Fisheries and Oceans Canada
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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2016/013

ASSESSMENT OF NEWFOUNDLAND AND LABRADOR (DIVISIONS 2HJ3KLNOP4R) SNOW CRAB

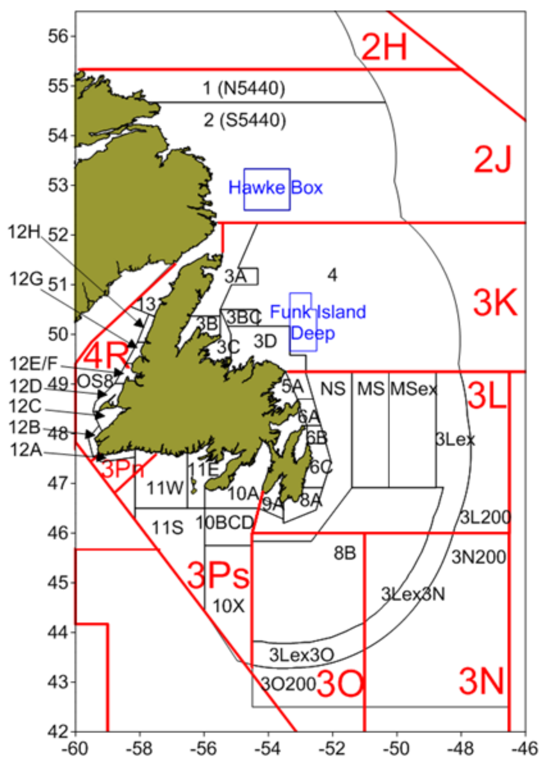

Figure 1. Northwest Atlantic Fisheries Organization (NAFO) Divisions (red lines), Newfoundland and Labrador Snow Crab Management Areas (black lines), and trawling and gillnetting closures (blue boxes)

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 2,600 license holders across several vessel fleets under enterprise allocation in 2015. 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 within each NAFO division. Resource status is evaluated based on trends in fishery catch per unit of effort (CPUE), exploitable biomass indices, recruitment prospects, and mortality indices. Data are derived from multi-species bottom trawl surveys in Divs. 2HJ3KLNOP, Fisheries and Oceans (DFO) inshore trap surveys in Divs. 3KLPs, fishery data from logbooks, observer catch-effort data, industry-DFO collaborative post-season (CPS) trap survey data, as well as biological sampling data from multiple sources.

A Regional Peer Review Process meeting was held February 22-24, 2016 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, and Aboriginal interests.

Canada

SUMMARY

Divisions 2HJ3KLNOP4R

- **Landings** most recently peaked at 53,500 t in 2009 and have since gradually declined to 47,000 t in 2015. Divs. 3LNO have accounted for a steadily increasing percentage in recent years, from about half in 2009 to 80% in 2015.
- The overall **exploitable biomass** has declined since 2013 to its lowest observed level.
- Overall, **recruitment** has recently declined. It was at or near its lowest observed level in all divisions in 2015. It is expected to decline further in the next 2-3 years, as the pre-recruit biomass index was at its lowest observed level in all divisions in 2015.
- A small pulse of young crabs emerged during 2013-14 which could contribute to modest improvements in recruitment in some divisions in about 5 to 7 years. However, a warm oceanographic regime coupled with relatively low abundance of young crabs for the past decade suggests overall weak **recruitment** in the long-term**.**

Divisions 2HJ

- **Landings** have remained relatively low at less than 2,000 t since 2011. Meanwhile, **effort** has been substantially reduced and been at its lowest level during the past three years.
- **Catch per unit of effort (CPUE)** has increased throughout the divisions since 2012.
- The trawl and collaborative post-season (CPS) trap survey-based **exploitable biomass** indices both increased sharply in 2014. The trawl index returned to a relatively low level in 2015 but the CPS trap survey index suggests the biomass remains unchanged on primary fishing grounds.
- **Recruitment** increased sharply to a recent high in 2014 but subsequently decreased to a relatively low level in both the trap and trawl surveys in 2015.
- Short-term **recruitment** prospects appear poor. With the exception of 2014 the pre-recruit biomass index has been relatively low in recent years and was at its lowest level in 2015. The thermal habitat index suggests further deterioration of recruitment potential over the next 2-3 years.
- **The pre-recruit fishing mortality** index was very low in 2015.
- The **exploitation rate** index peaked in 2012 but since decreased to about its lowest level in 2015. Status quo removals in 2016 would once again increase the index to a level similar to recent norms.

Division 3K

- **Landings** declined by 52% since 2008 to 7,200 t in 2015, their lowest level in two decades. Meanwhile, **effort** has declined by 35% and been near its lowest level for the past three years.
- **CPUE** declined by 55% from 2008 to 2011 and has since changed little, remaining near a historic low and reflecting trends throughout most of the division.
- The post-season trawl and trap survey **exploitable biomass** indices both declined since 2008 to their lowest observed levels. Both indices decreased by a third from 2014 to 2015, reflecting decreases throughout the division.

- **Recruitment** is at or near time series lows throughout the division.
- **Recruitment** is expected to decline further in the short term with all trawl and trap pre-recruit indices near historical lows during the past three years. The thermal habitat index suggests further deterioration of recruitment potential over the next 2-3 years.
- The **pre-recruit fishing mortality** index was relatively low from 2005-13 but has since increased to a recent high. The **exploitation rate** index was about average during 2014 and 2015.
- Maintaining the current level of removals would increase the **exploitation rate** in all management areas in 2016 with the overall trawl survey exploitation rate index increasing to its highest level in a decade and second highest level in the time series.

Divisions 3LNO Offshore

- **Landings** increased gradually since 2009 to a historic high of 28,750 t in 2015. **Effort** declined considerably from 2011-13 but increased slightly in the past two years.
- Overall **CPUE** most recently peaked in 2013. It declined slightly in the past two years but remains high.
- The trawl survey of **exploitable biomass** shows the resource has become increasingly localized into portions of Div. 3L, with the biomass index at its lowest observed level in 2015. The CPS trap survey index suggests the density of exploitable crabs remains unchanged on the primary fishing grounds.
- Overall **recruitment** has declined since 2012 to be near its lowest level, reflecting trends throughout most of the divisions.
- **Recruitment** is expected to decline further in the short term (2-3 years). The trawl survey pre-recruit biomass index has steadily declined since 2009 to a historic low while the CPS trap survey index is at or near its lowest observed level in most surveyed areas.
- The **pre-recruit fishing mortality** index has remained relatively low since 2008 while the **exploitation rate** index changed little from 2010-14.
- Maintaining the current level of fishery removals would substantially increase the trawl survey **exploitation rate** index to a new high in 2016.

Division 3L Inshore

- **Landings** increased gradually since 2012 to a historic high of 8,400 t in 2015 while effort changed little.
- Overall **CPUE** has been near its highest level for the past four years. This reflects trends in Crab Management Areas (CMAs) 6A, 6B, and 6C, while other CMAs have been declining during the past two years.
- The overall post-season trap survey **exploitable biomass** index increased steadily from 2011-14 to its highest levels in the time series. However, it decreased in all areas in 2015 and returned to the 2011 level.
- Overall **recruitment** has declined gradually since 2010 to its lowest observed level.
- **Recruitment** is expected to decline further in the short-term (2-3 years). Pre-recruit biomass surveys from CPS and Fisheries and Oceans (DFO) trap surveys throughout the division have been at or near their lowest levels in a decade during the past two years.

- The overall post-season trap survey-based **exploitation rate** index changed little from 2005-15.
- Maintaining the current level of fishery removals would increase the **exploitation rate** index in all areas in 2016.

Subdivision 3Ps

- **Landings** declined from a recent peak of 6,700 t in 2011 to 2,500 t in 2015. **Effort** reached a historic high in 2014 and decreased slightly in 2015, when only 60% of the Total Allowable Catch (TAC) was taken.
- **CPUE** has steadily declined since 2009 to a record low in 2015, reflecting declines throughout this subdivision in recent years.
- The trawl survey **exploitable biomass** index declined by 78% since 2009 to a time series low in 2015. The CPS trap survey was not conducted in most areas in 2015 due to poor resource status, thus no biomass index is available from that survey.
- Overall **recruitment** has declined since 2009 to its lowest observed level.
- **Recruitment** is expected to remain low in the short term (2-3 years) as the trawl survey pre-recruit biomass index has been at its lowest levels for three consecutive years.
- The **pre-recruit fishing mortality** index and the **exploitation rate** index have both been at or near their highest observed levels during the past three years.
- Maintaining the current level of fishery removals would result in a continued high **exploitation rate** in 2016.

