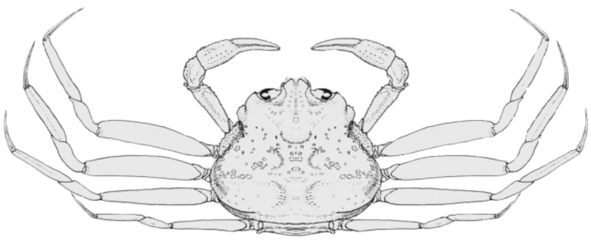
ASSESSMENT OF NEWFOUNDLAND AND LABRADOR SNOW CRAB



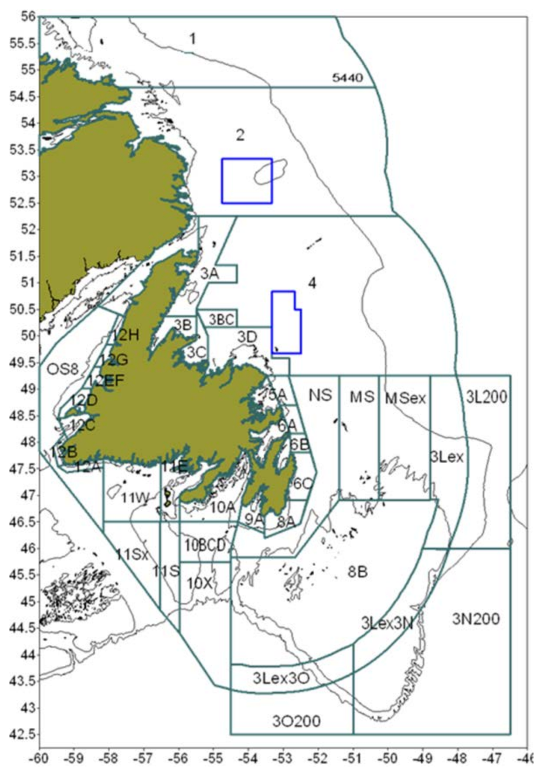


Figure 1. Newfoundland and Labrador Snow Crab Management Areas (CMAs). Blue boxes show trawling and gill-netting closures.

Context

Snow Crab (Chionoecetes opilio) occur 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 3,000 license holders across several vessel fleets under enterprise allocation in 2012. All fleets have designated trap limits, quotas, trip limits, fishing areas within Divisions, and differing seasons.

Stock status is assessed annually for inshore and offshore areas (where applicable) within each Northwest Atlantic Fisheries Organization (NAFO) Division. A vessel monitoring system (VMS) was fully implemented in the offshore fleets in 2004.

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 meeting of the Regional Advisory Process (RAP) was held February 27-March 1 and March 4-6, 2013 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** increased by 22 % from 44,000 t in 2005 to 53,500 t in 2009, and since declined marginally to 50,500 t in 2012, with an increase in the South (Div. 3LNOPs) and a decline in the North (Div. 2HJ3K).
- The multi-species trawl surveys indicate that the **exploitable biomass** declined from 2008 to 2011 and was unchanged in 2012.
- **Recruitment** has recently declined and is expected to decline further in the short term (2-3 years).
- **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime.

Divisions 2HJ

- **Landings** decreased by 37 % since 2008 to 1,600 t. Meanwhile effort increased by 55 % to 2011 before decreasing by 23 % in 2012. The TAC has not been taken in the past 2 years.
- **CPUE** most recently peaked in 2008, then declined steadily by half to 2011, and was unchanged in 2012.
- The **exploitable biomass**, as indicated by the post-season trawl survey, declined steadily from 2006 to 2011 and was unchanged in 2012.
- **Recruitment** declined from 2006 to 2011, changed little in 2012, and is expected to remain low in the short term (2-3 years). The post-season trawl survey pre-recruit index decreased sharply in 2005 and has since fluctuated without trend.
- **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime.
- The **exploitation rate index** has increased steadily after 2007 to its highest level since 2004.
- The **pre-recruit fishing mortality rate index** has been at its highest level since 2004 during each of the past two years. The **percentage of the catch handled and released** in the fishery increased from about 10 % in 2008 to about 35 % in 2012 implying a potential increase in pre-recruit mortality.
- Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2013 but would likely result in high mortality on **soft-shelled** immediate pre-recruits.

Division 3K Offshore

- **Landings** peaked at 12,600 t in 2009 but decreased by 52 % to 6,000 t in 2012. The TAC was not achieved in the past 3 years. **Effort** peaked in 2009 and has since declined by 31 %.
- **CPUE** declined by half from 2008 to 2011 and changed little in 2012.
- The **exploitable biomass,** as indicated by the post-season trap and trawl surveys, declined by more than half from 2008 to 2011 and was unchanged in 2012.

- **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 55 % after 2008.
- **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime.
- The trawl survey-based **exploitation rate index** increased sharply from 2008 to 2010 and changed little in 2011 before decreasing in 2012.
- The **pre-recruit fishing mortality rate index** increased from 2007 to 2011 but decreased in 2012. The **percentage of the catch handled and released** in the fishery increased from about 7 % in 2008 to about 20 % in 2012 implying a potential increase in pre-recruit mortality.
- Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** but would likely result in high mortality on **soft-shelled** immediate pre-recruits in 2013.

Division 3K Inshore

- **Landings** increased from 2,200 t in 2005 to 2,900 t in 2009, but decreased by 34 % to 1,900 t in 2012. The TAC was not taken in the past 4 years in two of the three management areas. **Effort** increased by 70 % from 2008 to 2011 before decreasing by 19 % in 2012.
- **CPUE** increased sharply from 2005 to a record high level in 2008, then declined by more than half before increasing slightly in 2012.
- The **exploitable biomass**, as indicated by the post-season trap survey, decreased from 2007 to 2009 and since changed little but there is considerable variability among management areas.
- While uncertain, **recruitment** prospects appear to have changed little and there is considerable variability among management areas.
- The trap survey-based **exploitation rate index** changed little between 2011 and 2012.
- 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 2013. However, it would likely result in high mortality on **soft-shelled** immediate pre-recruits in some management areas in 2013.

Divisions 3LNO Offshore

- **Landings** decreased by 11 % from 24,500 t in 2006 to 21,900 t in 2009 but since increased by 20 % to 26,200 t in 2012. **Effort** increased by 80 % from 2000 to 2008 and has since declined by 23 %.
- VMS-based **CPUE** declined to its lowest level in 2008, but has since increased steadily to above the average of the series.
- The trawl survey index of **exploitable biomass** declined from 2009 to 2011 and changed little in 2012. The index from the trap survey, which tends to capture older-shelled crabs relatively better than new-shelled crabs in this area, peaked two years later in 2011 and changed little in 2012.

- **Recruitment** has recently peaked and will likely decrease in the short term (2-3 years).
- **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime.
- The **exploitation rate index** increased during the past two years following a sharp decrease from 2008 to 2010.
- The **pre-recruit fishing mortality rate index** decreased from 2008 to 2011 but increased in 2012. The **percentage of the catch handled and released** in the fishery decreased from about 20 % in 2008 to 12 % in 2012, implying a potential decrease in pre-recruit mortality.
- Maintaining the current level of fishery removals would likely result in little change in the exploitation rate in 2013.

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 7,400 t in 2012. **Effort** increased by 24 % from 2008 to 2010 but has since declined by 22 %.
- **CPUE** increased sharply in 2012 to its highest level since 1995, after varying about the long term average for the previous 5 years.
- The post-season trap survey index suggests that the **exploitable biomass** increased in 2012 to its highest level in the time series.
- **Recruitment** has recently peaked and is in decline, although there is considerable variability among management areas. Short-term (2-3 years) prospects are uncertain.
- The trap survey-based **exploitation rate index** changed little in 2012 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 a decrease in the **exploitation rate** in 2013.

Subdivision 3Ps Offshore

- **Landings** almost doubled from 2,300 t in 2006 to a peak of 4,300 t in 2011, before decreasing by 14 % to 3,700 t in 2012. Effort increased by 57 % from 2008 to 2011 before decreasing slightly in 2012.
- **CPUE** increased from 2005 to 2009 and has gradually declined since.
- 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 sharply from 2009 to 2011 and changed little in 2012.
- **Recruitment** has recently declined and is expected to decline further in the short term (2-3 years). Pre-recruit biomass indices from both trap and trawl surveys declined sharply from 2009 to 2011 and changed little in 2012.
- **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime.

- **Exploitation and pre-recruit fishing mortality rates**, as indicated by spring trawl survey indices, decreased from 2007 to 2009 but increased sharply to 2011 and changed little in 2012.
- Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2013.

Subdivision 3Ps Inshore

- **Landings** peaked at 3,500 t in 1999, declined to 700 t in 2005, then more than tripled to 2,500 t in 2012. **Effort** declined from 2005 to 2010 and increased by 36 % to 2012.
- **CPUE** increased steadily from 2005 to 2010, its highest level since 1996, and has since changed little.
- The **exploitable biomass**, as indicated by the post-season trap survey index, increased substantially between 2006 and 2010 and has since changed little.
- **Recruitment** has recently decreased. The index of **pre-recruit-sized males** has recently decreased, suggesting a further decline in recruitment in the short term (2-3 years).
- The post-season trap survey-based **exploitation rate index** changed little during 2008 to 2011 but increased in 2012.
- 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 2013.

Division 4R Offshore

- **Landings** declined by 83 % from 190 t in 2007 to a historical low of 30 t in 2010, but increased back to 190 t in 2012. **Effort** increased by a factor of four in 2011 following the historical low in 2010 and changed little in 2012. The TAC has not been taken since 2002.
- VMS-based **CPUE** declined from 2004 to its lowest level in 2009 before increasing to the average of the series in 2012.
- The **exploitable biomass** remains low relative to other areas.
- **Recruitment** prospects are uncertain in the short term (2-3 years).
- **Long term recruitment** prospects are unfavourable due to a recent warm oceanographic regime.
- 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 2013 is unknown.

Division 4R Inshore

- **Landings** declined by 80 % from 950 t in 2003 to a historical low of 190 t in 2010. They more than doubled to 450 t in 2011 and increased further to 550 t in 2012. **Effort** declined by 95 % from 2004 to 2010 and doubled in 2011 before decreasing substantially in 2012. The TAC has not been taken since 2002.

- **CPUE** declined by more than half from 2002 to 2007 and changed little to 2010 before more than doubling to 2012.
- The **exploitable biomass**, as indicated by the post-season trap survey, fluctuated at a low level from 2006 to 2010 but tripled in 2011 and changed little in 2012.
- **Recruitment** has recently increased and is expected to remain strong in 2013, but short-term (2-3 years) prospects are unfavourable.
- The post-season trap survey-based **exploitation rate index** decreased sharply in 2012.
- 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 2013.

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. 2J3K) 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.

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 3,000 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. Landings increased by 22 % from 44,000 t in 2005 to 53,500 t in 2009, and since declined marginally to 50,500 t in 2012, with an increase in the South (Div. 3LNOPs) and a decline in the North (Div. 2HJ3K). Historically, most of the landings have been from Div. 3KL. Effort has increased since the 1980s and has been broadly distributed in recent years (Fig. 3).

The fishery has been delayed in northern Divisions (Div. 2J and 3K) in some years due to severe ice conditions. Late fishing seasons are believed to contribute to a high incidence of soft-shelled immediate pre-recruits in the catch. Such severe ice conditions can affect the spatial distribution of fishing effort and fishery performance. The fishery was delayed, in many areas, in 2010 due to a dispute relating to the price of crab. It was not delayed in any areas in 2011 and 2012, and began in early April.

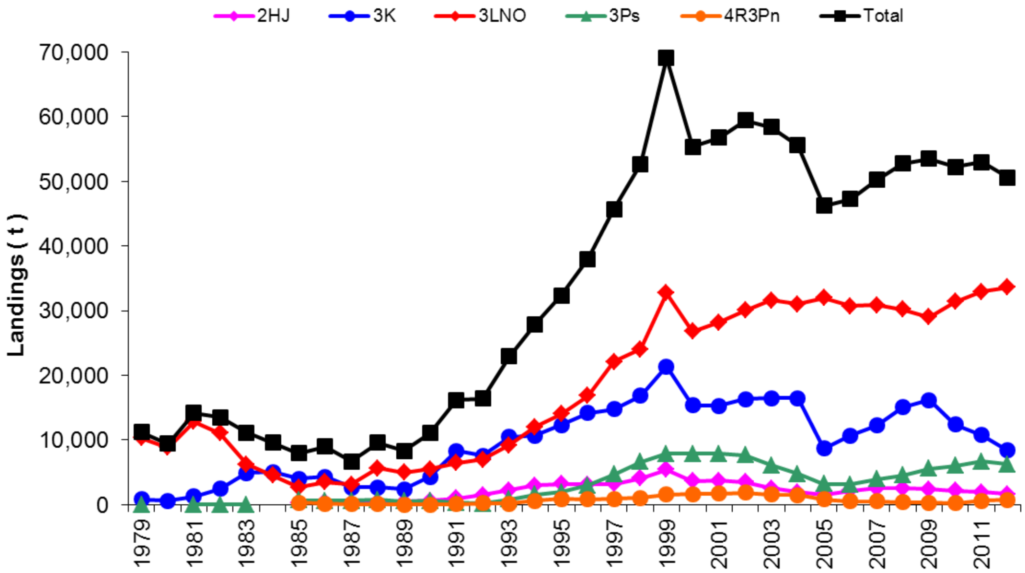


Figure 2. Trends in landings (t) by NAFO Division and in total.

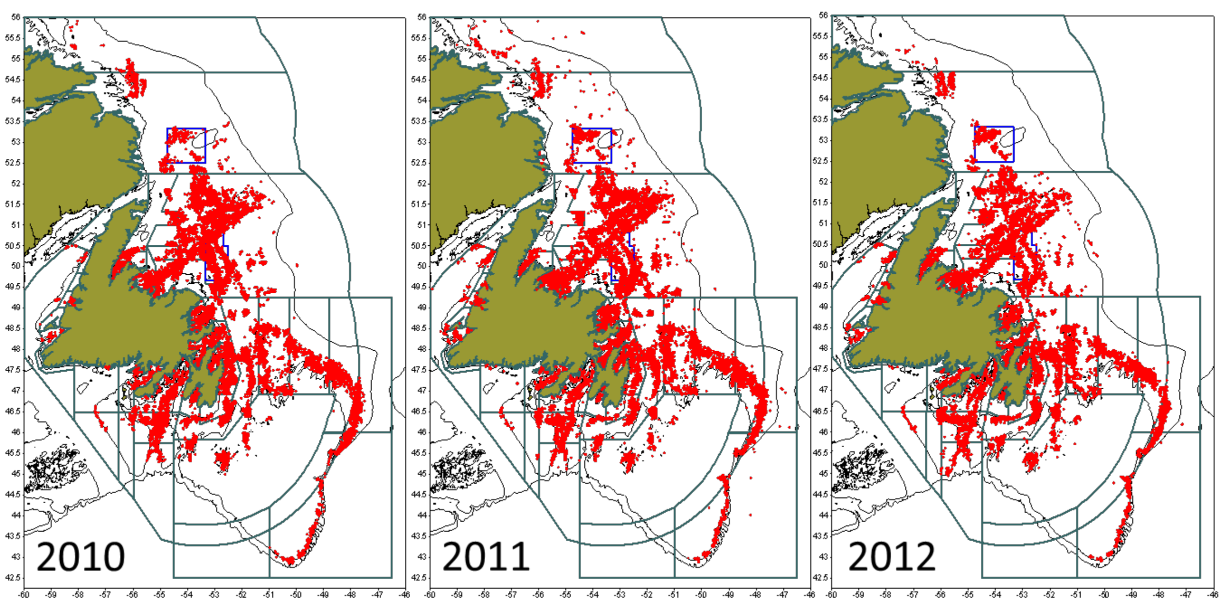


Figure 3. Spatial distribution of commercial fishing effort during 2010-12.

