Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2019/041

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

Snow Crab (Chionoecetes opilio)

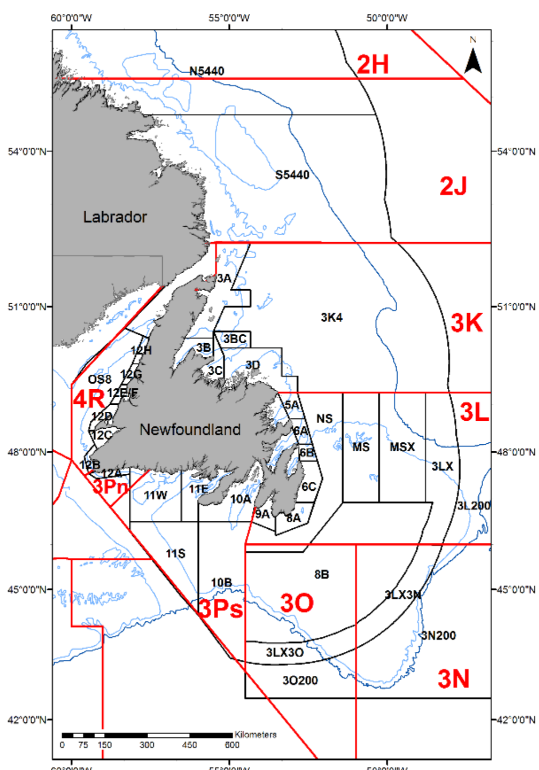

Figure 1: Map of NAFO Divisions (red) and Newfoundland and Labrador Snow Crab Management Areas (black).

Context

Snow Crab (Chionoecetes opilio) occupy a broad geographic range in the Northwest Atlantic from Greenland to the Gulf of Maine. Distribution in waters off Newfoundland and southern Labrador is widespread and continuous with the genetic stock spanning throughout the region.

Crab harvesters use fleets of baited conical traps. The minimum legal size is 95 mm carapace width (CW). This regulation excludes females and a large proportion of adult males from the fishery thereby partially safeguarding stock reproductive capacity.

Total Allowable Catch (TAC) management was initiated in the late 1980s. This led to the development of multiple TAC-controlled crab management areas (CMAs - Fig. 1) with about 2,400 license holders across numerous fleet sectors under enterprise allocation in 2018. All fleets have designated trap limits, quotas, trip limits, dedicated fishing areas within divisions, and pre-determined fishing seasons.

Stock status is assessed annually within assessment divisions comprised of combinations of the Northwest Atlantic Fisheries Organization (NAFO) Divisions. Resource status is evaluated based on trends in exploitable biomass indices, recruitment prospects, and mortality indices, as well as fishery catch per unit of effort (CPUE). Data are derived from multi-species bottom trawl surveys in Divs. 2HJ3KLNOP, DFO inshore trap surveys in Divs. 3KLPs, fishery logbooks, at-sea observer measurements, collaborative trap surveys, as well as biological sampling from multiple sources.

A Regional Peer Review Process meeting was held February 19-21, 2019, in St. John's, Newfoundland and Labrador (NL) to assess the status of the Snow Crab resource in NL.

SUMMARY

Overall – Divisions 2HJ3KLNOP4R

- **Landings** remained near 50,000 t from 2007 to 2015 but have since steadily declined to a two-decade low of 27,700 t in 2018. Overall **effort** remained at approximately 3.5 to 4.5 million trap hauls per year over that time.
- Overall **CPUE** was at a time-series low in 2018.
- Despite modest increases in the past two years, the trawl survey **exploitable biomass** index has remained at its lowest level for the past four years. Meanwhile, the trap survey index has declined by nearly 60% in the last two years to a time-series low.
- Despite modest increases in some divisions in the past two years, overall **recruitment** into the exploitable biomass will remain low in most divisions in 2019.
- **Total mortality** in exploitable crab is estimated to be near time-series' averages in most divisions. It has declined from very high levels in most divisions during the past two years, with the exception of Division (Div.) 3K, where it remains at a time-series high.
- **Exploitation rate** indices were at or near time-series highs in most divisions in 2017. In 2018, exploitation rates subsequently increased to a new high in Div. 3L Inshore, remained high in Divs. 2HJ, 3K, and 3LNO, and declined to be near or below long-term average levels in Divs. 3Ps and 4R3Pn.
- In 2019 most divisions are projected to fall within the cautious zone of the **proposed Precautionary Approach Framework**. Div. 3L Inshore would be in the critical zone. These projections assume status-quo landings.
- The **thermal habitat index** (defined as the areal extent of <2°C bottom water) has returned to near-average conditions in all divisions in recent years. Broad-scale climate indices appear favourable for improved recruitment to occur in most major areas of the stock range over the next few years.
- Ecosystem conditions in the NL Bioregion are indicative of an overall low **productivity** at the lower trophic levels (phytoplankton and zooplankton) in recent years and changes in zooplankton community structure that may impact the transfer of energy to higher trophic levels.
- A sharp decline in male **size-at-maturity** (i.e. terminal molt size) in most divisions in recent years may dampen short-term prospects for recruitment into the exploitable biomass.
- Elements of the **Precautionary Approach Framework** presented in this assessment are tentative. Limit Reference Points defining the critical zone have been established by a peer-reviewed Science process, but Upper Stock Reference lines defining the cautious and healthy zones remain under development.