Divisions 4R3Pn

- **Landings** increased from a historic low of 190 t in 2010 to between 750-900 t since 2012. **Effort** has been relatively unchanged since 2012.
- Overall **CPUE** has remained near its highest observed level in the past four years but there is considerable variability among management areas.
- The post-season trap survey **exploitable biomass** index has been unchanged for the past three years.
- Overall **recruitment** has been low for the past two years.
- **Recruitment** prospects appear relatively weak for the next 2-3 years. The CPS trap survey pre-recruit index has been relatively low since 2012.
- The post-season trap survey-based **exploitation rate** index has varied since 2005 and was about average in 2015.
- Maintaining the current level of fishery removals would result in little change to the **exploitation rate** index in 2016.

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 may become sexually mature at about 40 mm carapace width (CW) (~ four years of age).

Crabs grow by molting, in late winter or 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 likely enhances their mating ability. Males molt to adulthood at any size above about 40 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 8-10 years of age in warm areas (Divs. 2J3K4R3Pn) and at slightly older ages in cold areas (Divs. 3LNOPs), due to less frequent molting at low temperatures (Dawe et al. 2012).

Snow Crab is a 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 several 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 cold water 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 a maximum of about 6-8 years as adults after the terminal molt.

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

The Fishery

The fishery began in Trinity Bay (CMA 6A, Fig. 1) in 1967. Initially, crabs were taken as gillnet by-catch, but within several years a directed trap fishery developed in inshore areas along the northeast coast of Divs. 3KL. The minimum legal mesh size of traps is 135 mm (5¼”) to allow small crabs to escape. Under-sized and new-shelled males that are retained in the traps are returned to the sea and an unknown proportion dies.

Until the early 1980s, the fishery was prosecuted by approximately 50 vessels limited to 800 traps each. In 1981, fishing was restricted to the NAFO division adjacent to where the license holder resided. During 1982-87, there were major declines in the resource in traditional areas in Divs. 3K and 3L, while new fisheries started in Div. 2J, Subdiv. 3Ps, and offshore Div. 3K. A Snow Crab fishery began in Div. 4R in 1993.

Licences supplemental to groundfishing were issued in Div. 3K and Subdiv. 3Ps in 1985, in Div. 3L in 1987, and in Div. 2J in the early 1990s. Since 1989, there has been a further expansion in the offshore fishery. 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 2,600 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 during the past decade 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 Divs. 3LNO offshore and 3L inshore, the closure threshold was reduced to 15% in 2009. Mandatory use of the electronic vessel monitoring system (VMS) was fully implemented in offshore fleets in 2004 to ensure compliance with regulations regarding area fished.

Landings for Divs. 2HJ3KLNOP4R (Fig. 2) increased steadily from 1989 to peak at 69,100 t in 1999, largely due to expansion of the fishery to offshore areas. They decreased by 20% to 55,400 t in 2000 and changed little until they decreased to 44,000 t in 2005, primarily due to a sharp decrease in Div. 3K. In recent years, landings most recently peaked at 53,500 t in 2009 and have since gradually declined to 47,000 t in 2015. Divs. 3LNO have accounted for a steadily increasing percentage of the catch, from about half in 2009 to 80% in 2015.

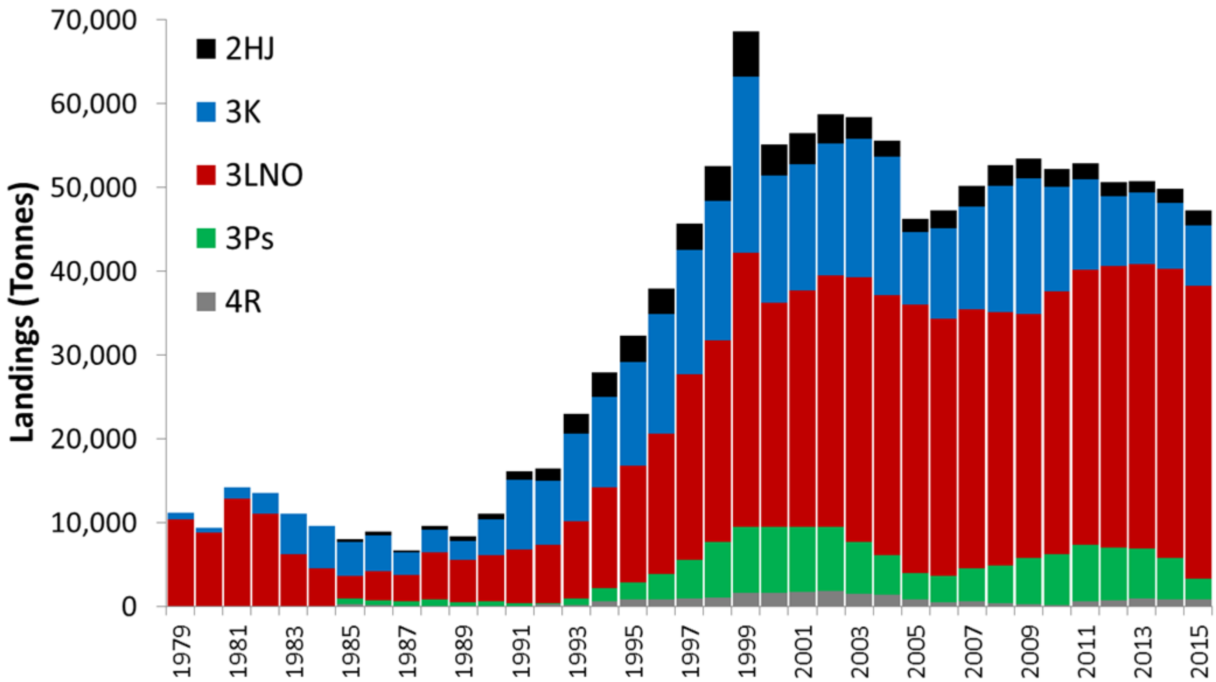

Figure 2. Annual landings by NAFO division.

Effort has increased since the 1980s and has been broadly distributed throughout most divisions in recent years. The most notable change has been a decrease in the spatial extent of fishing in far offshore areas of Div. 3K in the past two years (Fig. 3).

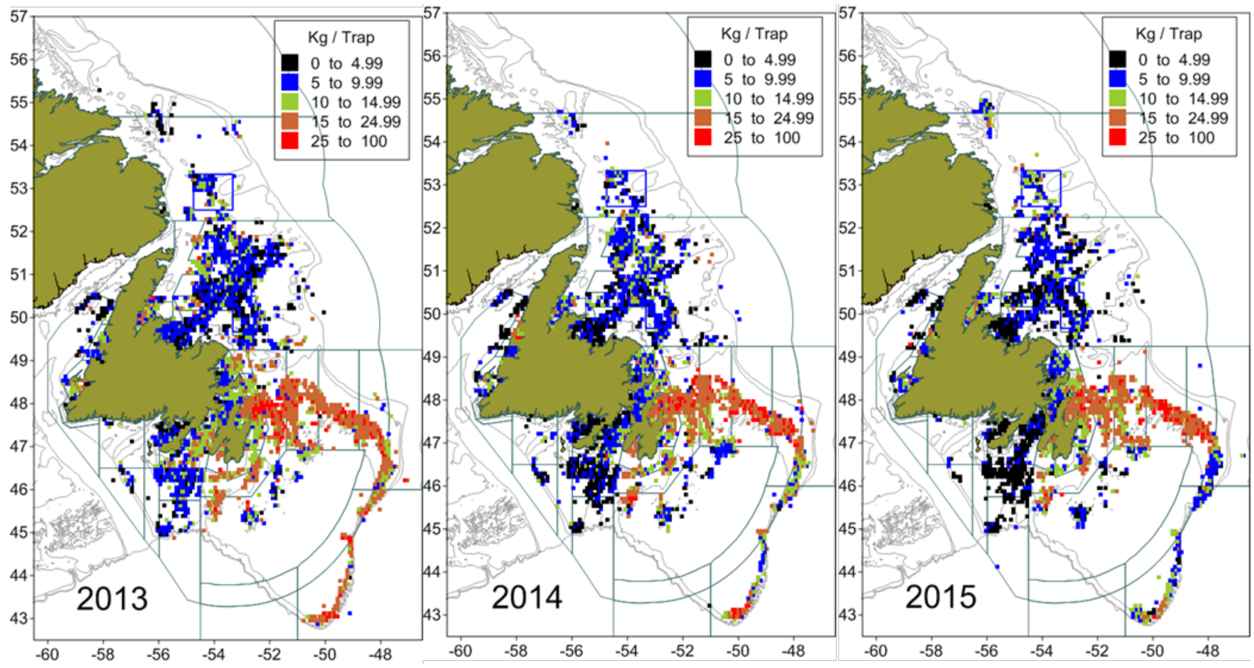

Figure 3. Spatial distribution of commercial fishing effort and CPUE during 2013-15.