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 RAP. 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.

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.

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), 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 lags of 9 and 10 years gave the best fits. 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 ratio of landings to the exploitable biomass index from the most recent trap and trawl surveys. The pre-recruit fishing mortality index reflects an unknown mortality on released pre-recruits. Trends in pre-recruit fishing mortality are inferred from changes in the ratio of the estimated total catch of undersized (<94 mm CW) males (adolescents and adults) to the trawl survey biomass index of pre-recruits plus undersized (76-94 mm CW) adults from the most recent trawl survey. The total catch of under-sized males is estimated as the observed catch of under-sized males scaled to total landings. Pre-recruit fishing mortality 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.

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 to 2008. Most of the increase was due to recovery in the South (Div. 3LNOPs) while the North

(Div. 2HJ3K) declined, as reflected in the Divisional trends. The multi-species trawl surveys indicate that the **exploitable biomass** declined from 2008 to 2011 and was unchanged in 2012. The recent decline was due to continued decline in the North together with a more recent decline in the South.

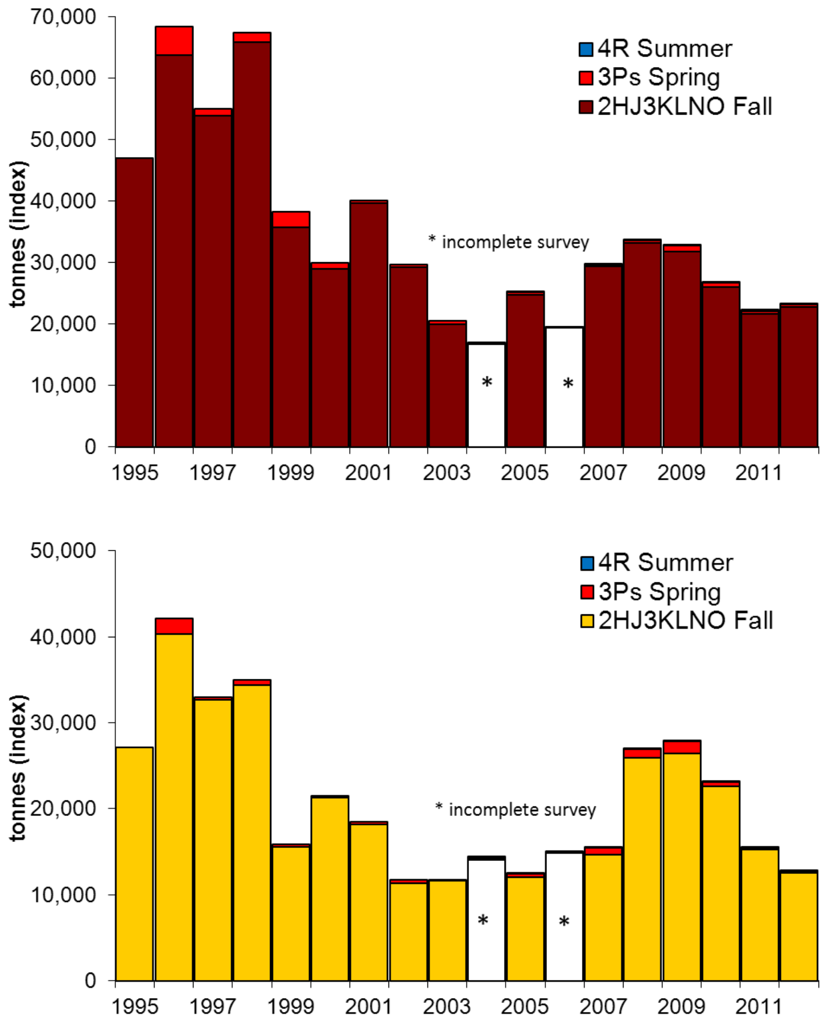


Figure 4. Trends in exploitable biomass indices (above) and pre-recruit biomass indices (below) from multi-species surveys during fall (Division 2HJ3KLNO), spring (Subdivision 3Ps), and summer (Div. 4R). Note that season-specific indices are not additive due to differences in trawl efficiency.

Recruitment increased from 2003 to 2008 but has recently declined and is expected to decline further in the short term (2-3 years). The survey biomass index of pre-recruits (Fig. 4) increased from 2007 to 2009 due to increases in the South (Div. 3LNOPs). It has declined in all areas since 2009. **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime.

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

Commercial Fishery

Landings (Fig. 5) 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 37 % since 2008 to 1,600 t. Meanwhile effort increased by 55 % to 2011 before decreasing by 23 % in 2012. The TAC has not been taken in the past two years. The 2012 fishery was concentrated in Hawke and Cartwright channels, as it was in the previous six years.

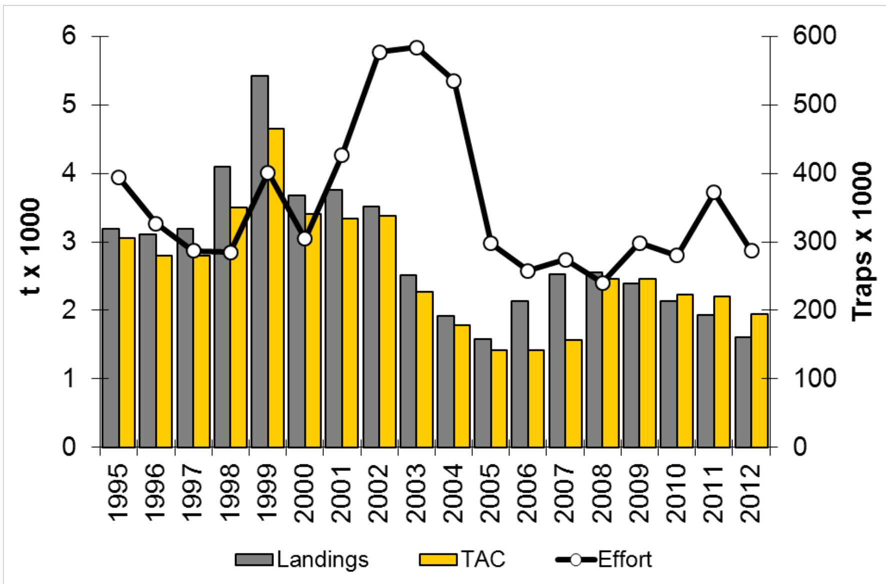


Figure 5. Trends in TAC, landings, and fishing effort in Division 2HJ.

Commercial catch rate (**CPUE**) is 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. 6), 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. It increased to a peak in 2008, declined steadily by half to 2011, and was unchanged in 2012.

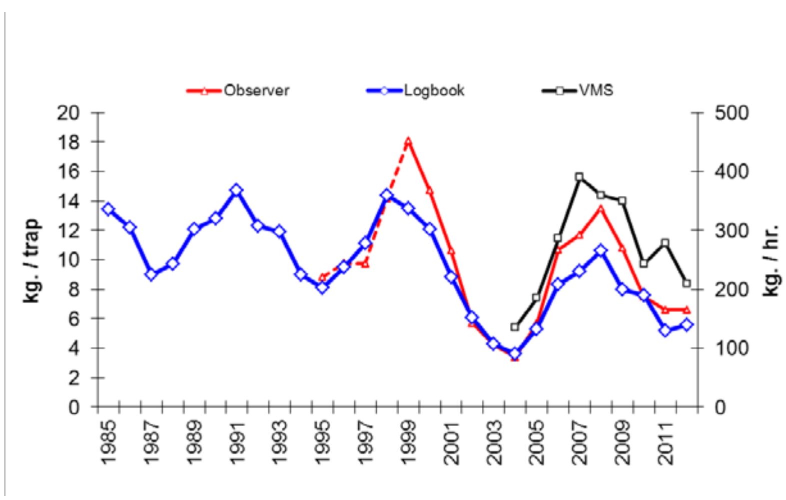


Figure 6. Trends in Division 2HJ commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line).

Biomass

The **exploitable biomass** has decreased in recent years. The post-season trawl survey exploitable biomass index decreased steadily by 92 %, from 1998 to 2002 (Fig. 7). It increased from 2002 to peak in 2006 but remained below pre-2002 levels. It declined steadily from 2006 to 2011 and was unchanged in 2012. The post-season trap survey index changed little during 2010-12, at a lower level than in 2009. The survey was incomplete in 2008 and 2009.

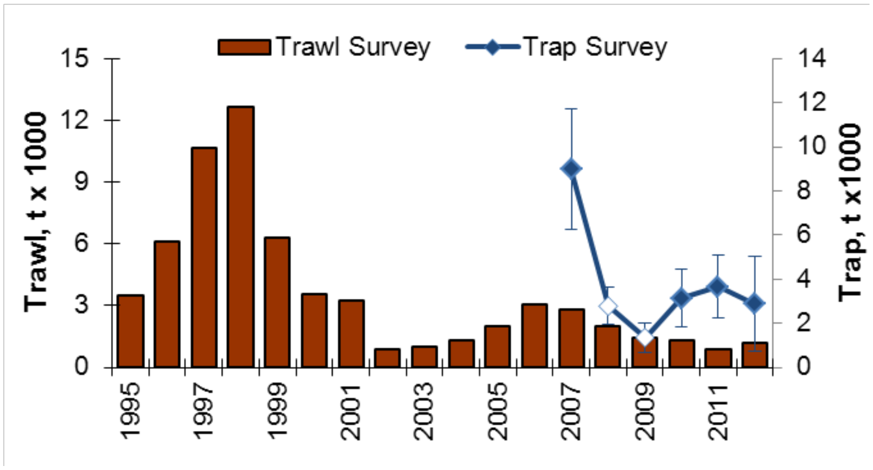


Figure 7. Trends in the Division 2HJ exploitable biomass indices based on post season trawl and trap surveys. The trap survey was conducted only in the southern portion of the Division (Hawke Channel) in 2008 and 2009. Error bars are 95 % confidence intervals.

Recruitment

Recruitment declined from 2006 to 2011, changed little in 2012, and is expected to remain low in the short term (2-3 years). The post-season trawl survey pre-recruit index decreased sharply in 2005 and has since fluctuated without trend (Fig. 8). The post-season trap survey index has changed little during the past 3 years (Fig. 8).

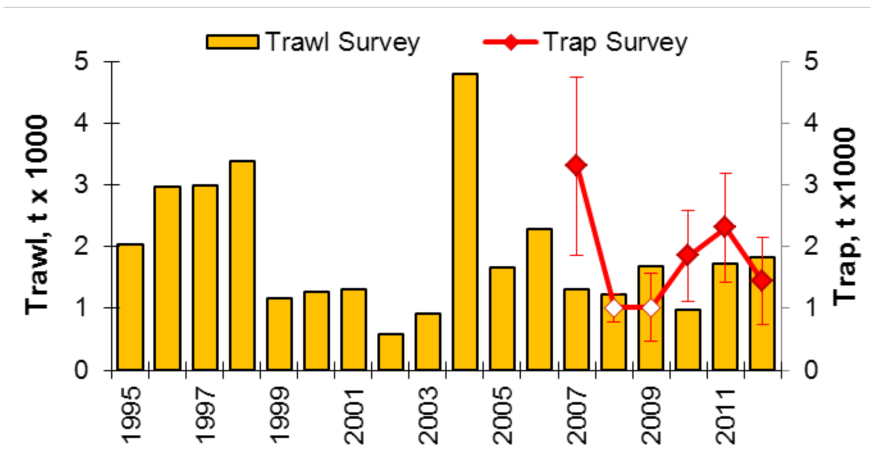


Figure 8. Trends in Division 2HJ pre-recruit biomass indices from the post-season trawl survey and the CPS trap survey. The trap survey is conducted only in the southern portion of the Division (Hawke Channel) in 2008 and 2009. Error bars are 95 % confidence intervals.

Long-term recruitment prospects are unfavourable due to a recent warm oceanographic regime. The ocean climate indices have varied considerably over the past 8 years (Fig. 9), introducing uncertainty beyond the short term. However, the overall trend is warming, with record warm conditions in 2010 and 2011.

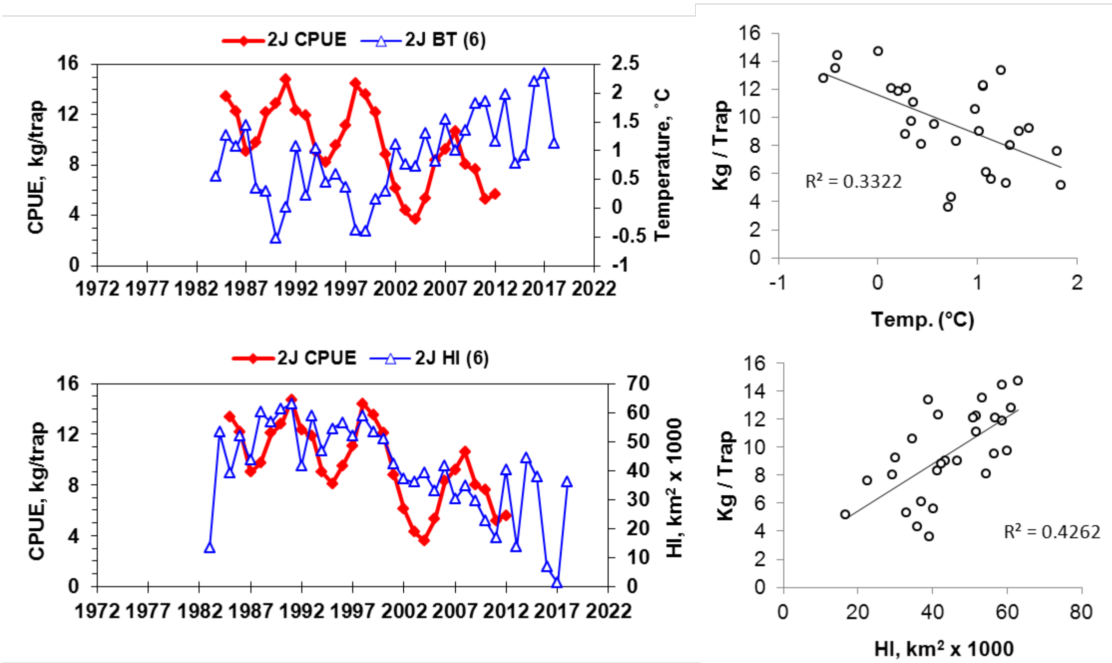


Figure 9. Relationship of Division 2J CPUE with ocean climate indices 6 years earlier; bottom temperature (BT) above and habitat index (HI) below.