Assessment Division 2HJ

- **Landings** have remained near 1,700 t for the past four years while **effort** has remained consistent.
- Standardized **CPUE** has remained near the decadal average in recent years.
- The **exploitable biomass** index has changed little during the past 15 years. A modest increase in 2018 reflects an increase in residual biomass.

- **Recruitment** into the exploitable biomass has changed little during the past 15 years. The 2018 trawl and trap surveys suggest recruitment will remain unchanged in 2019.
- **Total mortality** in exploitable crab had been at its highest level in recent years, but declined slightly in 2018.
- The **exploitation rate** index has been above the long-term average for the past three years. Status quo removals in 2019 would decrease the exploitation rate index, but it would remain at a relatively high level.
- Following the proposed **Precautionary Approach** the stock status would be in the provisional cautious zone in 2019.
- **Size-at-terminal molt** in males has precipitously declined in recent years, suggesting potentially dampened short-term recruitment prospects into the exploitable biomass.
- Poor monitoring and coverage levels of the collaborative post-season (CPS) trap survey in recent years compromises the integrity of biomass estimation. Efforts should be made to ensure the survey is fully complete with protocols followed moving forward.

Assessment Division 3K

- **Landings** have remained relatively low for the past three years (6,000 t in 2018). **Effort** has been maintained near a two-decade low for the past six years.
- Standardized **CPUE** increased in 2018 from a time-series low in 2017, but remains below the times-series average.
- Despite localized improvements, the post-season trawl and trap survey **exploitable biomass indices** have remained near time-series lows for the past five years.
- Despite localized improvements, the post-season trawl and trap survey indices of **recruitment** into the exploitable biomass have remained near time-series lows for the past five years.
- **Total mortality** in exploitable crab has remained at its highest level during the past four years.
- The **exploitation rate** index declined from a decadal high to near time-series average levels in 2018. Under status quo removals in 2019 the exploitation rate index would be unchanged.
- Following the proposed **Precautionary Approach** the stock status would be in the provisional cautious zone in 2019.
- **Size-at-terminal molt** in males has precipitously declined in recent years, suggesting potentially dampened short-term recruitment prospects into the exploitable biomass.

Assessment Division 3L Inshore

- **Landings** declined by 56% from a time series high in 2015 to 3,700 t in 2018. In 2018, the landings were 16% below the TAC. **Effort** remained at a time series high in 2018.
- Standardized **CPUE** has declined by 68% since 2013 to below 5 kg/trap, its lowest level in the time series.
- The exploitable biomass is severely depleted. The post-season trap survey **exploitable biomass** index remained near a time-series low in 2018. Crab Management Areas (CMAs) 6B and 6C had total catch rates of approximately 1 kg/trap in the 2018 surveys.

- **Recruitment** into the exploitable biomass steadily declined to a time-series low in 2017. In 2018, recruitment indices from DFO and CPS trap surveys remained near their lowest levels. Localized improvements in overall biomass available to the fishery could occur within the next 2 years.
- The overall trap survey-derived **exploitation rate** index has increased since 2013 and remained at its highest observed level in 2018. Status quo removals would maintain the exploitation rate at a time series high in 2019.
- **Size-at-terminal molt** in males has precipitously declined in recent years, suggesting potentially dampened short-term recruitment prospects into the exploitable biomass.
- Following the **proposed Precautionary Approach,** the stock status would be in the critical zone in 2019.