The fishery is sometimes delayed in certain areas and years due to ice conditions (Divs. 2HJ 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. Such severe ice conditions have delayed the start of the fishery by about a month in Divs. 2HJ and 3K in the past two years.

ASSESSMENT

Resource status was evaluated based on trends in fishery CPUE, survey exploitable biomass indices, fishery recruitment prospects, and mortality indices. Information was derived from multi-species bottom trawl surveys conducted during fall in Divs. 2HJ3KLNO and spring in Subdiv. 3Ps. A Campelen shrimp trawl has been used in these multi-species surveys beginning in 1995. Information was also available from a fall Industry-DFO CPS trap survey in Divs. 2J3KLOPs4R which was initiated in 2003. Fall post-season surveys provide the most recent data available for the annual assessment. Information is also utilized from DFO inshore trap and trawl surveys in Divs. 3KLPs, fishery data from VMS, logbooks, and observer catch-effort data, as well as biological sampling data from multiple sources. There are multiple CPUE indices used in the assessment including from logbooks, observers, and a VMS-based index (Mullowney and Dawe 2009). Bottom temperature data from DFO trawl surveys were used to develop ocean climate indices toward inferring long-term recruitment prospects.

The resource is assessed by NAFO division. However, Div. 2H is combined with Div. 2J as the resource extends only into the southern portion of Div. 2H and is managed at a spatial scale that extends over the divisional boundary line. Similarly, Divs. 3LNO offshore, representing the Grand Bank, is assessed as a unit because the resource is managed at that unit. Div. 3L inshore is assessed separately due to differences in data availability, with the trawl survey not normally extending into inshore bays. Finally, Subdiv. 3Pn is combined with Div. 4R to conform with management boundaries.

Generally, more data are available for offshore than inshore areas in most divisions with trawl survey data used only for offshore areas because these surveys have not consistently extended into inshore areas. However, in Subdiv. 3Ps the spring trawl survey covers much of the inshore fishing areas; and in Divs. 2HJ virtually all the crab habitat is covered by the trawl survey. Observer coverage and sampling has also been more extensive in offshore management areas of most NAFO divisions than in inshore areas. Also, VMS is used only on offshore vessels.

Trawl survey abundance and biomass indices are derived using ogive mapping (‘Ogmap’) (Evans et al. 2000). The set of strata included in the spatial expansion area did not include inshore strata or deep (> 730 m) slope strata that have not been regularly sampled by the multispecies trawl surveys throughout the time series. Biomass estimates are not absolute because 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 (Subdiv. 3Ps) and fall (Divs. 2HJ3KLNO) bottom trawl surveys provide data that are used to predict changes in biomass and recruitment for the upcoming fishery in the same year (spring Subdiv.3Ps) or the following year (fall Divs. 2HJ3KLNO). These surveys, based on a stratified random sampling scheme, provide an index of exploitable biomass that is expected to be available for the upcoming fishery. This exploitable biomass index is based only on adults of legal size (≥ 95 mm CW). It is used together with an exploitable biomass index (all legal-sized crabs) from the CPS trap survey to evaluate trends in biomass available to the fishery. In Div. 3L inshore and Divs. 4R3Pn no trawl survey is conducted and the CPS trap survey exploitable biomass index is compared with commercial CPUE and catch rates from inshore DFO trap surveys, where available (Div. 3L inshore).

Bottom trawl surveys also provide data on recruitment. 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 and trap surveys also provide indices of pre-recruit biomass, based solely on adolescent (non-terminally-molted) males larger than 75 mm CW. The adolescents of these groups would recruit in the short term (about 2-3 years).

Trawl surveys also provide abundance indices for males of all sizes. The abundance index for the smallest crabs consistently captured (about 12-30 mm CW) may indicate recruitment prospects about 6-7 years later, depending on NAFO division. Longer-term recruitment prospects are inferred from the relationship of exploitable biomass indices (CPUE and survey) with a ’habitat’ index several years earlier (Dawe et al. 2008, Marcello et al. 2012). The index used was a three-year running average of the percentage of bottom area covered by cold water. In Divs. 3LNO and Subdiv. 3Ps, this index is based on temperatures < 1°C, believed to be optimal for early life survival. In Divs. 2HJ and 3K, where such water is not common, the index is based on water < 2°C. Bottom-up temperature regulation of the resource would be strongest in periods with relatively low top-down pressures. The thermal habitat index has remained tightly coupled with lagged biomass and CPUE indices in all divisions since the early 1990s, when finfish abundances and consequently predation pressure have been low. In future, if top-down pressures increase, the reliability of the thermal habitat index as a leading indicator of snow crab stock status could diminish.

Trawl surveys also provide abundance indices of mature females. Females from survey catches are also sampled to determine the proportion carrying full clutches of viable eggs. Together these data may be used to infer changes in reproductive potential.

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

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

Resource Status

Landings

Landings most recently peaked at 53,500 t in 2009 and have since gradually declined to 47,000 t in 2015. Divs. 3LNO have accounted for a steadily increasing percentage in recent years, from about half in 2009 to 80% in 2015 (Fig. 2).

In Divs. 2HJ, landings have remained relatively low at less than 2,000 t since 2011 (Fig. 4). In Div. 3K, they declined by 52% since 2008 to 720 t in 2015, their lowest level in two decades. In Divs. 3LNO offshore, landings increased gradually since 2009 to a historic high of 28,750 t in 2015. In Div. 3L inshore, they increased gradually since 2012 to a historic high of 8,400 t in 2015. In Subdiv. 3Ps, landings declined from a recent peak of 6,700 t in 2011 to 2,500 t in 2015, while in Divs. 4R3Pn they increased from a historic low of 190 t in 2010 to between 750-900 t since 2012.

Effort

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

In Divs. 2HJ, effort has been substantially reduced and been at its lowest level during the past three years (Fig. 4). In Div. 3K, it has declined by 35% since 2008 and been near its lowest level for the past three years. In Divs. 3LNO offshore, effort declined considerably from 2011-13 but increased slightly in the past two years, while in Div. 3L inshore effort has changed little since 2012. In Subdiv. 3Ps, effort reached a historic high in 2014 and decreased slightly in 2015, when only 60% of the TAC was taken. Finally, in Divs. 4R3Pn, effort has been relatively unchanged since 2012.