Mortality

The **exploitation rate index** declined from 2003 to 2007 and then increased steadily to its highest level since 2004 (Fig. 10). The **pre-recruit fishing mortality rate index** has been at its highest level since 2004 during each of the past two years. The **percentage of the catch handled and released** in the fishery increased from about 10 % in 2008 to about 35 % in 2012 implying a potential increase in pre-recruit mortality.

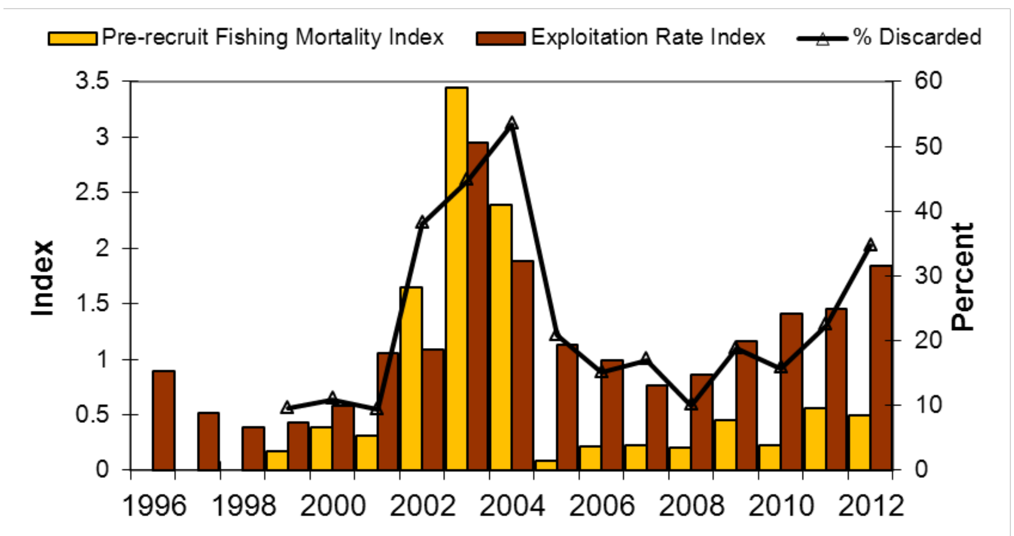


Figure 10. Trends in the Division 2HJ exploitation rate and pre-recruit fishing mortality rate indices and percentage of the catch discarded in the fishery.

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

Commercial Fishery

Landings increased from 2005 to peak at 12,600 t in 2009, but decreased by 52 % to 6,000 t in 2012 (Fig. 11). The TAC was not achieved in the past 3 years. **Effort** peaked in 2009 and has since declined by 31 %.

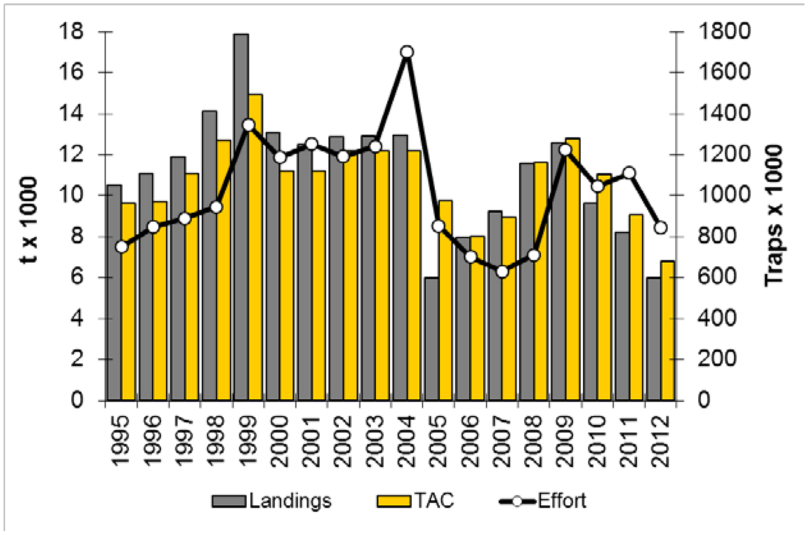


Figure 11. Trends in TAC, landings, and fishing effort in Division 3K offshore.

Commercial **CPUE** (Fig. 12) indicates substantial deterioration of fishery performance in recent years. All three indices agree that **CPUE** declined by half from 2008 to 2011 and changed little in 2012.

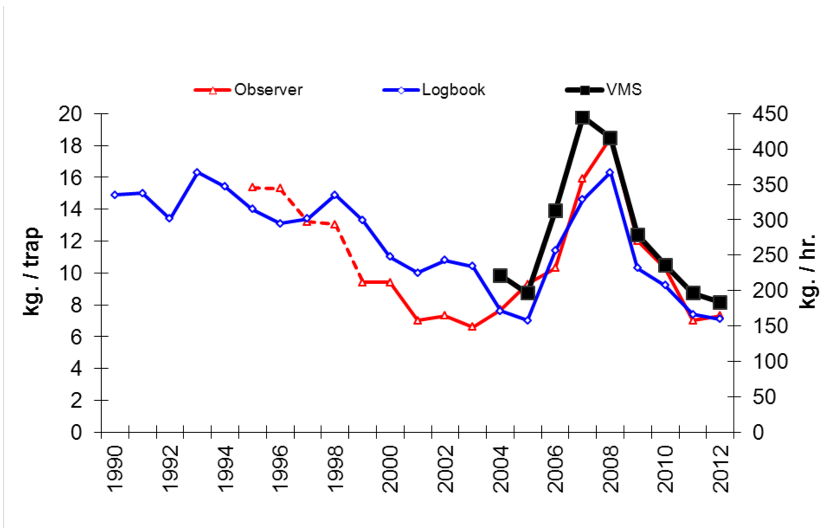


Figure 12. Trends in Division 3K offshore commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line).

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 both survey indices, declined by more than half from 2008 to 2011 and was unchanged in 2012.

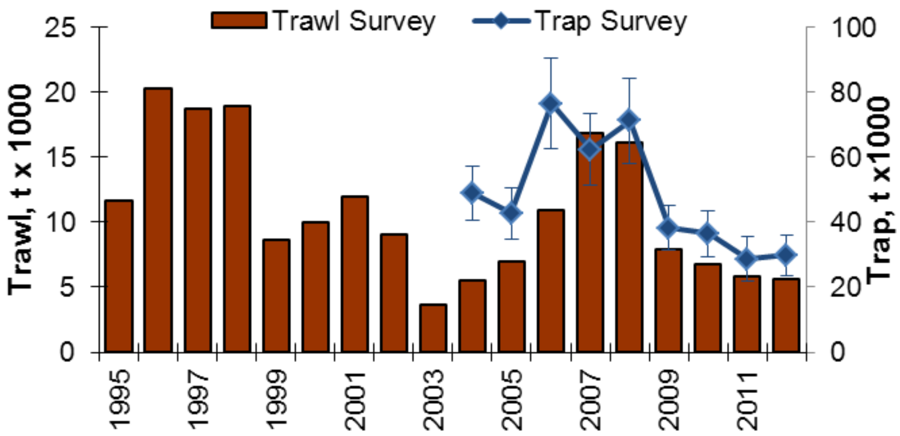


Figure 13. Trends in the Division 3K offshore exploitable biomass indices based on post-season trawl and trap surveys. Error bars are 95 % confidence intervals.

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 55 % since 2008 (Fig. 14).

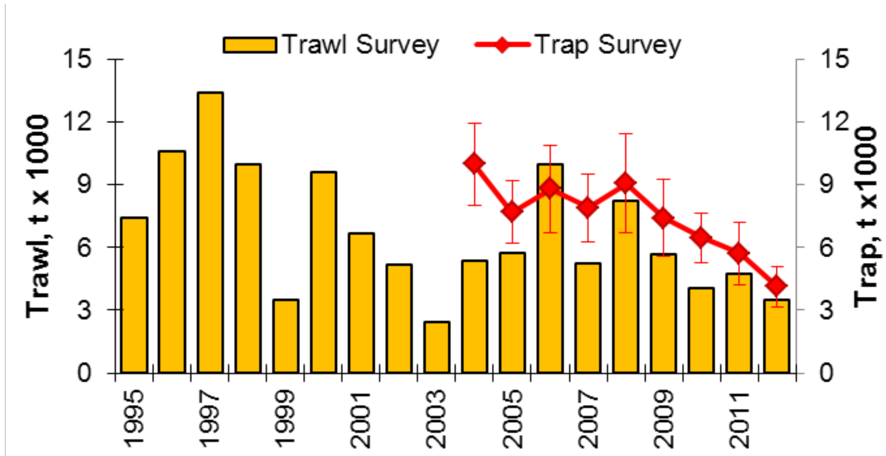


Figure 14. Trends in Division 3K offshore pre-recruit biomass indices based on post-season trawl and trap surveys. Error bars are 95 % confidence intervals.

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.

Long-term recruitment prospects are unfavourable due to a recent warm oceanographic regime. The ocean climate indices have varied considerably over the past 8 years, introducing uncertainty beyond the short term (Fig. 15). However, the overall trend is warming, with record warm conditions in 2011.

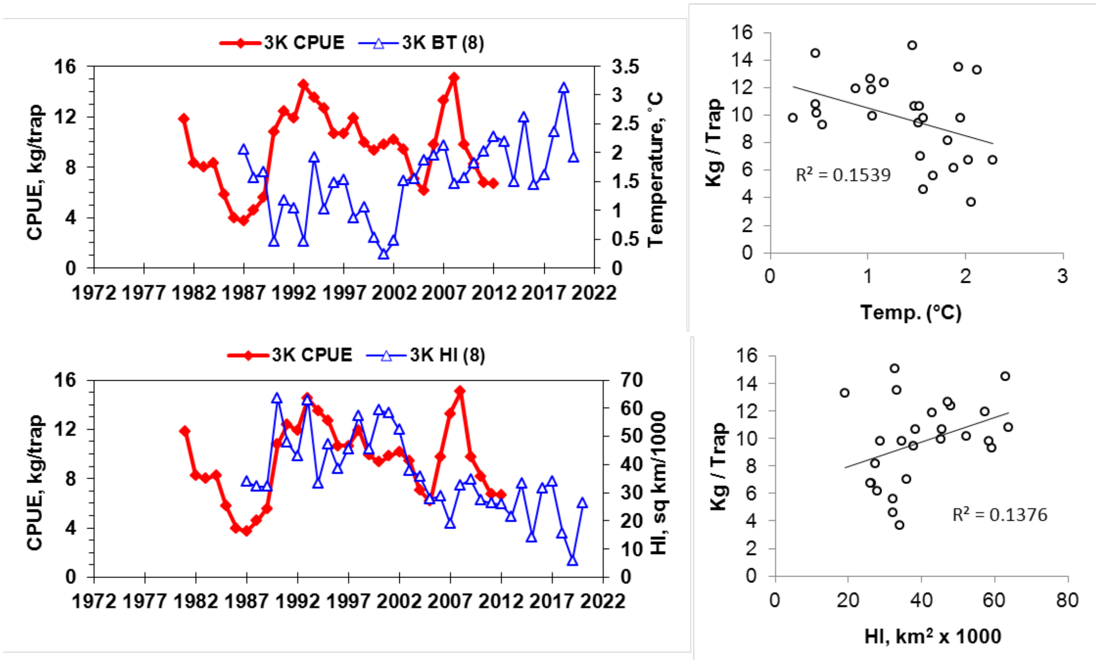


Figure 15. Relationship of offshore Division 3K CPUE with ocean climate indices 8 years earlier; bottom temperature (BT) above and habitat index (HI) below.

Mortality

The trawl survey-based **exploitation rate index** increased sharply from 2008 to 2010 and changed little in 2011 before decreasing in 2012 (Fig. 16). The **pre-recruit fishing mortality rate index** increased from 2007 to 2011 but decreased in 2012. The **percentage of the catch handled and released** in the fishery (Fig. 16) increased from about 7 % in 2008 to about 20 % in 2012 implying a potential increase in pre-recruit mortality.

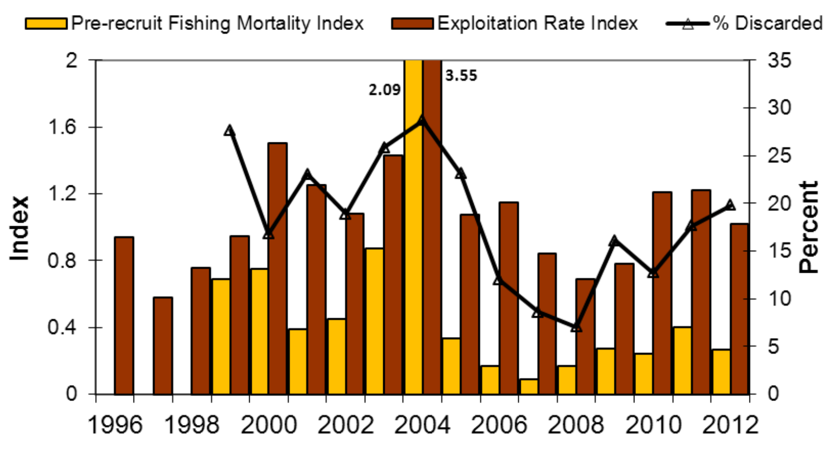


Figure 16. Trends in the Division 3K offshore exploitation rate and pre-recruit fishing mortality rate indices and percentage of the catch discarded in the fishery.

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

Commercial Fishery

Landings (Fig. 17) 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, but decreased by 34 % to 1,900 t in 2012. The TAC was not taken in the past four years in two of the three management areas (3C and 3D). **Effort** increased by 70 % from 2008 to 2011 before decreasing by 19 % in 2012.