Assessment Division 3LNO Offshore

- **Landings** declined by 43% from 2016 to 14,000 t in 2018 because of reductions in the TAC, to the lowest level in two decades. **Effort** expanded rapidly from 1992 to the mid-2000s and has oscillated at a similar level since.
- Standardized **CPUE** most recently peaked near a time-series high in 2013 and has since declined by 49% to its lowest level since 1992.
- The trawl-derived **exploitable biomass** index showed a modest increase in 2018, but both it and the trap-derived exploitable biomass index remain at or near time-series' lows.
- **Recruitment** into the exploitable biomass has been at or near time-series lows in both the trawl and trap surveys in the past three years, but increased slightly in 2018.
- **Total mortality** declined from its highest observed level in 2016 to a relatively low level in 2018.
- The **exploitation rate** index increased by a factor of five from 2014 to 2017, and remained high in 2018. The **exploitation rate** index would decline to near the long-term average with status quo removals in 2019.
- Following the **proposed Precautionary Approach** the stock status would be in the provisional cautious zone in 2019.
- **Size-at-terminal molt** in males has precipitously declined in recent years, suggesting potentially dampened short-term recruitment prospects into the exploitable biomass.

Assessment Division 3Ps

- **Landings** increased from decadal lows to 1,900 t in 2018. The landings exceeded the TAC, which was set at 1,792 t. **Effort** has declined by 60% since 2014 to be near its lowest level in two decades.
- Standardized **CPUE** increased from time-series low levels in 2016 and 2017 to more than 5 kg/trap in 2018.
- The in-season trawl survey **exploitable biomass** index was at a time-series low in 2016, but has improved during the past two years. The post-season trap survey index suggests an increase in the exploitable biomass throughout the major fishing grounds.
- **Recruitment** into the exploitable biomass was near a decadal high in 2018, with the exception of Fortune Bay. Despite a small decline in recruitment available to the 2019 fishery, survey data of pre-recruit abundance suggest short-term prospects are positive

relative to the recent 2013-16 low period. The distribution of pre-recruit crab appears concentrated on the major fishing grounds of the division.

- **Total mortality** in exploitable crab has varied considerably throughout the time series, but was low in 2018. The **exploitation rate** index was near its lowest observed level in the time series in 2018 and status quo removals would result in the exploitation rate index being near a time series low in 2019.
- Following the **proposed Precautionary Approach,** the stock status would be in the provisional cautious zone in 2019.
- **Discards** declined sharply in 2018 to be near the long-term average. A continuation of current measures is recommended to re-establish a strong residual biomass to help minimize discards.

Assessment Division 4R3Pn

- **Landings** have steadily declined since a recent peak in 2013 and were 250 t in 2018. Meanwhile, **effort** has remained at a low level.
- Standardized **CPUE** has declined since 2013 to below the long-term average.
- The **exploitable biomass** is severely depleted, with few residual crab in the population. The trap survey exploitable biomass index most recently peaked in 2012 and declined to a time series low in 2017. The index increased slightly in 2018, reflecting localized improvements in CMA 12EF.
- **Recruitment** into the exploitable biomass was low from 2014 to 2017, but survey data from 2018 suggest localized improvements may occur in 2019, particularly in CMA 12EF.
- The overall **exploitation rate** index declined to below the long-term average in 2018. Status quo removals in 2019 would result in little change to the exploitation rate index.
- Poor monitoring coverage throughout this division results in large uncertainty in the biomass estimates provided in 2018 and predictions for 2019. Caution is warranted when developing conclusions from these estimates.
- This division was not included in the scientific **proposed Precautionary Approach** due to data deficiencies.

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 approximately 40 mm carapace width (CW) (~ 4 years of age).

Crab grow by molting in late winter or spring. Females cease molting after sexual maturity is achieved at 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) that likely enhance their competitiveness for mating. Males molt to adulthood at any size larger than approximately 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 Crab are believed to recruit to the fishery at 8-10 years of age in warm areas and at slightly older ages in cold areas (Dawe et al. 2012), with delays in cold areas reflecting less frequent molting at low temperatures.

The 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 crab failing to recruit to the fishery. However, with respect to overall productivity, the positive effect of cold water on early survival appears stronger than the negative effect on size-at-terminal molt.

Adult legal-sized males remain new-shelled 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, but such longevity is not thought to be common, particularly in heavily exploited areas.