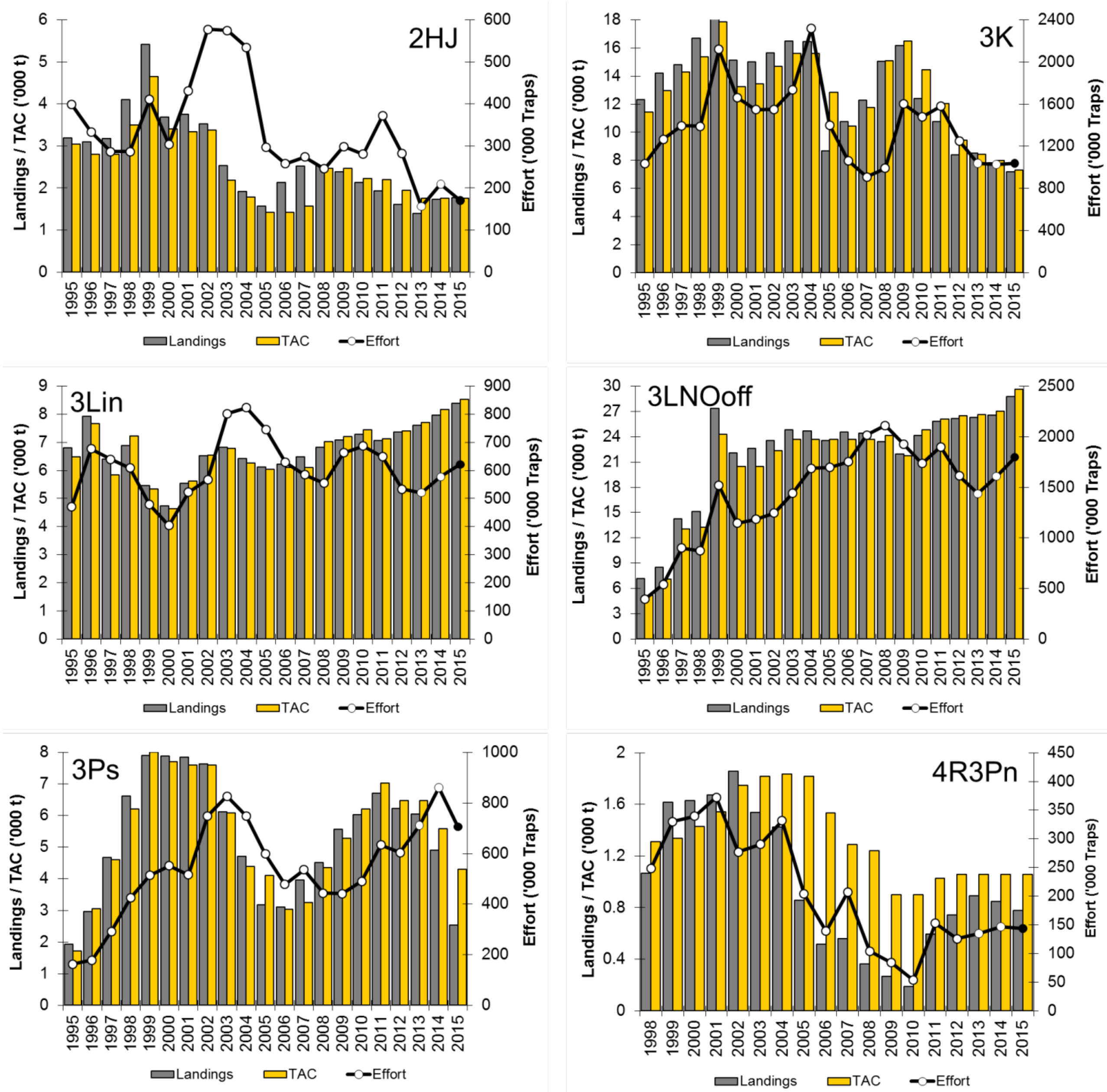

Figure 4. Annual landings, TAC, and estimated effort by assessment division.

CPUE

Commercial catch rate (catch per unit of effort) is best reflected using commercial logbook data because observer coverage can be low and many vessels are not equipped with VMS.

CPUE has increased throughout Divs. 2HJ since 2012 (Fig. 5). In Div. 3K, it declined by 55% from 2008 to 2011 and has since changed little, remaining near a historic low and reflecting trends throughout most of the division. In Divs. 3LNO offshore, CPUE most recently peaked in 2013. It declined slightly in the past two years but remains high. In Div. 3L inshore, overall CPUE has been near its highest level for the past four years. This reflects trends in CMAs 6A, 6B, and 6C, while other CMAs have been declining during the past two years.

In Subdiv. 3Ps, CPUE has steadily declined since 2009 to a record low in 2015, reflecting declines throughout the division in recent years. Finally, in Divs. 4R3Pn, overall CPUE has remained near its highest observed level in the past four years but there is considerable variability among management areas.

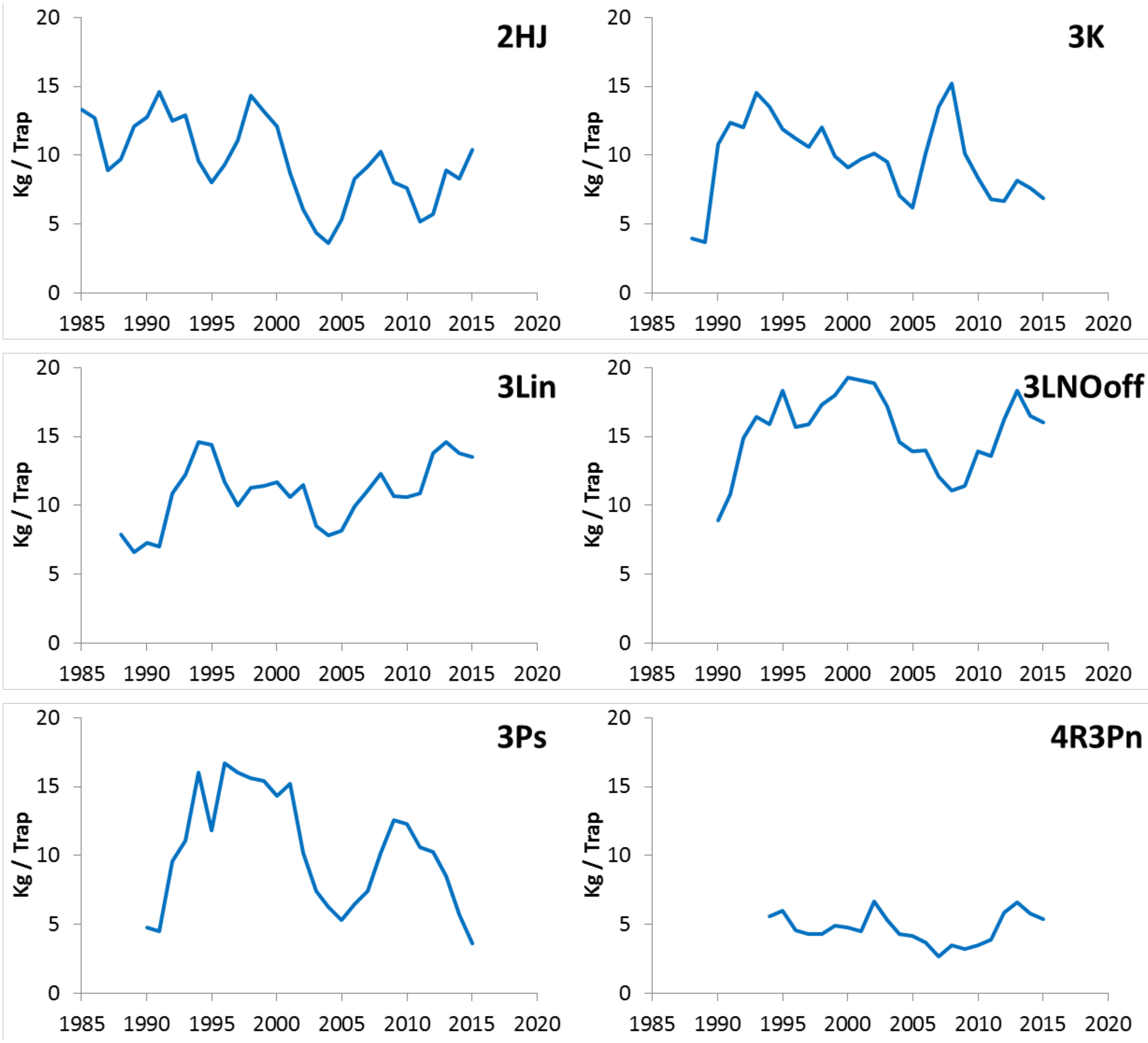

Figure 5. Trend in commercial logbook CPUE by assessment division from 1985-2015.

Exploitable Biomass

Multi-species trawl surveys indicate that the exploitable biomass was highest at the start of the survey series (1995-98) (Fig. 6). It declined from the late 1990s to 2003 and then varied without trend until 2013. The Divs. 2HJ3KLNO exploitable biomass index has declined since 2013 to its lowest observed level. Both trap and trawl surveys indicate that Divs. 3LNO have accounted for a steadily increasing percentage in recent years, such that Divs. 3LNO now account for most of the biomass (Fig. 6).