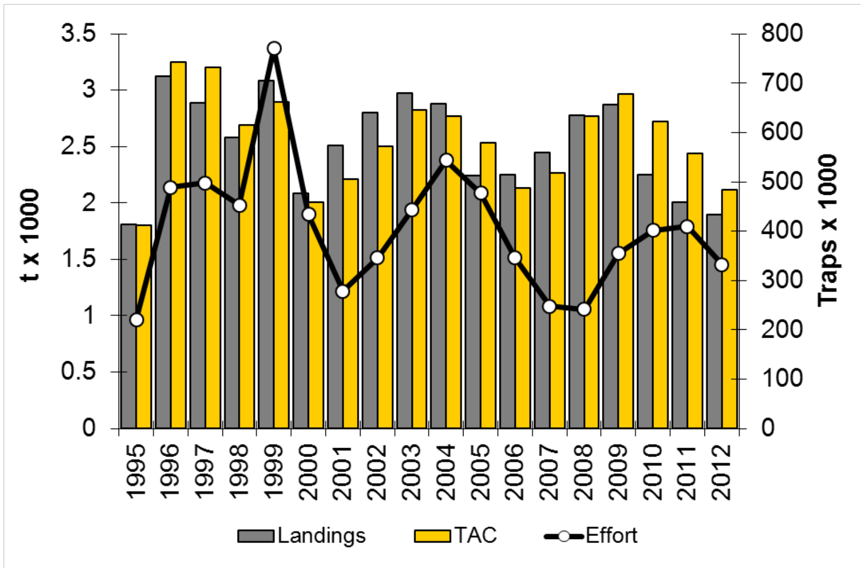


Figure 17. Trends in TAC, landings, and fishing effort in Division 3K inshore.

Commercial **CPUE** (Fig. 18) increased sharply from 2005 to a record high level in 2008, then declined by more than half before increasing slightly in 2012.

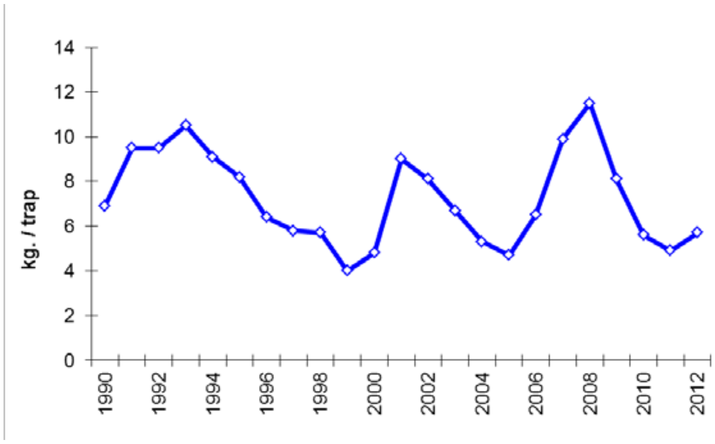


Figure 18. Trend in Division 3K inshore commercial CPUE.

Biomass

The **exploitable biomass**, as indicated by the post-season trap survey index, decreased between 2007 and 2009 and since changed little, but there is considerable variability among management areas (Fig. 19).

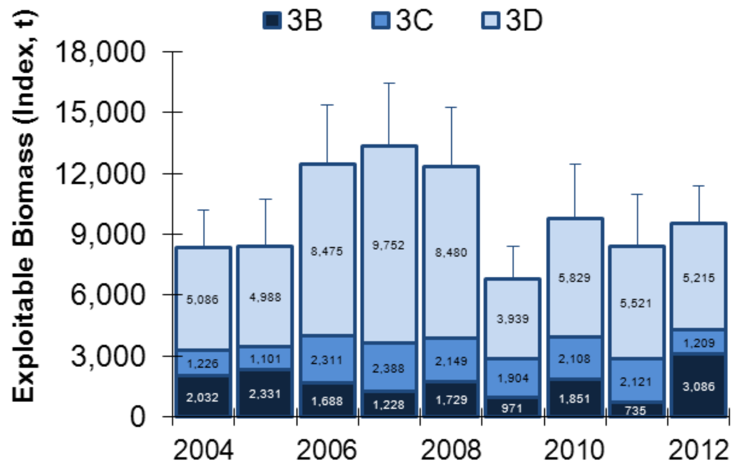


Figure 19. Exploitable biomass index based on the post-season trap survey in inshore Division 3K. Error bars are upper 95 % confidence intervals.

Recruitment

While uncertain, **recruitment prospects** appear to have changed little and there is considerable variability among management areas. The CPS pre-recruit biomass index of undersized crabs (Fig. 20) has varied without trend throughout the time series.

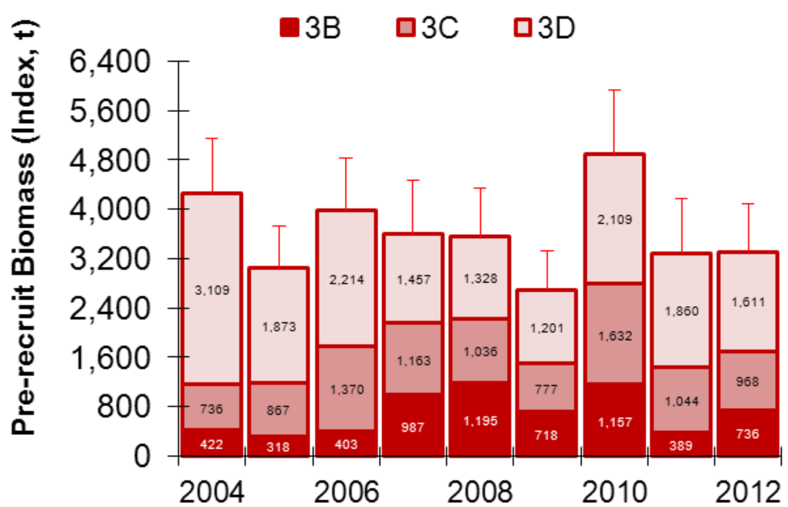


Figure 20. Pre-recruit biomass index of under-sized crabs from the post-season trap survey in inshore Division 3K. Error bars are upper 95 % confidence intervals.

Mortality

The trap survey-based **exploitation rate index** changed little overall between 2011 and 2012 (Fig. 21). However, there was considerable variability among management areas, with the index decreasing slightly in two areas. The sharp increase in White Bay (CMA 3B) was a function of the anomalously low 2011 exploitable biomass index. Data are insufficient to estimate the **pre-recruit fishing mortality rate index.**

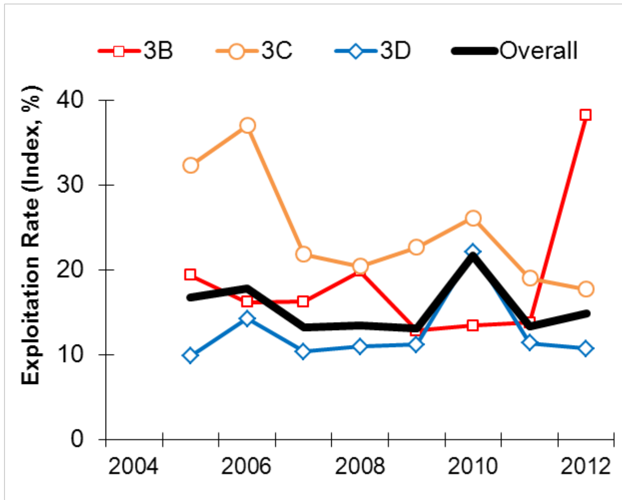


Figure 21. Exploitation rate index from the post-season trap survey in inshore Division 3K.

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

Commercial Fishery

Landings, mostly in Div. 3L, decreased by 11 % from 24,500 t in 2006 to 21,900 t in 2009 but since increased by 20 % to 26,200 t in 2012 (Fig. 22). **Effort** increased by 80 % from 2000 to 2008 and has since declined by 23 %.

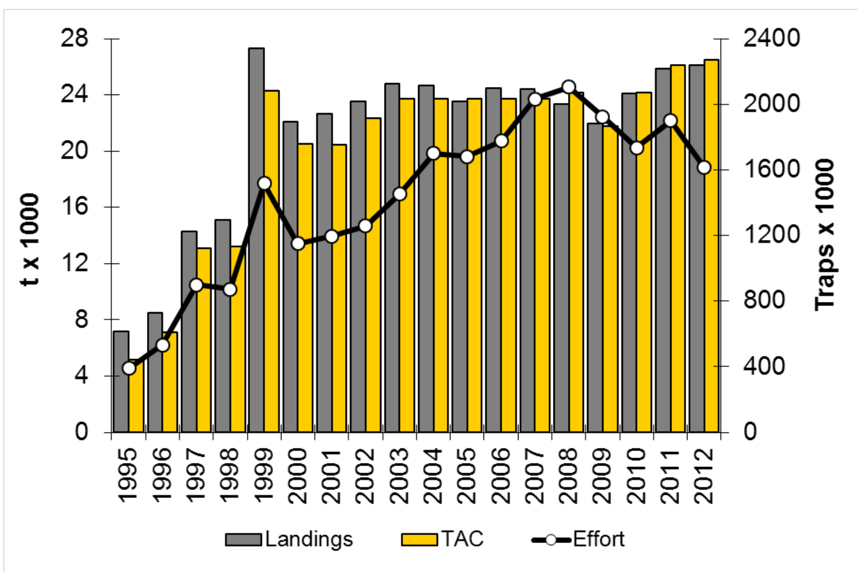


Figure 22. Trends in TAC, landings, and fishing effort in Division 3LNO offshore.

VMS-based **CPUE** declined to its lowest level in 2008 (Fig. 23), but has since increased steadily to above the average of the series.

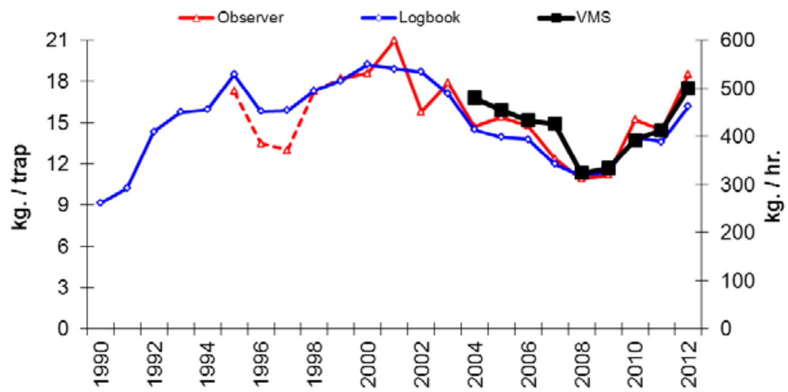


Figure 23. Trends in Division 3LNO offshore commercial CPUE. The observer index is based on at-sea sampling since 1998 (solid line) and catch estimates in earlier years (dashed line).

Biomass

The trawl survey index of **exploitable biomass** declined from 2009 to 2011 and changed little in 2012 (Fig. 24). Traps and trawls have different catchabilities for different components of the population. The index from the trap survey, which tends to capture older-shelled crabs relatively better than new-shelled crabs in this area, peaked two years later in 2011 and changed little in 2012. The decline in the trawl survey index, which is driven by new recruitment, implies that the exploitable biomass has recently declined. This suggests that the residual component of the exploitable biomass, as reflected in the trap survey index, will also soon decline.

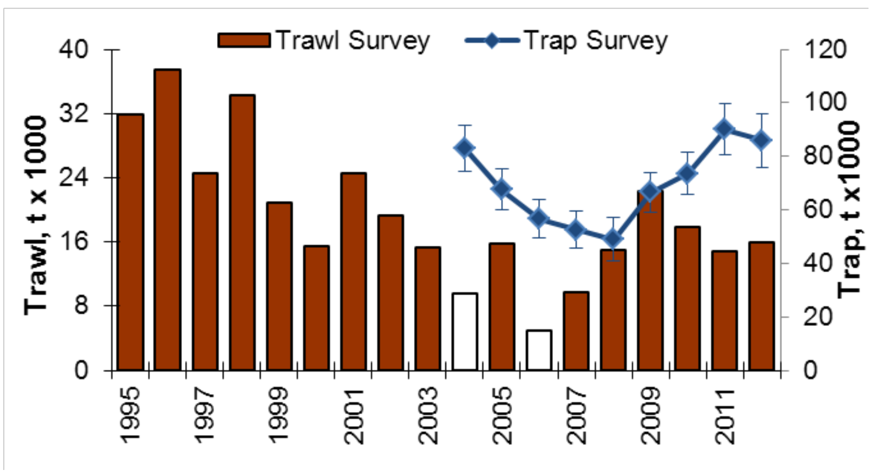


Figure 24. Trends in the Division 3LNO offshore exploitable biomass indices based on post-season trawl and trap surveys; the trawl survey was incomplete in 2004 and 2006. Error bars are 95 % confidence intervals.

Recruitment

Recruitment has recently peaked and will likely decrease in the short term (2-3 years). The high level of pre-recruit biomass indices from both trap and trawl surveys during 2008-10 (Fig. 25) reflects the prominence of a group of large adolescents in both in the trap and trawl survey size distributions in those years. The sharp decrease in the pre-recruit biomass index from both surveys in 2011 (Fig. 25) reflects the progression of that modal group to legal size.

Most adolescents of this recruitment pulse have now recruited to the exploitable biomass as terminally-molted adults.

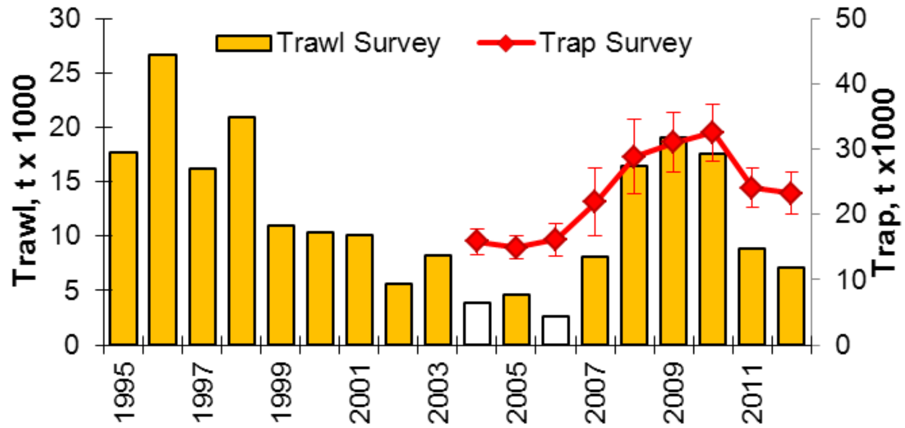


Figure 25. Trends in Division 3LNO offshore pre-recruit biomass indices based on post-season trawl and trap surveys; the trawl survey was incomplete in 2004 and 2006. Error bars are 95 % confidence intervals.

