2J and 3K), but fishery and survey catch rates show no indication of any such imminent increase in recruitment. There is particular uncertainty associated with large annual fluctuations in temperature indices in most divisions in recent years. 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 (Div. 2J and 3K) than in the southern areas (Div. 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 Div. 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. The discrepancy between shell-age based and other indicators of fishery-induced mortality (which also occurs when 2HJ and 3K data are combined) is puzzling and unexplained. 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-shell crab prevalence in recent years (i.e. Div. 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** declined steadily from 2006 to 2011 and has changed little since. **Recruitment** declined from 2006 to 2011, changed little since, and prospects are uncertain in the short term (2-3 years). A recent warm oceanographic regime suggests weak **recruitment** in the **long term**. The **exploitation rate index** increased steadily from 2007 to 2012 before decreasing in 2013. The **pre-recruit fishing mortality rate index** was at its highest level since 2004 during 2011 and 2012 but decreased by more than half in 2013. The **percentage of the catch handled and released** in the fishery decreased from 35 % in 2012 to 20 % in 2013, implying a decrease in pre-recruit mortality.

Maintaining the current level of fishery removals would likely have little effect on the **exploitation rate** in 2014.

Division 3K

Offshore

The **exploitable biomass** declined by more than two thirds since 2008. **Recruitment** declined after 2008 and prospects remain poor in the short term (2-3 years). A recent warm oceanographic regime suggests weak **recruitment** in the **long term**. The trawl survey-based **exploitation rate index** was at its highest level, since 2004, in 2010-2011. It decreased in 2012 before increasing again in 2013. The **pre-recruit fishing mortality rate index** increased from 2007 to 2011 but decreased in 2012 before increasing again in 2013. The **percentage of the catch handled and released** in the fishery decreased from about 20 % in 2012 to about 10 % in 2013, implying a decrease in pre-recruit mortality.

Maintaining the current level of fishery removals would likely result in an increase in the **exploitation rate** in 2014.

Inshore

The **exploitable biomass** decreased from 2007 to 2009 and has since fluctuated. **Recruitment** prospects are poor in the short term (2-3 years). The trap survey-based **exploitation rate index** has changed little throughout the time series. Data are insufficient to estimate **the pre-recruit fishing mortality rate index**.

Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2014.

Divisions 3LNO Offshore

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. However both indices have since increased slightly. Biological data from several sources indicate that **Recruitment** will likely decrease in the short term. A recent warm oceanographic regime suggests weak **recruitment** in the **long term**. The **exploitation rate index** decreased marginally in 2013. The **pre-recruit fishing mortality rate index** decreased from 2008 to 2011 but increased in 2012 and changed little in 2013. The **percentage of the catch handled and released** in the fishery decreased from about 20 % in 2008 to 9 % in 2013, implying a decrease in pre-recruit mortality.

Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2014.

Division 3L Inshore

The **exploitable biomass** increased steadily since 2008 to its highest level in the time series. **Recruitment** has declined slightly since 2010 and is expected to decline further in the short-term (2-3 years). The trap survey-based **exploitation rate index** has changed little over the time series, but there was considerable variability among management areas. Data are insufficient to estimate a **pre-recruit fishing mortality rate index**.

Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2014.

Subdivision 3Ps

Offshore

The **exploitable biomass** increased steadily from 2006 to 2009 before declining sharply to its lowest level in 2013. **Recruitment** has recently declined and is expected to decline further in the short term (2-3 years). A recent warm oceanographic regime suggests weak **recruitment** in the **long term**. The spring trawl survey-based **exploitation rate index** more than doubled from 2009-2012, before doubling again in 2013. The **pre-recruit fishing mortality rate index** has increased steadily since 2009 to about its previous highest level.

Maintaining the current level of fishery removals would result in an increase in the **exploitation rate** in 2014.

Inshore

The **exploitable biomass** increased substantially between 2006 and 2010, changed little in 2011-2012 then decreased by half in 2013. **Recruitment** decreased substantially in 2013 and is expected to remain low in the short term (2-3 years). The post-season trap survey-based **exploitation rate index** has changed little in the past six years. Data are insufficient to estimate a **pre-recruit fishing mortality rate index.**

Maintaining the current level of fishery removals would increase the **exploitation rate** in 2014.

Division 4R

Offshore

The **exploitable biomass** remains low relative to other areas. **Recruitment** prospects are uncertain in the short term (2-3 years). A recent warm oceanographic regime suggests weak **recruitment** in the **long term**. Data are insufficient to calculate the **exploitation rate and pre-recruit fishing mortality rate indices.**

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

Inshore

The **exploitable biomass** fluctuated from 2006 to 2010 but tripled in 2011 and changed little in 2012 before decreasing in 2013. **Recruitment** prospects are unfavourable in the short term (2-3 years). The post-season trap survey-based **exploitation rate index** decreased in 2012 and changed little in 2013. Data are insufficient to estimate a **pre-recruit fishing mortality rate index**.

Maintaining the current level of fishery removals would result in an increase in the **exploitation rate** in 2014.

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 is at very low levels during the past 3 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 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 Div. 2J3KL.

Management Considerations

The development of relationships between biomass indices and ocean climate indices provides the basis for some long-term recruitment prediction. A warming oceanographic regime in recent years suggests weak recruitment for up to 6-10 years. If the current warm regime (Colbourne et al. 2011) persists, weak recruitment can be expected 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 mortality on soft-shelled immediate pre-recruits has increased in Div. 2J3K in recent years due to increased catchability associated with reduced competition from exploitable crabs. There is an additional concern that the abundance of immediate pre-recruits appeared to be very low in Divs. 3K in 2013, as reflected by a low incidence of soft-shell crabs in the fishery despite low catch rates of exploitable crabs. There is also concern for Div. 2J because the resource and fishery have become concentrated in two localized areas (Hawke and Cartwright channels) in recent years such that there is limited ability of fishing fleets to avoid areas of high soft-shelled crab prevalence. The fishery became further concentrated in the southern area (Hawke Channel) in 2013 which may have benefited the exploitable biomass in the northern area (Cartwright Channel), while increasing pre-recruit mortality in the Hawke Channel.

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 development of a Precautionary Approach (PA) Framework for the management of this resource requires clear management objectives.

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 renewal rate.

For resource size, initial results were presented from an ongoing depletion-method project for converting current biomass indices to absolute biomass. If the harvest is depleting a resource during the fishing season, one would expect CPUE to decrease as the season progressed. Comparing the amount harvested with the decrease in CPUE leads to an estimate of the resource initially present. Biomass estimates produced on this basis for Div. 2J, where CPUE consistently decreases, were found to be similar both in pattern in time and magnitude to those from trawl surveys.

For renewal rate, a method was presented for combining data on catch, biomass index, and any proposed factor that might affect or indicate renewal rate, to display which combinations of catch and indicator were sustainable.

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 18-20, 2014 regional peer review process on 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.

Colbourne, E., Craig, J., Fitzpatrick, C., Senciall, D., Stead, P., and Bailey, W. 2011. An assessment of the physical oceanographic environment on the Newfoundland and Labrador Shelf during 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/089. iv + 31p.

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