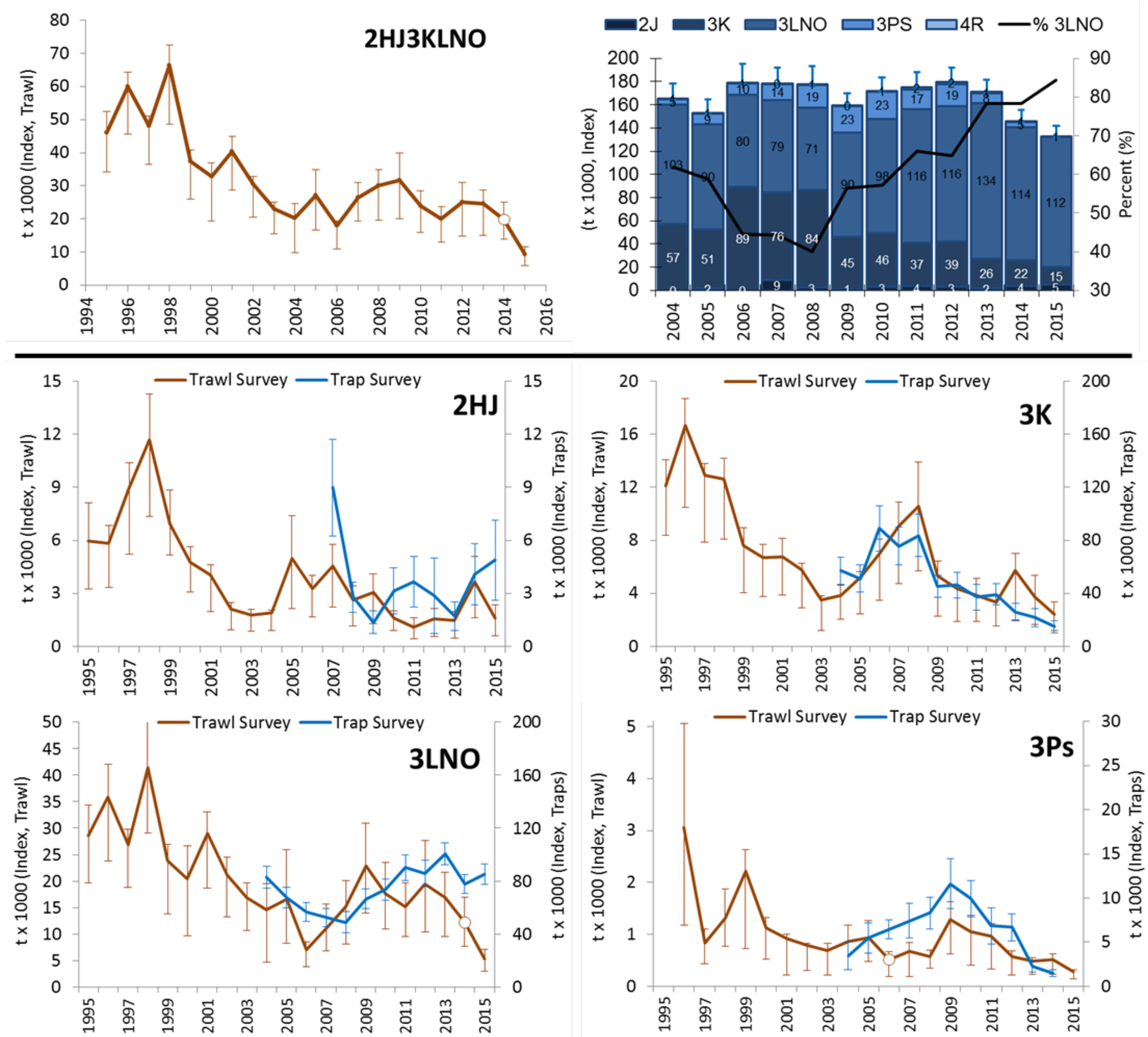

Figure 6. Trends in trawl survey exploitable biomass indices and the CPS trap survey exploitable biomass indices by division. Top panels show overall fall trawl survey index (Divs. 2HJ3KLNO (top left)) and overall CPS trap survey index (Divs. 2J3KLOPs4R (top right)), and middle and bottom panels show division-specific indices from both surveys. Open symbols on the trawl abundance indices depict incomplete surveys. Note – no trap survey in Subdiv. 3Ps in 2015.

In Divs. 2HJ, the trawl and CPS trap survey-based exploitable biomass indices both increased sharply in 2014. The trawl index returned to a relatively low level in 2015 but the CPS trap survey index suggests the biomass remains unchanged on primary fishing grounds. In Div. 3K, the post-season trawl and trap survey exploitable biomass indices both declined since 2008 to their lowest observed levels. Both indices decreased by a third from 2014 to 2015, reflecting decreases throughout the division. In Divs. 3LNO offshore, the trawl survey of exploitable biomass shows the resource has become increasingly localized into portions of Div. 3L, with the biomass index at its lowest observed level in 2015. However, the CPS trap survey index suggests the density of exploitable crabs remains unchanged on the primary fishing grounds. In Div. 3L inshore, the overall post-season trap survey exploitable biomass index increased steadily from 2011-14 to its highest levels in the time series. However, it decreased in all areas in 2015 and returned to the 2011 level. In Subdiv. 3Ps, the trawl survey exploitable biomass index declined by 78% since 2009 to a time series low in 2015. The CPS trap survey was not conducted in most areas in 2015 due to poor resource status, thus no biomass index is available from that survey. Finally, in Divs. 4R3Pn, the post-season trap survey exploitable biomass index has been unchanged for the past three years.

Mortality

In Divs. 2HJ, the exploitation rate index peaked in 2012 but since decreased to about its lowest level in 2015 and the pre-recruit fishing mortality index was very low in 2015 (Fig. 7). In Div. 3K, the exploitation rate index was about average during 2014 and 2015 and the pre-recruit fishing mortality index was relatively low from 2005-13 but has since increased to a recent high. In Divs. 3LNO offshore, the exploitation rate index changed little from 2010-14 and the pre-recruit fishing mortality index has remained relatively low since 2008. In Div. 3L inshore, the overall post-season trap survey-based exploitation rate index changed little from 2005-15. In Subdiv. 3Ps, the exploitation rate index and the pre-recruit fishing mortality have both been at or near their highest observed levels during the past three years. Finally, in Divs. 4R3Pn, the post-season trap survey-based exploitation rate index has varied since 2005 and was about average in 2015.