Long-term recruitment prospects are unfavourable due to a recent warm oceanographic regime. The ocean climate indices imply some variability in recruitment beyond the short term (Fig. 26). However the overall trend is warming, with record warm conditions in 2011.

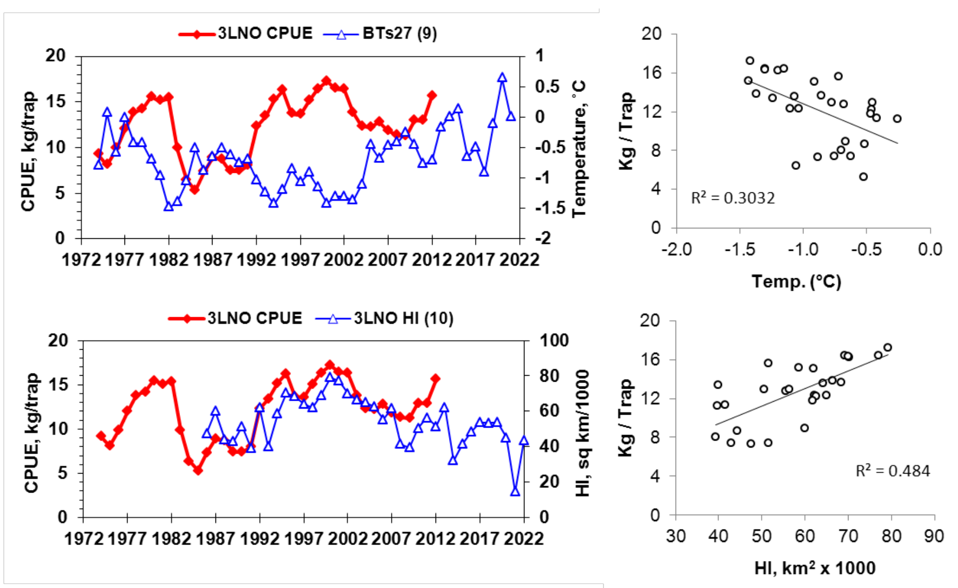


Figure 26. Relationship of Division 3LNO CPUE (inshore and offshore data pooled) with the Station 27 bottom temperature (BTs27) index 9 years earlier (above) and the habitat index (HI) 10 years earlier (below).

Mortality

The **exploitation rate index** increased during the past two years following a sharp decrease from 2008 to 2010 (Fig. 27). The **pre-recruit fishing mortality rate index** decreased from 2008 to 2011 but increased in 2012. The **percentage of the catch handled and released in the fishery** decreased from about 20 % in 2008 to 12 % in 2012, implying a potential decrease in pre-recruit mortality.

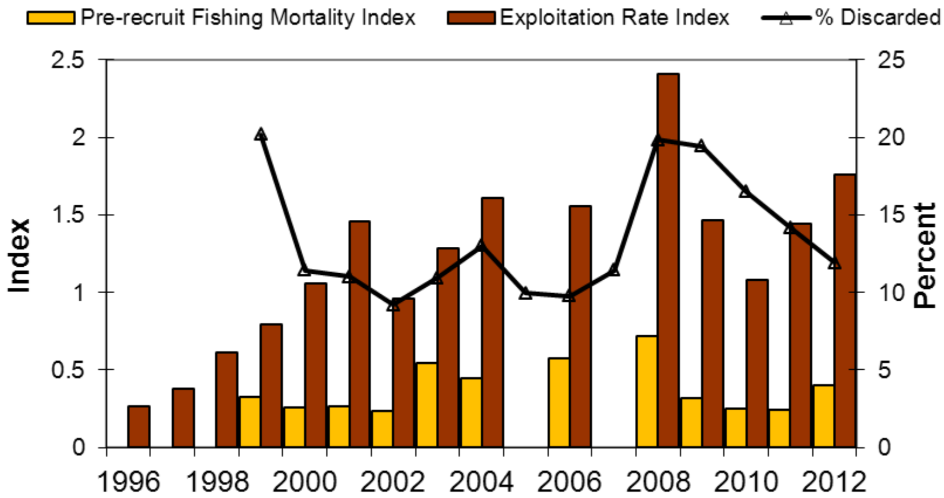


Figure 27. Trends in the Division 3LNO offshore exploitation rate and pre-recruit fishing mortality rate indices and percentage of the catch discarded in the fishery. Mortality indices were not calculated for 2005 and 2007 because the survey was incomplete in 2004 and 2006.

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 7,400 t in 2012 (Fig. 28). **Effort** increased by 24 % from 2008 to 2010 but has since declined by 22 %.

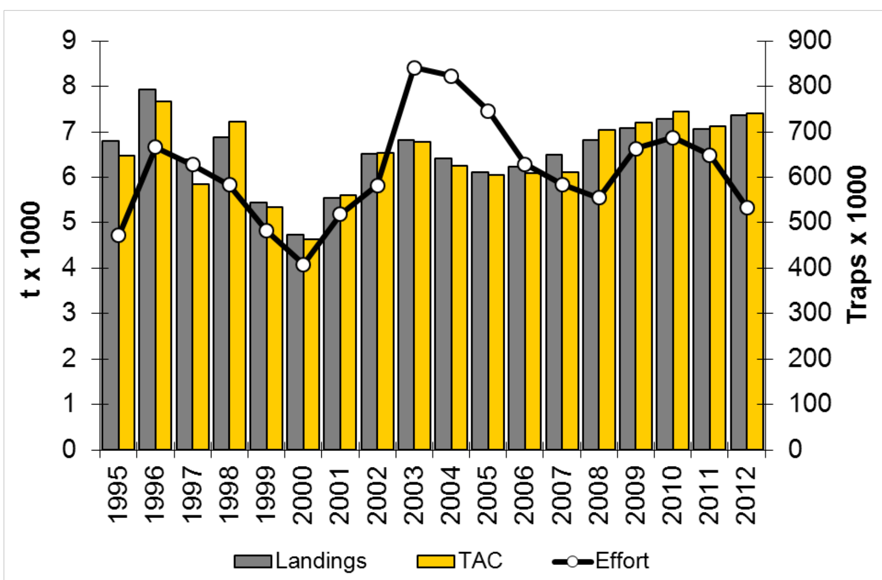


Figure 28. Trends in TAC, landings, and fishing effort in Division 3L inshore.

CPUE increased sharply in 2012 to its highest level since 1995, after varying about the long term average for the previous 5 years (Fig. 29).

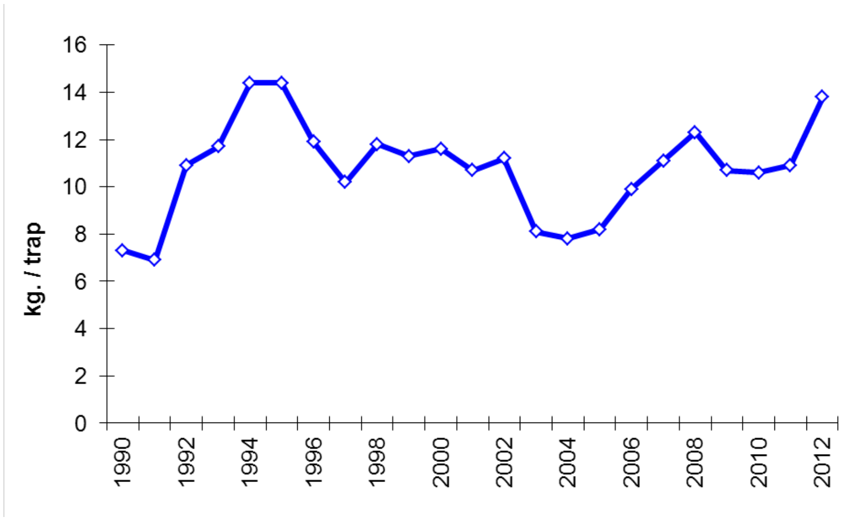


Figure 29. Trends in Division 3L inshore commercial CPUE.

Biomass

The post-season trap survey index suggests that the **exploitable biomass** increased in 2012 to its highest level in the time series (Fig. 30).

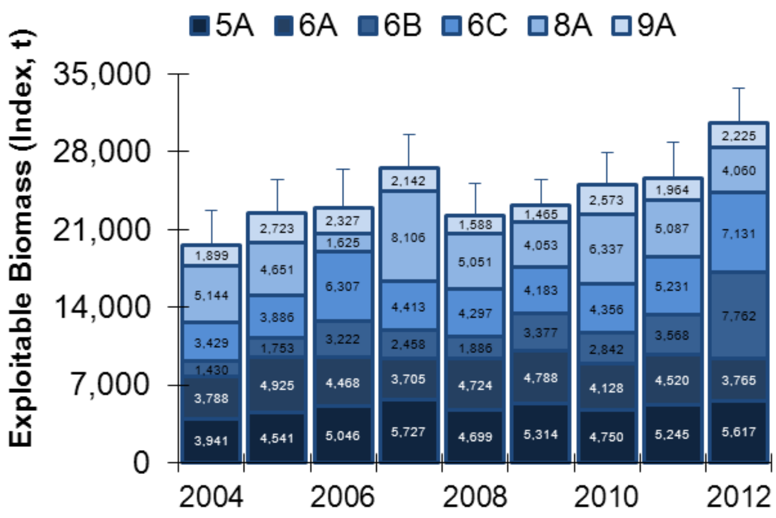


Figure 30. Exploitable biomass index based on the post-season trap survey in inshore Division 3L. Error bars are upper 95 % confidence intervals.

Recruitment

Recruitment, as indicated by new-shelled legal-sized males, has recently peaked and is in decline, although there is considerable variability among management areas. Short-term (2-3 years) prospects are uncertain. The **pre-recruit biomass index** in this area (Fig. 31) is dominated by old-shelled crabs and their proportion has increased in recent years, particularly in 2012. It is believed that most of those are terminally-molted and will never contribute to the exploitable biomass.

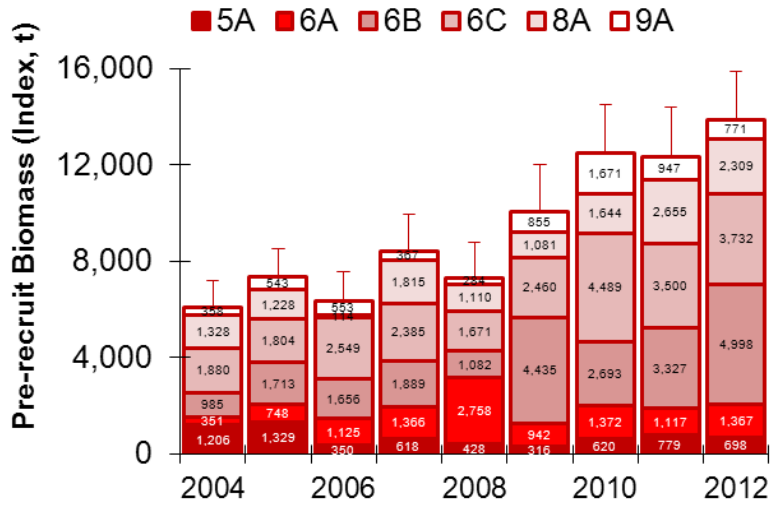


Figure 31. Pre-recruit biomass index of under-sized crabs from the post-season trap survey in inshore Division 3L. Error bars are upper 95 % confidence intervals.

Mortality

The trap survey-based **exploitation rate index** changed little in 2012 but there was considerable variability among management areas (Fig. 32). Data are insufficient to estimate a **pre-recruit fishing mortality rate index**.

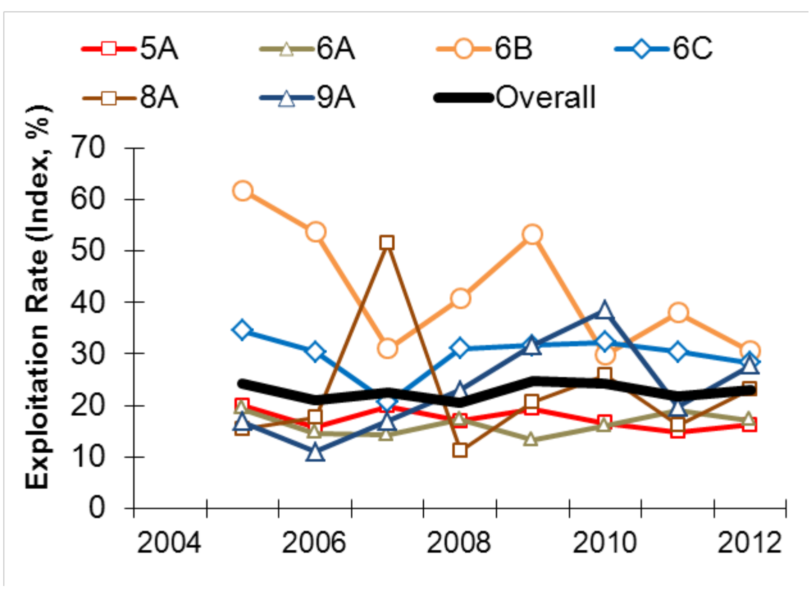


Figure 32. Exploitation rate index from the post-season trap survey in inshore Division 3L.

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 4,300 t in 2011, before decreasing by 14 % to 3,700 t in 2012 (Fig. 33). **Effort** increased by 57 % from 2008 to 2011 before decreasing slightly in 2012.

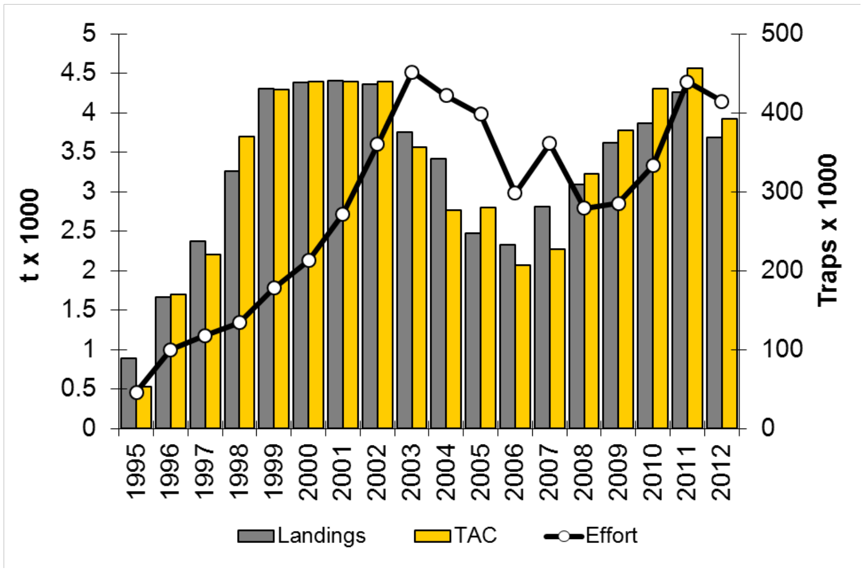


Figure 33. Trends in TAC, landings, and fishing effort in Subdivision 3Ps offshore.