Snow Crab 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 in deep areas, while smaller crab are common on harder substrates typically associated with shallow areas. Some crab also undertake a migration in the spring for mating and/or molting. Although the dynamics of spring migrations are not fully understood, they are generally from deep to shallow areas. Snow Crab are opportunistic feeders with the diet including fish, clams, polychaete worms, brittle stars, shrimp, Snow Crab, and other crustaceans. Predators include various groundfish, other Snow Crab, and seals.

The Fishery

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

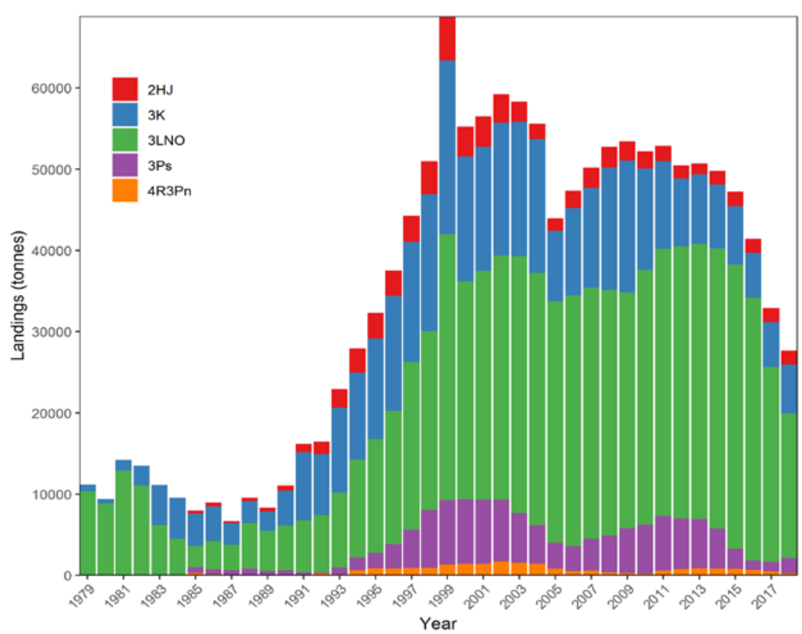

Figure 2: Annual landings by NAFO Division (1979-2018).