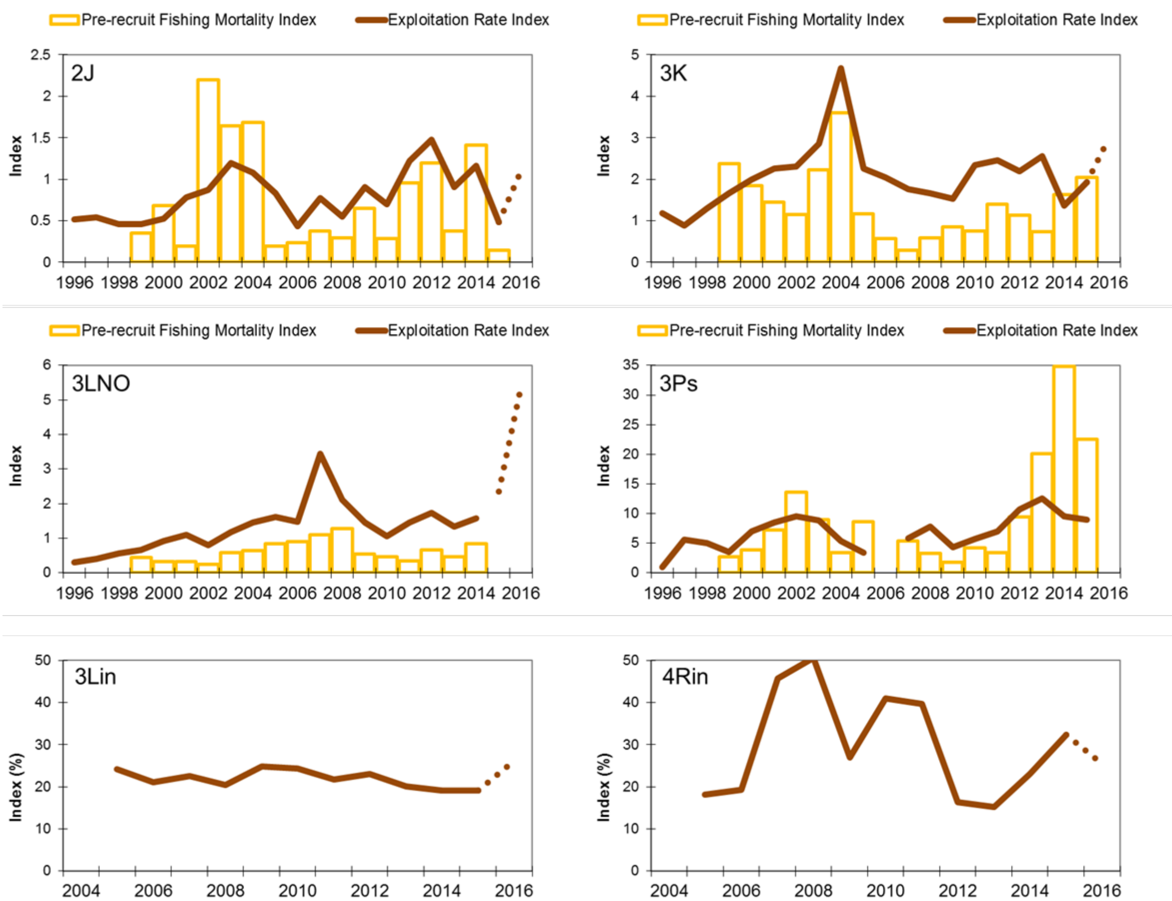

Figure 7. Trends in mortality indices (the ERI and the pre-recruit fishing mortality rate index for offshore assessment divisions based on trawl data and the exploitation rate index for inshore assessment divisions based of CPS trap data). Dashed brown lines depict projected 2016 exploitation rate indices based on status quo landings.

Recruitment and Outlook

Overall, recruitment has recently declined. It was at or near its lowest observed level in all divisions in 2015. It is expected to decline further in the next 2-3 years, as the pre-recruit biomass index was at its lowest observed level in all divisions in 2015 (Fig. 8).

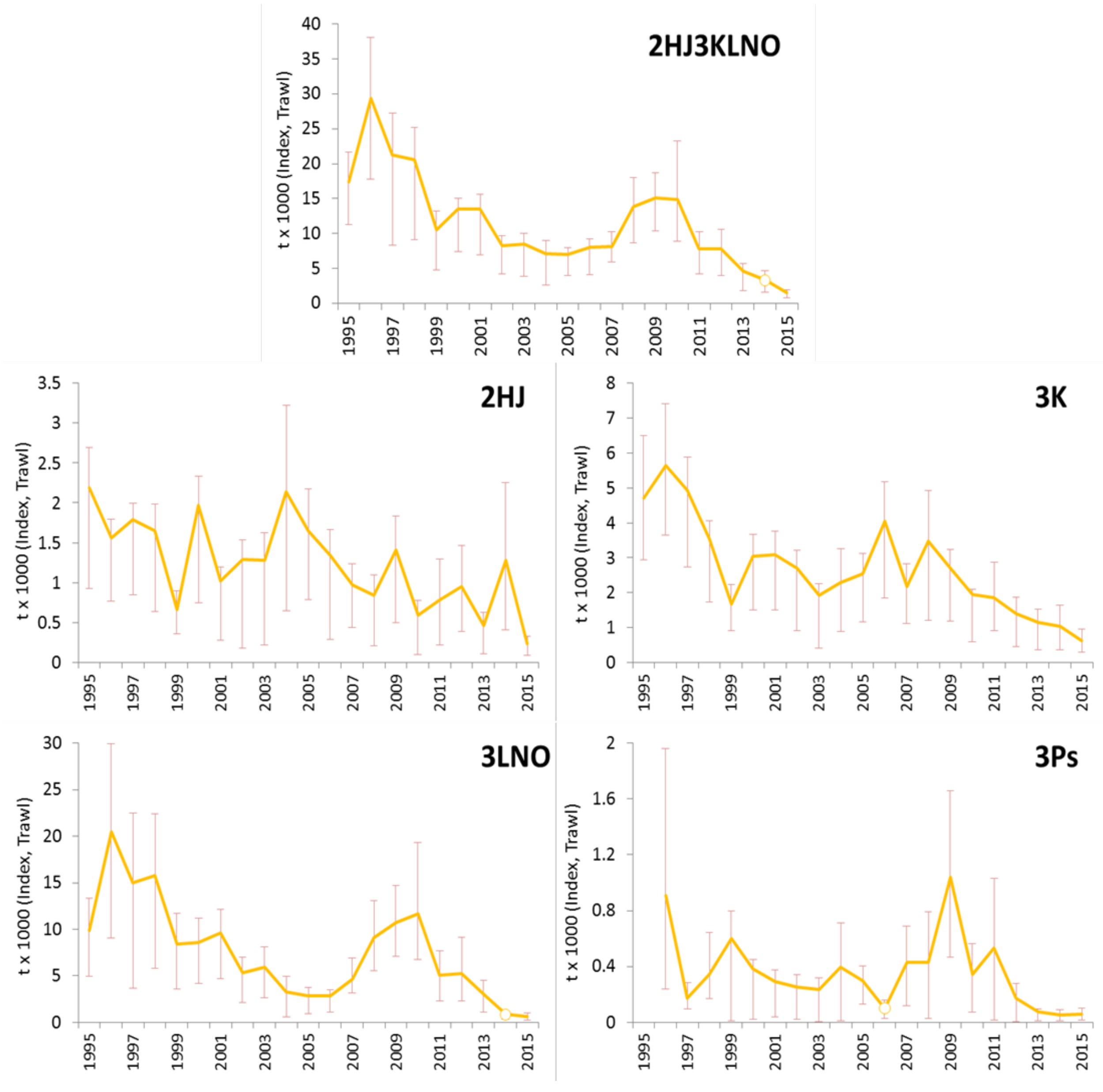

Figure 8. Trends in trawl survey pre-recruit biomass indices by division. Open symbols depict incomplete surveys.

In Divs. 2HJ, recruitment was unusually high in 2014 but was close to recent values in 2015. Short-term recruitment prospects appear poor; with the exception of 2014 the pre-recruit biomass index has been relatively low in recent years and was at its lowest level in 2015. Furthermore, the thermal habitat index suggests further deterioration of recruitment potential over the next 2-3 years (Fig. 9).

In Div. 3K, recruitment is at or near time series' lows throughout the division. It is expected to decline further in the short term with all trawl and trap pre-recruit indices near historical lows during the past three years (i.e. Fig. 8). The thermal habitat index suggests further deterioration of recruitment potential over the next 2-3 years (Fig. 9).

In Divs. 3LNO offshore, overall recruitment has declined since 2012 to be near its lowest level reflecting trends throughout most of the divisions. It is expected to decline further in the short term (2-3 years). The trawl survey pre-recruit biomass index has steadily declined since 2009 to a historic low (Fig. 8) while the CPS trap survey index is at or near its lowest observed level in most surveyed areas. The thermal habitat index suggests recruitment potential could improve over the next few years, however, it is expected to remain low compared to the early 2000s (Fig. 9).

In Subdiv. 3Ps, overall recruitment has declined since 2009 to its lowest observed level. It is expected to remain low in the short term (2-3 years) as the trawl survey pre-recruit biomass index has been at its lowest levels for three consecutive years (Fig. 8). The thermal habitat index suggests recruitment potential could improve over the next few years. However, this is inconsistent with the lack of increase in the pre-recruit biomass index in recent years.

No figures on recruitment in Div. 3L inshore or Divs. 4R3Pn are presented in this report, as there is no trawl survey conducted in these areas and the assessment is based exclusively on CPS and DFO trap surveys. The assessment found that in Div. 3L inshore overall recruitment has declined gradually since 2010 to its lowest observed level and that it is expected to decline further in the short-term (2-3 years) as pre-recruit biomass surveys from CPS and DFO trap surveys throughout the division have been at or near their lowest levels in a decade during the past two years. In Divs. 4R3Pn, overall recruitment has been low for the past two years and prospects appear relatively weak for the next 2-3 years with the CPS trap survey pre-recruit index being relatively low since 2012.