CPUE declined substantially from 1999 to 2005 (Fig. 34). It increased from 2005 to 2009 and has gradually declined since.

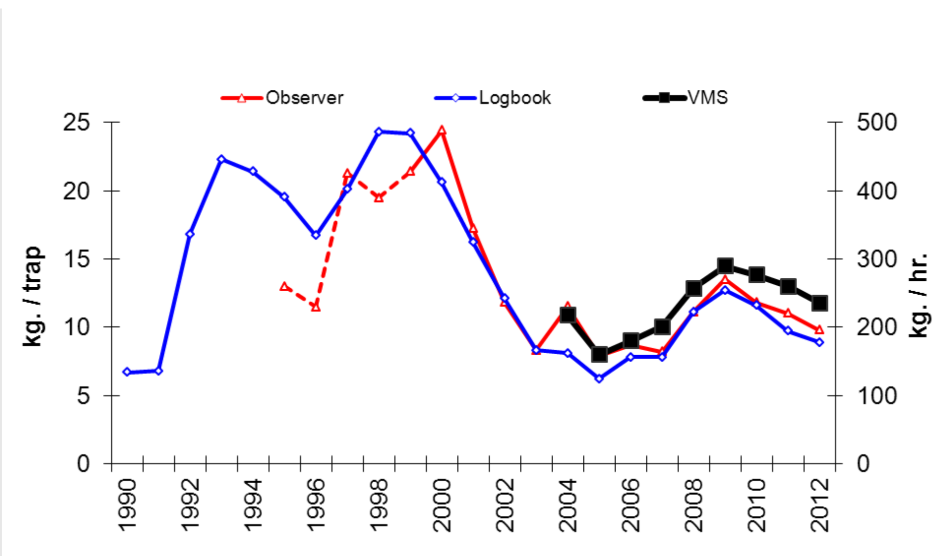


Figure 34. Trends in Subdiv. 3Ps offshore commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line).

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 sharply from 2009 to 2011 and changed little in 2012 (Fig. 35). Both surveys indicate the biomass has decreased in most of the area in 2012, except near the boundary with the inshore area to the north.

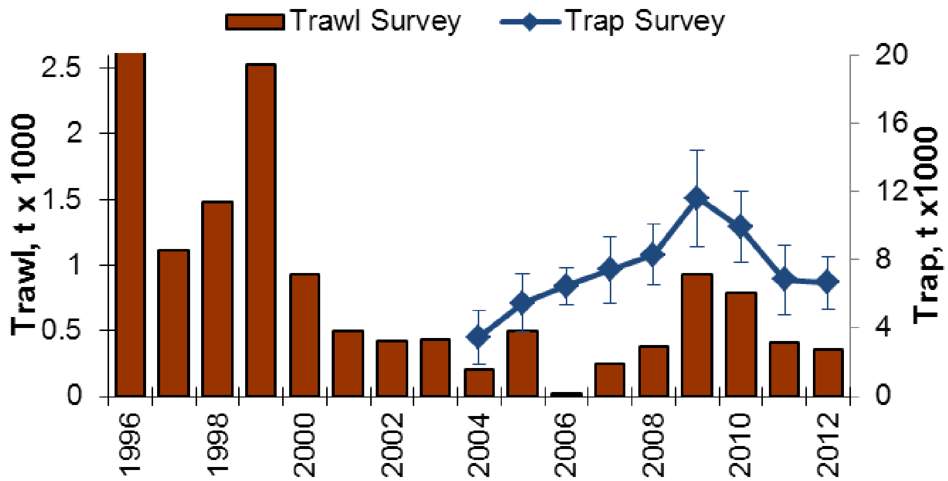


Figure 35. Trends in the Subdivision 3Ps offshore exploitable biomass indices from the pre-season trawl survey and the post-season trap survey; the trawl survey was incomplete in 2006. Error bars are 95 % confidence intervals.

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 sharply from 2009 to 2011, and changed little in 2012 (Fig. 36).

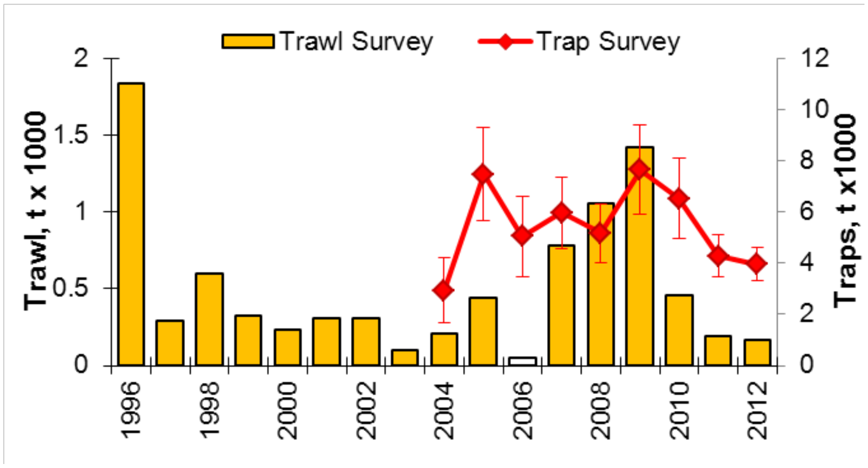


Figure 36. Trends in the pre-recruit biomass indices from the pre-season trawl survey and the post-season trap survey in Subdivision 3Ps offshore; the trawl survey was incomplete in 2006. Error bars are 95 % confidence intervals.

Long-term recruitment prospects are unfavourable due to a recent warm oceanographic regime. The ocean climate indices imply some variability in recruitment beyond the short term (Fig. 37). However, the overall trend is warming, with near record warm conditions in 2011.

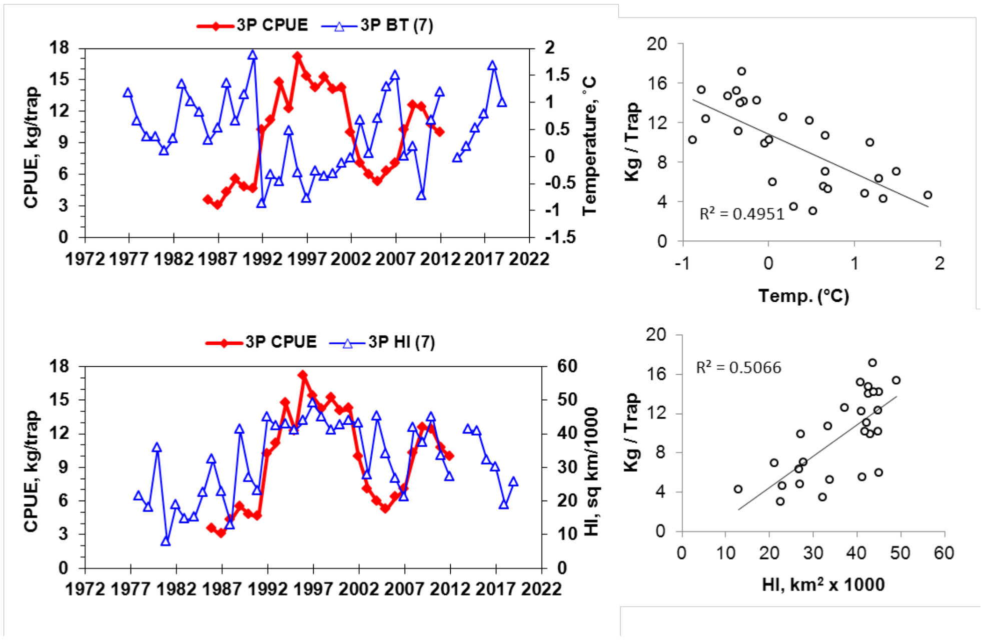


Figure 37. Relationship of offshore Subdivision 3Ps CPUE with ocean climate indices 7 years earlier; bottom temperature (BT) above and habitat index (HI) below. Note: the ocean climate indices are missing for 2013 due to an incomplete 2006 survey.

Mortality

Exploitation and pre-recruit fishing mortality rates, as indicated by spring trawl survey indices, decreased from 2007 to 2009 but increased sharply to 2011, and changed little in 2012 (Fig. 38). The **percentage of the total catch handled and released in the fishery** peaked at about 45 % in 2005, declined by half to 2008, and has since changed little (Fig. 38), implying little change in pre-recruit mortality in recent years.

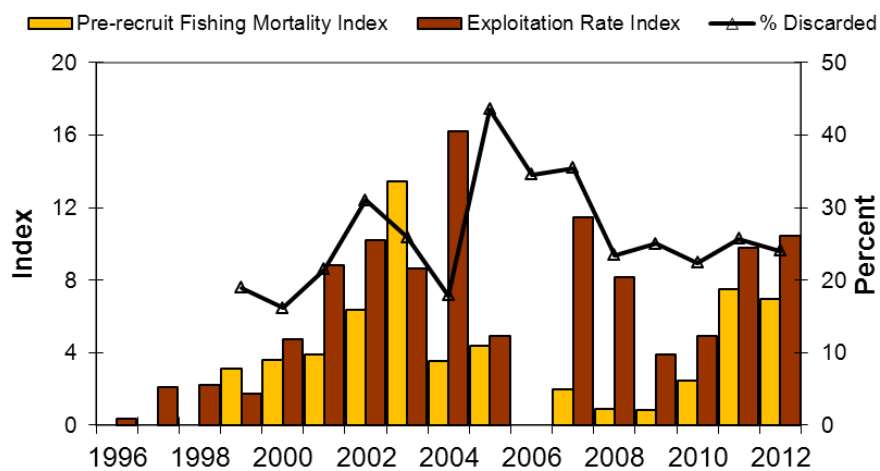


Figure 38. Trends in the Subdivision 3Ps offshore exploitation rate and pre-recruit fishing mortality indices and percentage of the catch discarded in the fishery. Mortality indices were not calculated for 2006 because the survey was incomplete in that year.

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

Commercial Fishery

Landings peaked at 3,500 t in 1999, declined to 700 t in 2005, then more than tripled to 2,500 t in 2012 (Fig. 39). **Effort** declined from 2005 to 2010 and increased by 36 % to 2012.

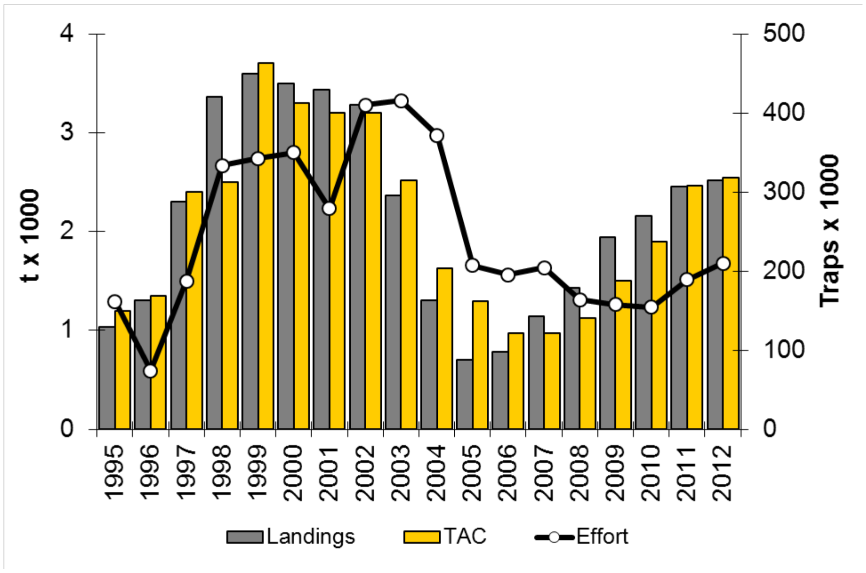


Figure 39. Trends in TAC, landings, and fishing effort in Subdivision 3Ps inshore.

CPUE declined from 2001 to 2005, increased steadily from 2005 to 2010, its highest level since 1996, and has since changed little (Fig. 40).

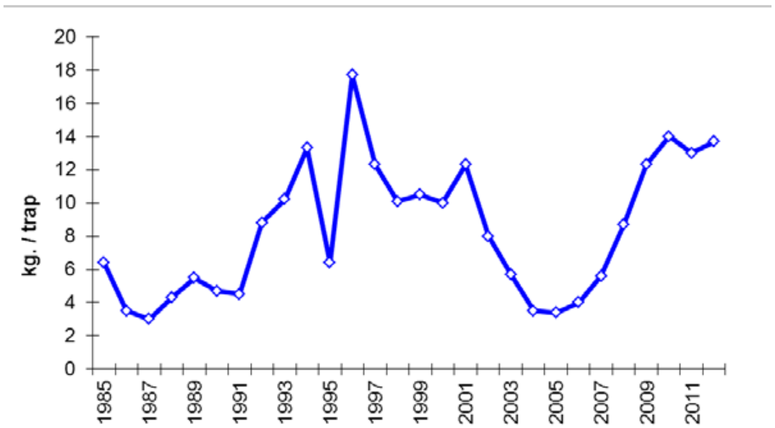


Figure 40. Trends in Subdivision 3Ps inshore commercial CPUE.

Biomass

The **exploitable biomass**, as indicated by the post-season trap survey index, increased substantially between 2006 and 2010, and has since changed little (Fig. 41). Most of the biomass is in Placentia Bay (CMA 10A).

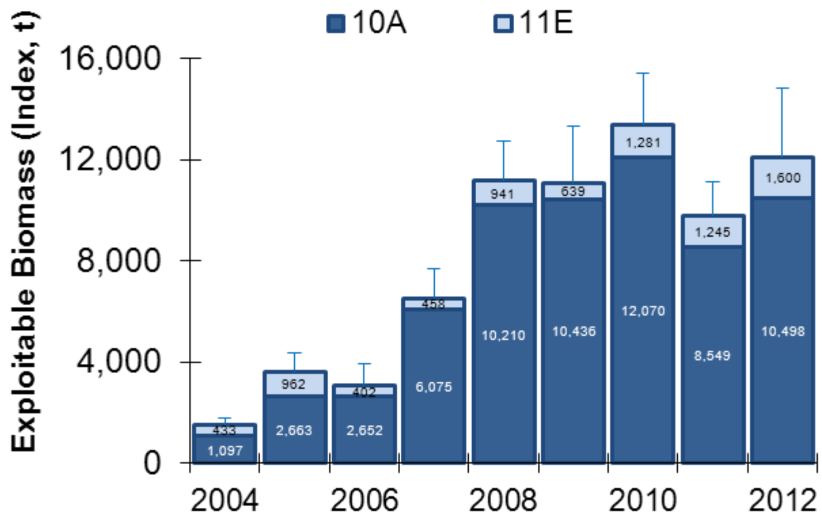


Figure 41. Exploitable biomass index based on the post-season trap survey in inshore Subdivision 3Ps. Error bars are upper 95 % confidence intervals.