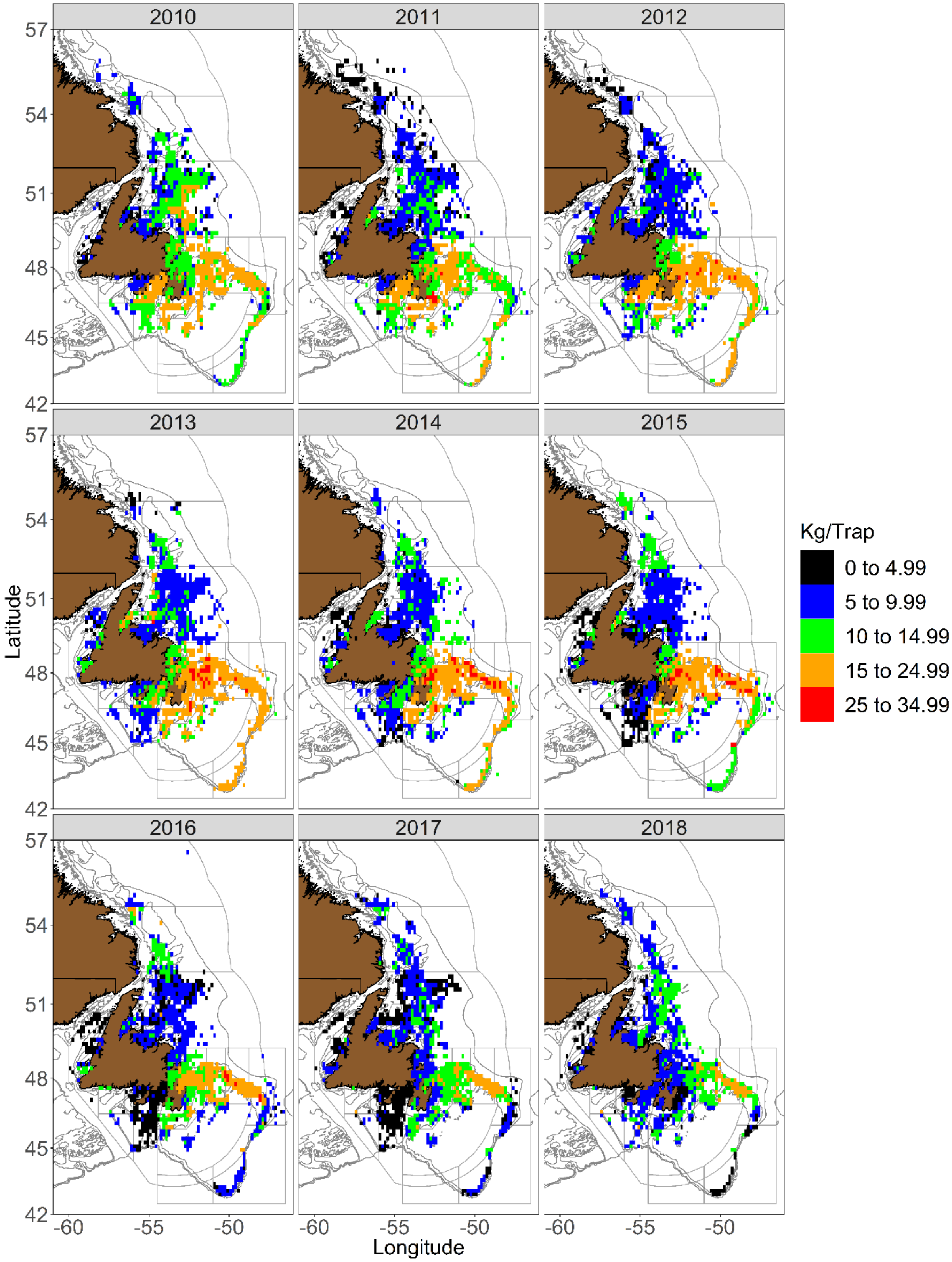

Figure 3: Locations of fishery sets and catch rates (kg/trap) from logbooks (2010-18).

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 to1987, 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 2,400 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 crab in the catch. A protocol was initiated in 2004 that results in closure of localized areas when soft-shelled crab exceeds 20% of the legal-sized catch. In Assessment Divisions (ADs) 3LNO Offshore and 3L Inshore, 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 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 remained near 50,000 t from 2007 to 2015, but have since steadily declined to a two-decade low of 27,700 t in 2018.