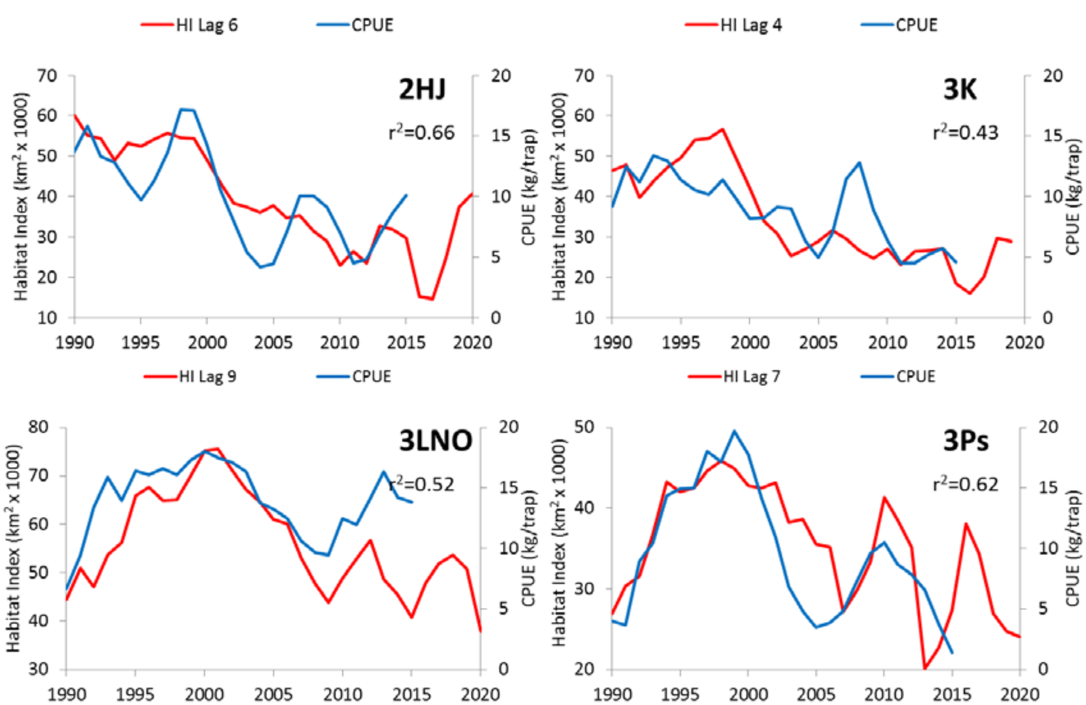

Figure 9. Temporal relationship of thermal habitat indices (HI) and CPUE in assessment divisions. Best fit correlation lags shown.

A small pulse of young crabs emerged during 2013-14 (Fig. 10) which could contribute to modest improvements in recruitment in some divisions in about 5 to 7 years. However, a warm oceanographic regime coupled with relatively low abundance of young crabs for the past decade suggests overall weak recruitment in the long-term**.**

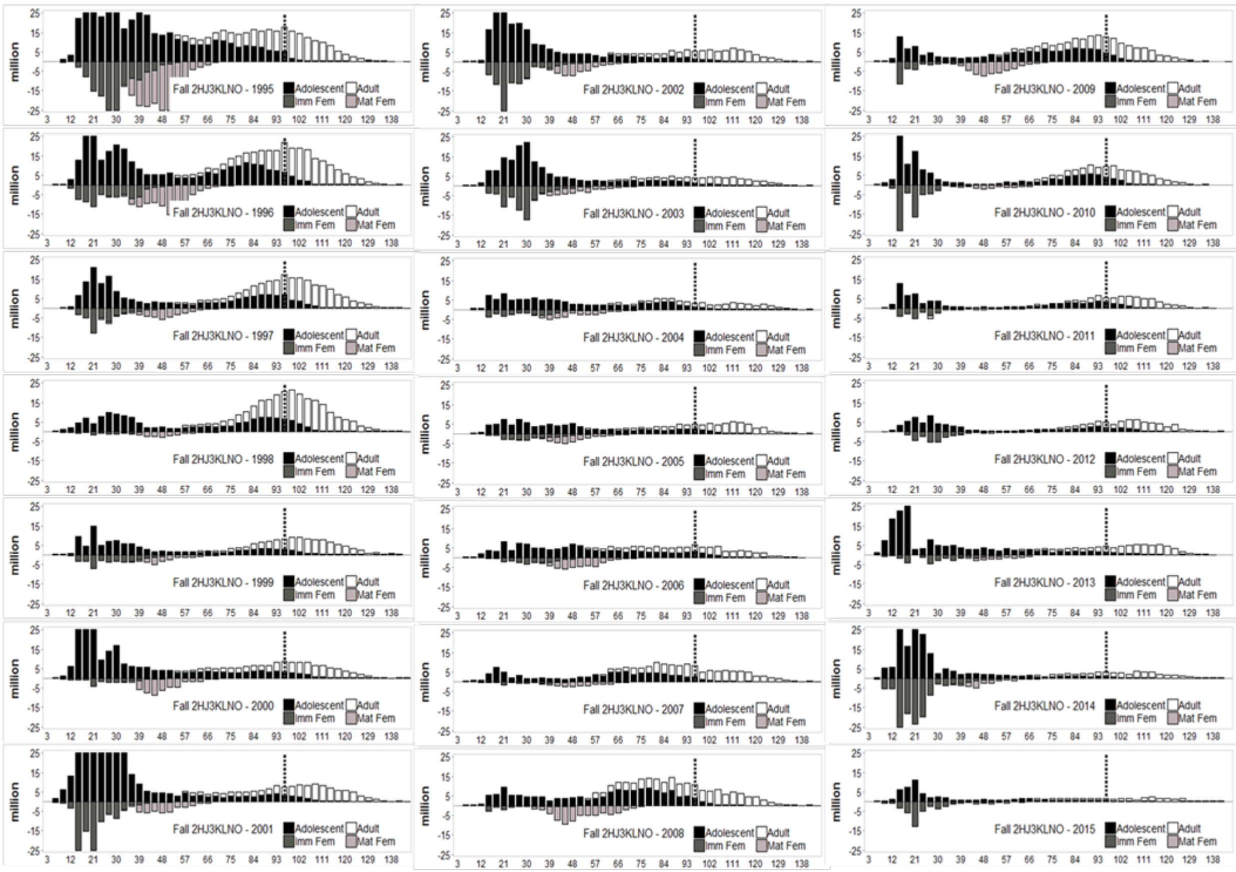

Figure 10. Fall trawl survey size frequency distributions for Divs. 2HJ3KLNO. Adolescent males (dark black - top), adult males (white – top), immature females (dark gray – bottom), mature females (light gray – bottom).

Since the collapse of most of the finfish community in the early 1990s, the Snow Crab resource appears to have largely been under bottom-up temperature control (Fig. 9). The resource was most productive throughout the 1990s, but productivity has diminished coincident with warming over the past decade (Mullowney et al. 2014). Besides exerting a direct impact on early-life survival, a shift toward warmer conditions could affect Snow Crab indirectly, such as in the form of increased predation if temperate finfish populations respond positively to the warming. A suite of consumption models developed for this assessment suggest predation pressure from large benthivores and piscivores has (Subdiv. 3Ps) or is (Divs. 2J3KLNO) increasing in recent years in most divisions (Fig. 11). These trends predominately reflect increasing abundances of predatory finish. Although the impacts on the fishery in most areas would be expected to be minimal at present, with finfish predation predominantly occurring on small Snow Crabs below about 40 mm CW (Chabot et al. 2008), increased top-down controls could become more important in regulating the resource and consequently impact the fishery in the coming years. However, at present, it is not known if current levels of predation constitute a major concern for

Snow Crab recruitment prospects, particularly with overall finfish abundances still low relative to pre-collapse levels.