Recruitment

Recruitment has recently decreased. The index of pre-recruit-sized males has recently decreased (Fig. 42), suggesting a further decline in recruitment in the short term (2-3 years). However, this index includes a high and increasing proportion of small adults in this area that will never recruit to the fishery.

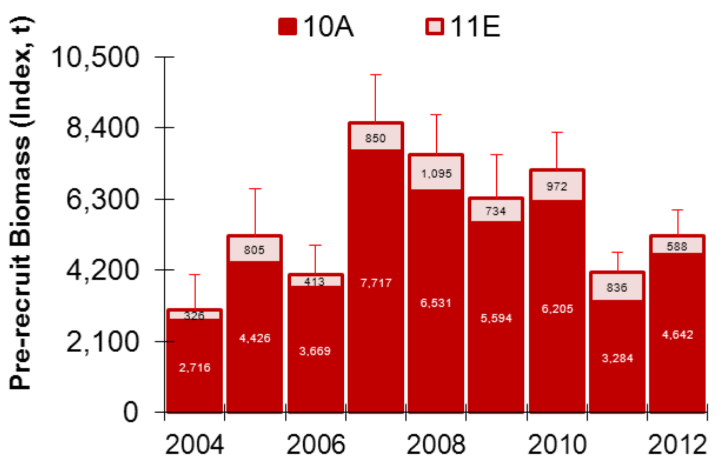


Figure 42. Pre-recruit biomass index of under-sized crabs from the post-season trap survey in inshore Subdivision 3Ps. Error bars are upper 95 % confidence intervals.

Mortality

The post-season trap survey-based exploitation rate index changed little during 2008-11 but increased in 2012. Data are insufficient to estimate a pre-recruit fishing mortality rate index (Fig. 43).

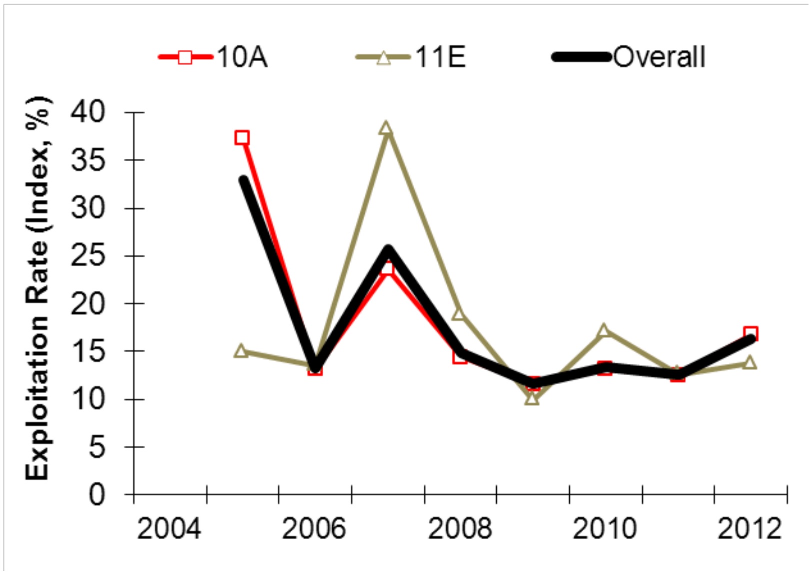


Figure 43. Exploitation rate index from the post-season trap survey in inshore Subdivision 3Ps.

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 to 190 t in 2007 (Fig. 44). They then declined by 83 % to a historical low of 30 t in 2010, but increased back to 190 t in 2012. **Effort** increased by a factor of four in 2011 following the historical low in 2010 and changed little in 2012. The TAC has not been taken since 2002.

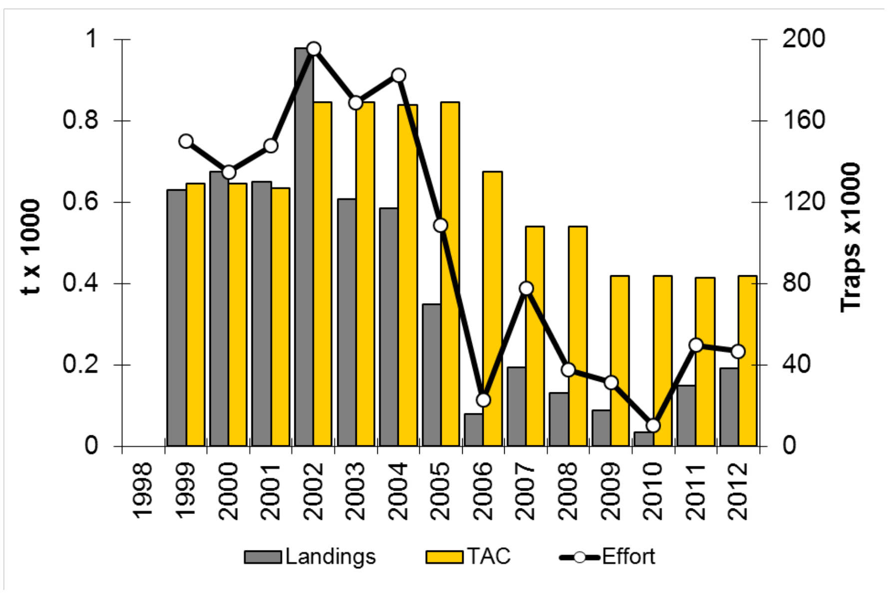


Figure 44. Trends in TAC, landings, and fishing effort in Division 4R offshore.

VMS-based **CPUE** declined from 2004 to its lowest level in 2009 before increasing to the average of the series in 2012 (Fig. 45). CPUE has consistently been low relative to other Divisions.

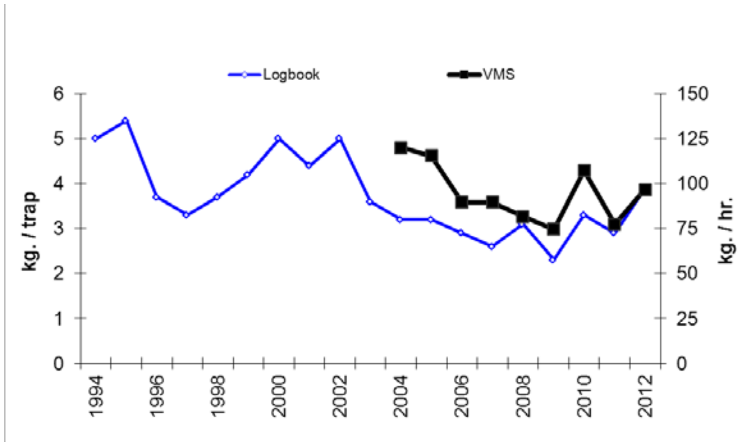


Figure 45. Trends in Division 4R offshore commercial CPUE.

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. This introduces high uncertainty in interpreting annual changes (Fig. 46).

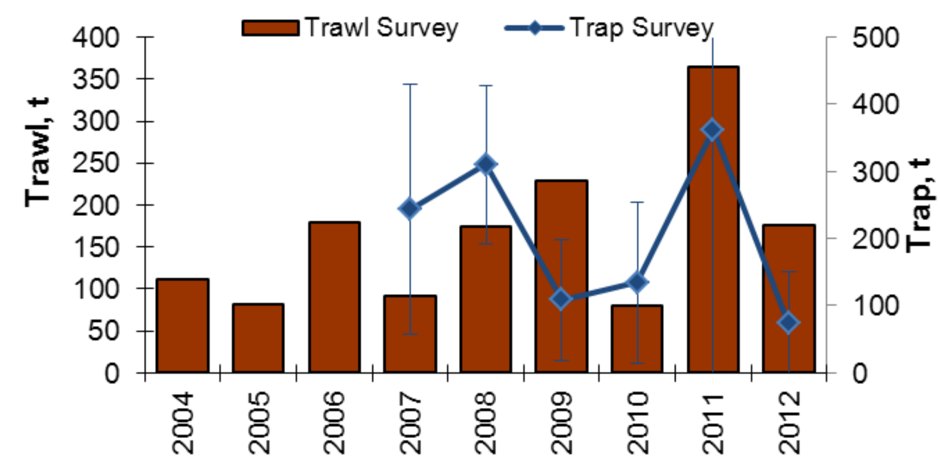


Figure 46. Trends in the Division 4R offshore exploitable biomass indices from the post-season trawl and trap surveys. Error bars are 95 % confidence intervals.

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. This introduces high uncertainty in interpreting annual changes (Fig. 47).

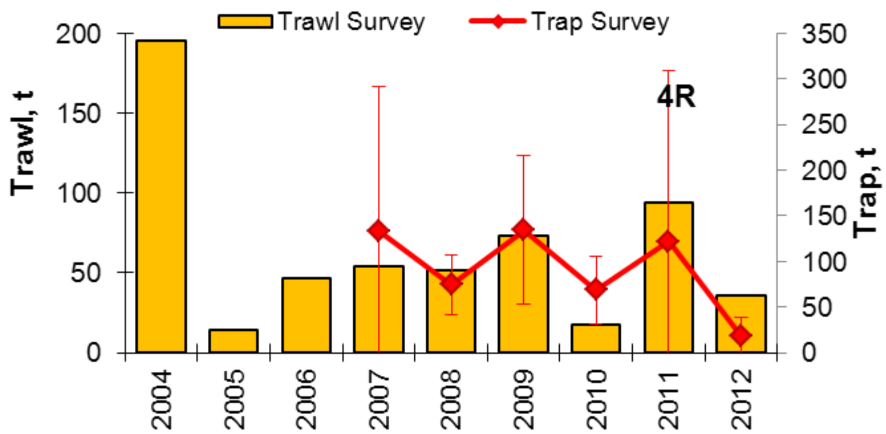


Figure 47. Trends in the pre-recruit biomass indices from the pre-season trawl survey and the post-season trap survey in Division 4R offshore. Error bars are 95 % confidence intervals.

Long term recruitment prospects are unfavourable due to a recent warm oceanographic regime. 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. 48). A more recent temperature series from a nearby oceanographic station trends similarly and shows steady warming since 2008.

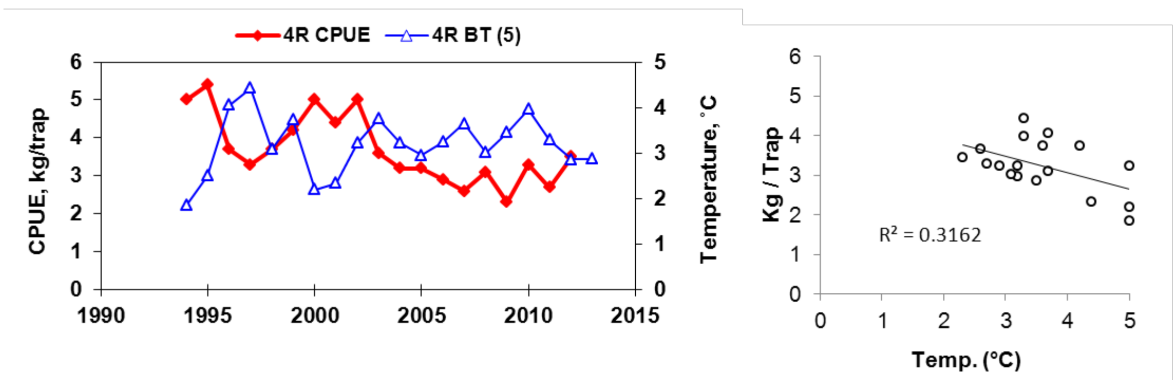


Figure 48. Relationship of offshore Div. 4R CPUE with bottom temperature (BT) 5 years earlier.

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 950 t in 2003 to a historical low of 190 t in 2010. They more than doubled to 450 t in 2011 and increased further to 550 t in 2012 (Fig. 49). **Effort** declined by 95 % from 2004 to 2010 and doubled in 2011 before decreasing substantially in 2012. The TAC has not been taken since 2002.

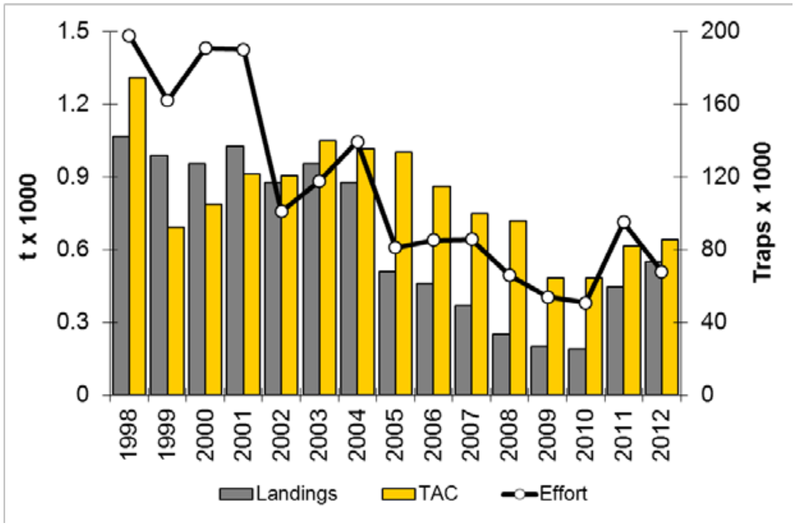


Figure 49. Trends in TAC, landings, and fishing effort in Division 4R inshore.

CPUE declined by more than half from 2002 to 2007 and changed little to 2010 before more than doubling to 2012 (Fig. 50).

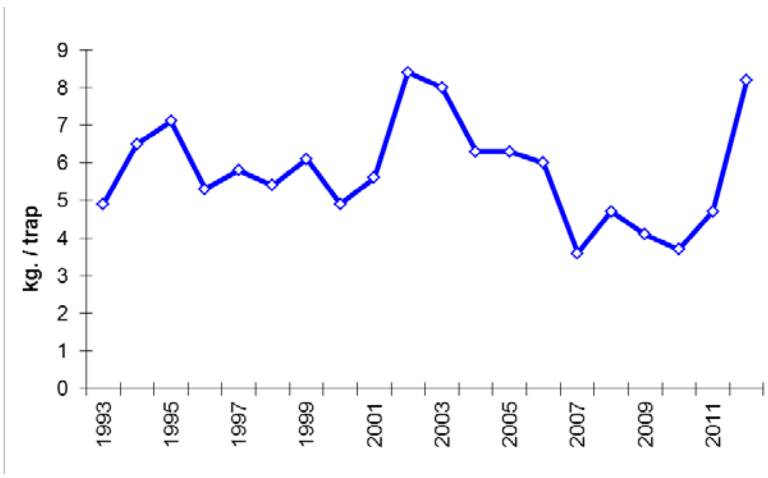


Figure 50. Trends in Division 4R inshore commercial CPUE.