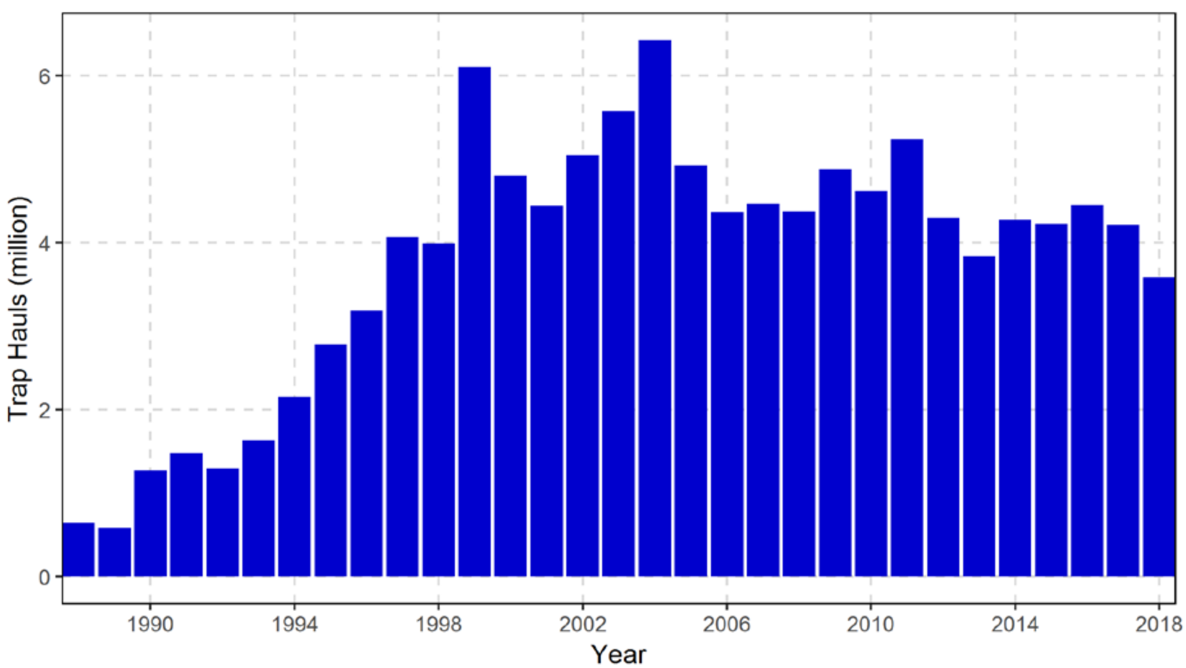

Figure 4: Estimated number of trap hauls per year for the fishery in Divs. 2HJ3KLNOP4R.

The spatial distribution of the fishery grew as licences and landings increased throughout the 1980s-90s. The resource is now deemed fully-exploited, with fishing effort typically spanning from the fringes of the Makkovik Bank off central Labrador in the north to the far offshore slope edges of the Grand Bank in AD 3LNO Offshore, to near the border of Quebec in the westernmost portions of AD 4R4Pn (Fig. 3). Fishery CPUE is typically highest in ADs 3L Inshore and 3LNO Offshore (Fig. 3). Overall effort remained at approximately 3.5 to 4.5 million trap hauls per year since 2007 (Fig. 4). Overall CPUE was at a time series low in 2018 (Fig. 5).

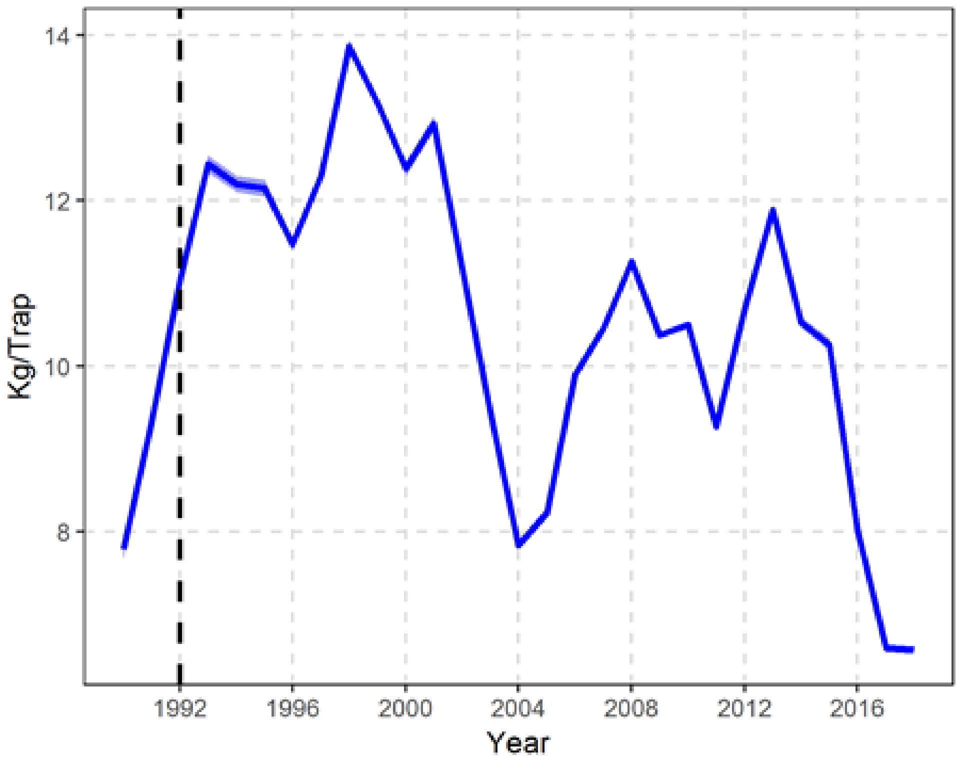

Figure 5: Fishery CPUE (kg/trap) for Divs. 2HJ3KLNOP4R. Solid line is standardized CPUE and band is 95% confidence intervals. Dotted lines are raw means and hashed lines are raw medians. Vertical dashed line represents the beginning of the cod moratorium in most ADs.

Assessment

Resource status was evaluated based on trends in survey exploitable biomass indices, fishery CPUE, fishery recruitment prospects, and mortality indices. Information was derived from multiple sources: multi-species bottom trawl surveys conducted during fall in Divs. 2HJ3KLNO and spring in Subdiv. 3Ps, Industry-DFO CPS trap surveys in Divs. 2HJ3KLO4R, DFO inshore trap surveys in Divs. 3KLPs, fishery data from logbooks, and observer catch-effort data.