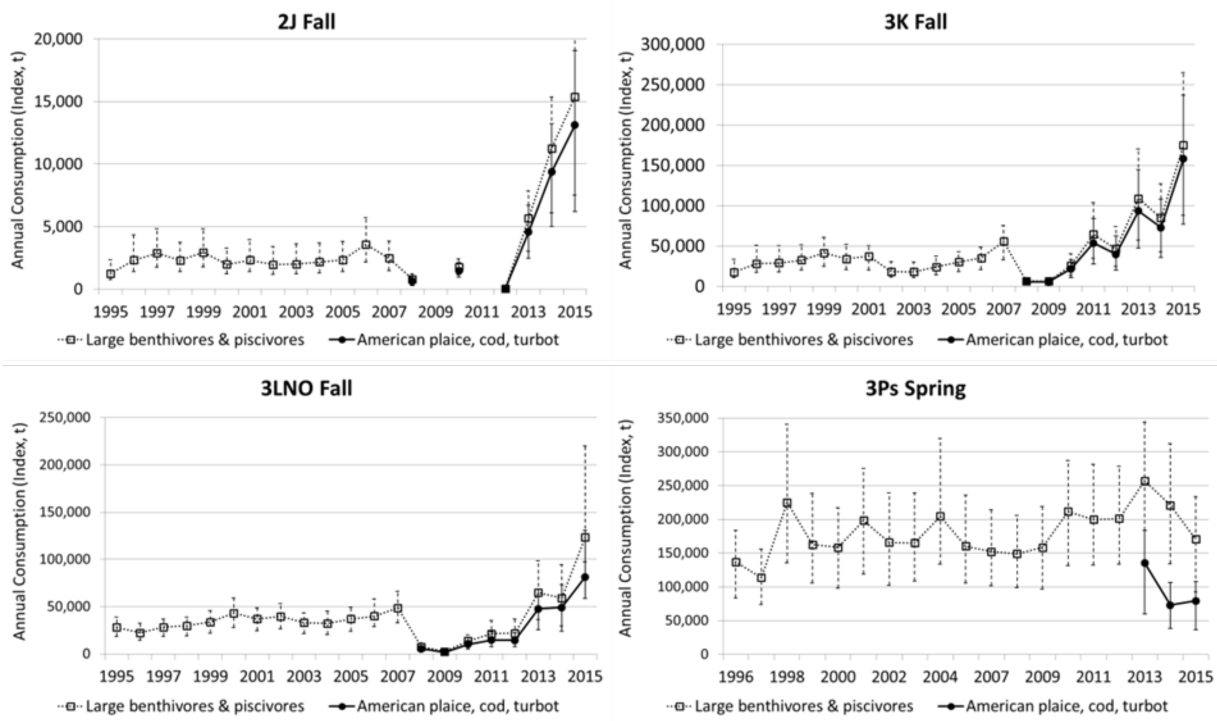

Figure 11. Indices of consumption estimates of Snow Crab by predatory finfish from multi-species trawl surveys by assessment division.

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 fail to sample inshore areas in some NAFO divisions.

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. Thus, annual survey catchability depends on the substrate conditions at the positions randomly selected for the survey each year. Interpretation of indices from the spring trawl survey in Subdiv. 3Ps is more uncertain than for those from the fall surveys because they occur after a variable fraction of fishery removals.

Exploitable and pre-recruit biomass indices from trap surveys are also affected by annual variation in catchability of crabs. There is uncertainty in interpreting trends in biomass indices from the CPS survey because there is limited spatial coverage. Also, catch rates in this survey may be affected by adverse weather and other factors that affect soak time and trap efficiency.

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 pre-recruits. 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 (e.g. Divs. 3LNOPs) than under warm regimes (e.g. Divs. 2J3K4R).

Long-Term Recruitment

There is high uncertainty about the reliability of lagged HI as a leading indicator of future biomass or CPUE, particularly under the scenario of changing oceanographic conditions and shifts in trophic control. A trend of recent warming is clearer in the northern areas (Divs. 2J and 3K) than in the southern areas (Divs. 3LNO and Subdiv. 3Ps). Continued long-term warming in all areas is inferred from multi-decadal oscillations in the ocean climate of the entire Atlantic Ocean that, in recent years, are consistent with 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.

Fishery Indices

Completion and timely return of logbooks is mandatory in this fishery. Data for the current year is typically incomplete at the time of the assessment and thus the associated CPUE and effort values are potentially biased and considered preliminary. Overall, for the current assessment, 60% of the 2015 logbooks 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 broadest coverage and therefore the most representative fishery performance index.

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 Divs. 3L inshore and 4R3Pn. These concerns introduce a strong bias in interpreting trends in catch rates at broad spatial scales. Observer-based indices are also biased by inconsistent sampling methods and levels resulting from changing priorities. 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. An exploitation rate index is estimated for Divs. 3L inshore and 4R3Pn 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 is also not estimated for inshore areas due to insufficient observer data.

CONCLUSIONS AND ADVICE

Divisions 2HJ

Status quo removals in 2016 would once again increase the **exploitation rate** index to a level similar to recent norms.

Division 3K

Maintaining the current level of removals would increase the **exploitation rate** in all management areas in 2016 with the overall trawl survey exploitation rate index increasing to its highest level in a decade and second highest level in the time series.

Divisions 3LNO Offshore

Maintaining the current level of fishery removals would substantially increase the trawl survey **exploitation rate** index to a new high in 2016.

Division 3L Inshore

Maintaining the current level of fishery removals would increase the **exploitation rate** index in all areas in 2016.

Subdivision 3Ps

Maintaining the current level of fishery removals would result in a continued high **exploitation rate** in 2016.

Divisions 4R3Pn

Maintaining the current level of fishery removals would result in little change to the **exploitation rate** index in 2016.

OTHER CONSIDERATIONS

Bitter Crab Disease (BCD)

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

Reproductive Biology

The percentage of mature females carrying full clutches of viable eggs has generally remained high throughout the time series wherever measured. Fishery-induced mortality on mature males (including undersized males) could adversely affect insemination of females. Egg clutches have remained high but the abundance of mature females has declined wherever measured and been at very low levels during the past five years. 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.

Management Considerations

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.

Fishery-induced mortality on pre-recruits could possibly 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.

Low and spatiotemporally variable observer coverage introduces high uncertainty in interpreting indices of biomass, recruitment, and mortality. Measures should be taken to ensure representative observer coverage and analysis so as to improve data quality from this program.

Among other uses, the observer program forms the basis of the soft-shell protocol, which was introduced in 2005 to protect soft-shelled immediate pre-recruits from handling mortality by closing localized areas (70 nM^2 grids) for the remainder of the season when a threshold level of 20% of the legal-sized catch is reached. It became evident during 2010-12 that this protocol, as implemented, is inappropriate and ineffectual in controlling handling mortality. This is largely due to very low observer coverage, together with the decision to treat unobserved grids as if they had no problem. In addition, failure to draw all the inferences possible from moderate-sized samples frequently resulted in failure to invoke the protocol even when it was clear that the level of soft-shelled crabs had exceeded the threshold. These shortcomings undermine the intent of the protocol. Although soft-shell incidence in the catch has been very low in all divisions for the past two years, consistent with diminishing recruitment prospects, measures should be taken to ensure representative observer coverage and analysis so as to better quantify prevalence of soft-shelled crabs in the fishery to afford better protection to recruitment if and when the situation improves.

The CPS trap survey is one of the primary data sources used to assess the resource. It operates under a compensation scenario of ‘quota-for-survey’ whereby harvesters are allocated additional quota in the following season in exchange for conducting the survey. However, the survey was incomplete this year in Subdiv. 3Ps due to resource shortages and the perception that additional quota would not be catchable and therefore would not meet the costs of conducting the survey. This has also occurred in other divisions in previous years. In the future, under the scenario of expected reduced exploitable biomass in most divisions, there are concerns the integrity of this survey could further deteriorate.

Precautionary Approach

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

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

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

SOURCES OF INFORMATION

This Science Advisory Report is from the February 22-24, 2016, Newfoundland and Labrador Snow Crab Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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THIS REPORT IS AVAILABLE FROM THE:

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Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2016. Assessment of Newfoundland and Labrador (Divisions 2HJ3KLNOP4R) Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/013.

Aussi disponible en français :

MPO. 2016. Évaluation du crabe des neiges de Terre-Neuve et du Labrador (Divisions 2HJ3KLNOP4R). Secr. can. de consult. sci. du MPO, Avis sci. 2016/013.