Biomass

The **exploitable biomass**, as indicated by the post-season trap survey, fluctuated at a low level from 2006 to 2010 but tripled in 2011 and changed little in 2012 (Fig. 51).

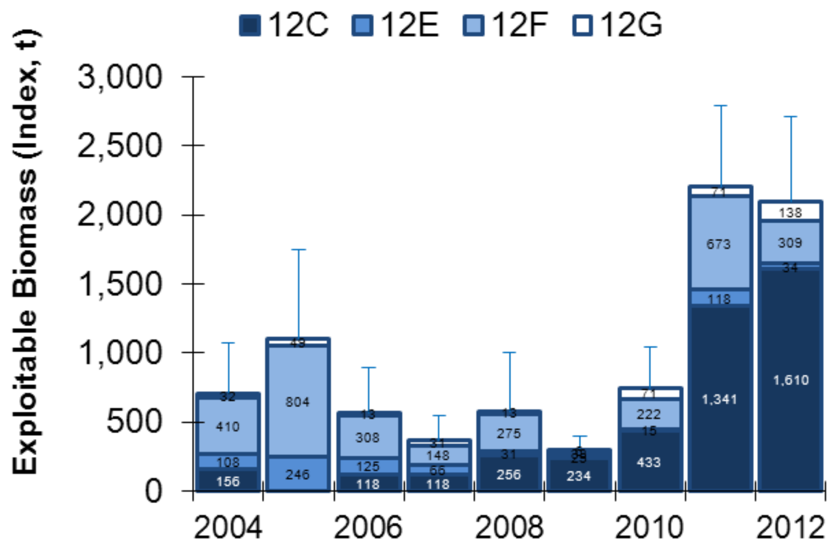


Figure 51. Exploitable biomass index based on the post-season trap survey in inshore Div. 4R. Error bars are upper 95 % confidence intervals.

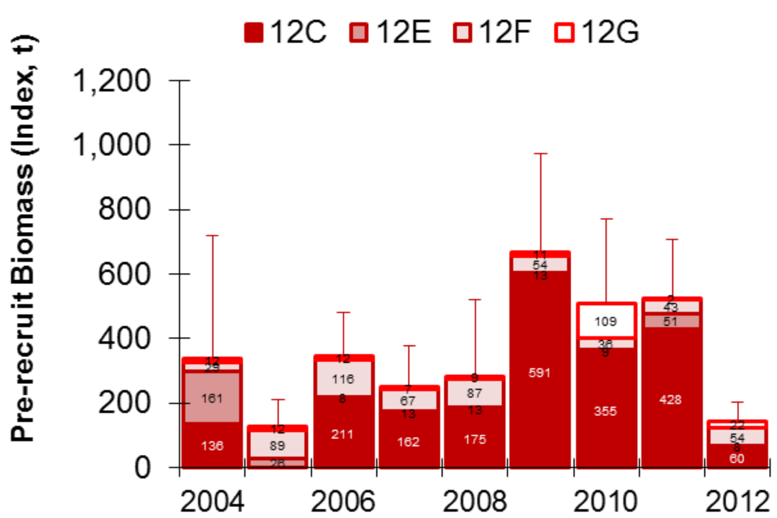


Figure 52. Trends in the pre-recruit biomass index from the post-season trap survey in inshore Div. 4R. Error bars are upper 95 % confidence intervals.

Recruitment

Recruitment has recently increased and is expected to remain strong in 2013, but short-term (2-3 years) prospects are unfavourable. The post-season trap survey pre-recruit biomass index increased substantially in 2009 and changed little until it decreased substantially in 2012 (Fig. 52).

Mortality

The post-season trap survey-based **exploitation rate index** decreased sharply in 2012 (Fig. 53). This was due to a decrease in three of the four crab management areas. Data are insufficient to estimate a **pre-recruit fishing mortality rate index**.

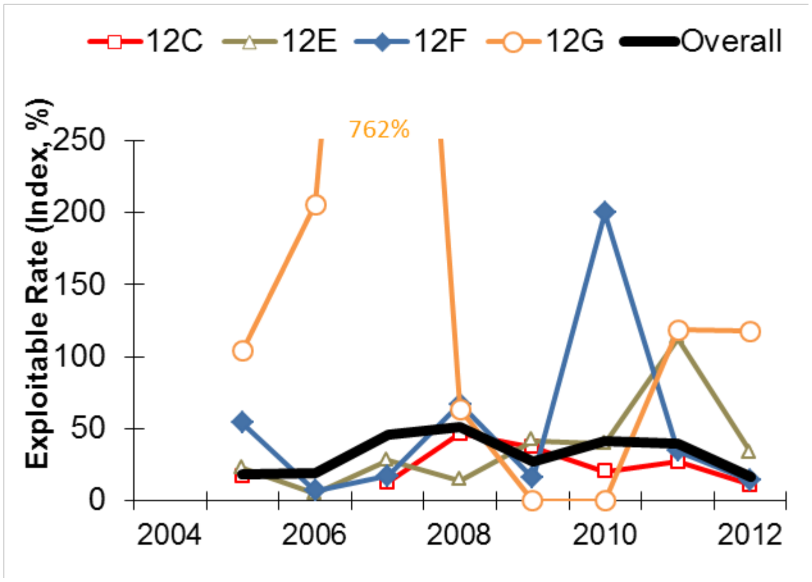


Figure 53. Exploitation rate index from the post-season trap survey in inshore Div. 4R.

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.

Biomass and Recruitment

Surveys

Interpretation of trends in exploitable and pre-recruit biomass indices from surveys is highly uncertain if the survey was incomplete (i.e., Div. 3LNO in 2004 and 2006 and Subdiv. 3Ps in 2006). 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. In the present assessment an incomplete DFO trap survey in 2009 and 2011 introduced considerable uncertainty in interpreting trends for inshore Div. 3K.

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 catchability which likely affects trends in both indices.

Trawl efficiency is directly related to substrate type and crab size, so it is not possible to evaluate long term recruitment prospects based on the abundance index of smallest crabs.

Indices from the spring trawl survey in Subdiv. 3Ps carry higher uncertainty than do those from the fall surveys because it occurs 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. Both DFO and collaborative post-season trap surveys showed anomalously low biomass indices in inshore Div. 3K in 2009, due to reduced catchability, that resulted in high uncertainty regarding recent trends. There is also 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 greatest concern in Subdiv. 3Ps where a high proportion of males terminally molt below the legal size limit. 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.

Long-Term Recruitment Indices

Recruitment prospects for 6-10 future years are inferred from lagged relationships between fishery and survey exploitable biomass indices. These relationships are convincing because they are consistent among four offshore areas that show differing biomass oscillations at differing lags that are biologically meaningful. However, there is uncertainty regarding the reliability of these relationships as recruitment predictors. There is high uncertainty with respect to the sensitivity of these relationships in predicting response to slight changes in the ocean climate regime. For example, bottom temperature and habitat indices imply that 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 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 low-frequency 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, based on the exploitable biomass do not account for possible effects of the fishery. Of particular concern is the potential effect of future changes in the fishery on these associations. Relationships have been developed only for offshore areas, for which extensive time series of biomass indices and ocean climate indices are available. Accordingly, there is uncertainty regarding their applicability to inshore areas.

Fishery Indices

Completion and timely return of logbooks is mandatory in this fishery. 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 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-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.

ADDITIONAL STAKEHOLDER PERSPECTIVES

Division 2J

While catch rates and landings have declined in recent years, harvesters feel that the resource has stabilized. Harvesters are concerned, however, over the abundance of seals and groundfish in the area and the effect that these species are having on the crab resource.

Division 3K

While catch rates and landings have declined in recent years, harvesters are encouraged by the abundance of soft shell crab observed in 2012 and are hopeful that this will result in an increase in catch rates in 2013. There are concerns, however, that mortality has been high on soft shell crab as a result of fishing pressure in areas where soft shell crab is abundant. There are also questions on the soft shell protocol and its effectiveness. Harvesters have serious concerns over the increasing abundance of seals and groundfish and believe it is having a negative impact on the crab resource. Harvesters are also concerned about the effects shrimp trawling may be having on crab abundance.

Catch rates in all inshore areas in 2012 were similar to 2011. Harvesters feel that the resource has stabilized. There is a major concern over the abundance of cod in the inshore areas and its effect on crab abundance.

Division 3L

Inshore

Catch rates and landings have been stable in recent years. Inshore harvesters are encouraged with the positive signs of recruitment and feel that the fishery remains strong.

Harvesters feel that voluntary initiatives such as the Bonus Program, buffer zones, exclusion zones, escape mechanism and bio-degradable twine that have been implemented in Div. 3L have contributed to the overall health of the stock.

Offshore

While landings in 2012 reached its highest level since 1999, catch rates have been stable at a high level and remain above the long term average. Soft shell has not been an issue in this area and harvesters feel strongly that the resource is in good shape and remain optimistic about the future.

Subdivision 3Ps

While catch rates and landings declined slightly in the offshore in 2012, harvesters in most offshore areas had no trouble catching their individual quotas. Harvesters noted that the distance from shore and the high cost of fuel and bait were major contributing factors why all the quota was not taken in 2012. Harvesters are encouraged by very positive signs and high catch rates in an area that was not traditionally fished, and expect this area to contribute to the fishery in 2013.

Catch rates have been stable at a high level in the inshore areas in recent years while landings have increased. Harvesters feel that the stock in the inshore areas is in good shape which leads them to remain optimistic about the future of the fishery.

Division 4R

Effort and landings have increased in the offshore since 2010 while catch rates have remained stable at around the long term average. Harvesters are encouraged by the increased abundance of soft shell crab observed in 2012 and believe that this will contribute to fishery performance in 2013.

Catch rates and landings have increased significantly in the inshore areas since 2010. Harvesters are encouraged by positive signs of recruitment and are optimistic that the fishery will be strong in 2013.

CONCLUSIONS AND ADVICE

Divisions 2HJ

The exploitable biomass declined steadily from 2006 to 2011 and was unchanged in 2012.

Recruitment declined from 2006 to 2011, changed little in 2012, and is expected to remain low in the short term (2-3 years). **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime. The **exploitation rate index** has increased steadily after 2007 to its highest level since 2004. The **pre-recruit fishing mortality rate index** has been at its highest level since 2004 during each of the past two years. The **percentage of the catch handled and released** in the fishery increased from about 10 % in 2008 to about 35 % in 2012 implying a potential increase in pre-recruit mortality.

Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2013 but would likely result in high mortality on **soft-shelled** immediate pre-recruits.

Division 3K

Offshore

The **exploitable biomass** declined by more than half from 2008 to 2011 and was unchanged in 2012. **Recruitment** declined after 2008 and prospects remain poor in the short term (2-3 years). **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime. The trawl survey-based **exploitation rate index** increased sharply from 2008 to 2010 and changed little in 2011 before decreasing in 2012. The **pre-recruit fishing mortality rate index** increased from 2007 to 2011 but decreased in 2012. The **percentage of the catch handled and released** in the fishery increased from about 7 % in 2008 to about 20 % in 2012 implying a potential increase in pre-recruit mortality.

Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** but would likely result in high mortality on **soft-shelled** immediate pre-recruits in 2013.

Inshore

The **exploitable biomass** decreased from 2007 to 2009 and since changed little but there is considerable variability among management areas. While uncertain, **recruitment** prospects appear to have changed little and there is considerable variability among management areas. The trap survey-based **exploitation rate index** changed little between 2011 and 2012. 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 2013. However, it would likely result in high mortality on **soft-shelled** immediate pre-recruits in some management areas in 2013.

Divisions 3LNO Offshore

The trawl survey index of **exploitable biomass** declined from 2009 to 2011 and changed little in 2012. The index from the trap survey, which tends to capture older-shelled crabs relatively better than new-shelled crabs in this area, peaked two years later in 2011 and changed little in 2012. **Recruitment** has recently peaked and will likely decrease in the short term (2-3 years). **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime. The **exploitation rate index** increased during the past two years following a sharp decrease from 2008 to 2010. The **pre-recruit fishing mortality rate index** decreased from 2008 to 2011 but increased in 2012. The **percentage of the catch handled and released** in the fishery decreased from about 20 % in 2008 to 12 % in 2012, implying a potential decrease in pre-recruit mortality.

Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2013.

Division 3L Inshore

The **exploitable biomass** increased in 2012 to its highest level in the time series. **Recruitment** has recently peaked and is in decline, although there is considerable variability among management areas. Short-term (2-3 years) prospects are uncertain. The trap survey-based **exploitation rate index** changed little in 2012 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 a decrease in the **exploitation rate** in 2013.

Subdivision 3Ps

Offshore

The **exploitable biomass** increased steadily from 2006 to 2009 before declining sharply from 2009 to 2011 and changed little in 2012. **Recruitment** has recently declined and is expected to decline further in the short term (2-3 years). **Long-term recruitment** prospects are unfavourable due to a recent warm oceanographic regime. **Exploitation and pre-recruit fishing mortality rates** decreased from 2007 to 2009 but increased sharply to 2011 and changed little in 2012.

Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** in 2013.

Inshore

The **exploitable biomass** increased substantially between 2006 and 2010 and has since changed little. **Recruitment** has recently decreased. The index of **pre-recruit-sized males** has recently decreased, suggesting a further decline in recruitment in the short term (2-3 years). The post-season trap survey-based **exploitation rate index** changed little during 2008 to 2011 but increased in 2012. 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 to the **exploitation rate** in 2013.

Division 4R

Offshore

The **exploitable biomass** remains low relative to other areas. **Recruitment** prospects are uncertain in the short term (2-3 years). **Long term recruitment** prospects are unfavourable due to a recent warm oceanographic regime. 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 2013 is unknown.

Inshore

The **exploitable biomass** fluctuated at a low level from 2006 to 2010 but tripled in 2011 and changed little in 2012. **Recruitment** has recently increased and is expected to remain strong in 2013, but short-term (2-3 years) prospects are unfavourable. The post-season trap survey-based **exploitation rate index** decreased sharply in 2012. 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 2013.

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 record low levels during the past 1-2 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 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 unfavourable recruitment for up to 6-10 years. If a warm regime persists, as expected (Colbourne et al. 2011), poor 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 believed to be a function of both 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 declining exploitable biomass. There is additional concern for Div. 2J because the resource and fishery have become concentrated in two localized areas (Hawke and Cartwright channels) such that there is limited ability of fishing fleets to avoid areas of high soft-shelled crab prevalence. It would be precautionary to reduce the exploitation rate so as to promote recovery of the exploitable biomass.

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.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 27–March 6, 2013 regional peer review process on the assessment of Snow Crab. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule.

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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