Bottom temperature data from various surveys were incorporated into a snow crab thermal habitat index, defined as the areal extent of water below 2^{o}C in each AD. Cool conditions (a high index) are deemed favourable for long-term production potential in the stock.

The resource is assessed by ADs, which are comprised of combinations of NAFO Divisions. Div. 2H is combined with Div. 2J (AD 2HJ) 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 because of differences in data availability, with the trawl survey not normally extending to inshore bays. Finally, Subdiv. 3Pn is combined with Div. 4R to conform to management boundaries.

Generally, more data are available for offshore than inshore management areas within ADs. Trawl survey data are often only available for offshore areas because inshore areas are excluded when issues and time constraints occur in these surveys. However, in Subdiv. 3Ps, the spring trawl survey covers much of the inshore fishing areas, and in AD 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 ADs compared to inshore management areas.

The spring (Subdiv. 3Ps) and fall (Divs. 2HJ3KLNO) bottom trawl surveys are based on a stratified random sampling scheme and are used to provide an index of exploitable biomass that is expected to be available for the upcoming fishery in the same year (spring Subdiv. 3Ps) or the following year (fall Divs. 2HJ3KLNO). A Campelen shrimp trawl has been used for the multi-species surveys since 1995. Fisheries have begun earlier since the mid-2000s and now overlap with the timing of the spring trawl surveys in Subdiv. 3Ps. The exploitable biomass index is based only on male crab of legal size (≥ 95 mm CW). It is used together with an exploitable biomass index from the CPS trap survey to evaluate trends in biomass available to the fishery. In ADs 3L Inshore and 4R3Pn, no trawl survey is conducted, so the CPS trap survey exploitable biomass index is used. The CPS survey was initiated in 2003 and provides the most recent data available for the annual assessment.

Trawl and trap survey biomass indices are derived using ogive mapping (‘Ogmap’) (Evans et al. 2000). Biomass estimates are not absolute because the capture efficiency of Snow Crab by the survey trawl is unknown but low, and the effective fishing area of a baited trap is also unknown. 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. Trawl survey catch rates also appear affected by the diurnal cycle, being higher during dark periods. Other potential factors affecting trawl catchability include vessel and gear configuration. Trap effective fishing areas could potentially be affected by numerous factors including bait type, quantity, and quality, soak times, gear spacing, currents, and crab density. For the trawl and AD-level trap surveys, raw Ogmap exploitable biomass estimates were adjusted by a catchability factor (Q) in each division. This Q was determined through logbook catch rate Delury depletion models, with each year in the time series scaled by a time-series Q calculated as the median ratio of annual survey biomass to Delury logbook biomass in each AD. For trap surveys, the effective fishing area of a trap was estimated at 0.01 km^2 to enable spatial expansion and biomass estimation in Ogmap.

Bottom trawl surveys also provide data on recruitment. Recruitment prospects for the upcoming fishery are inferred from biomass indices or catch rates of new-shelled legal-sized crab (immediate recruits) from post-season or in-season trawl surveys. Trawl and trap surveys also provide indices of pre-recruit abundance, based solely on adolescent (non-terminally-molted) males 65-94 mm CW. The adolescents of these groups would be expected to be recruited to the exploitable biomass in approximately 2-4 years.

Trawl surveys also provide abundance indices for males of all sizes. The abundance index for the smallest crab consistently captured (< 50 mm CW) may indicate recruitment prospects approximately 5-7 years later, depending on AD. Longer-term recruitment prospects are inferred from the relationship of exploitable biomass indices with the annual average of monthly directional anomalies of the North Atlantic Oscillation (NAO) index. The NAO is an index of the relative strength of atmospheric forcing in the Northern Atlantic and its impacts have a strong impact on the ocean climate of the NL shelf, with positive phases associated with generally cool conditions. The annual NAO anomalies are lagged by 6-8 years, with a smoothed 3 year period moving average centred value used in cross-correlations. The strong correlation of NAO with subsequent biomass at these lags is consistent with the notion of strong effects of climate in regulating snow crab success in early life stages (Dawe et al. 2008, Marcello et al. 2012).

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 (kg/trap) of legal-sized adults. These core stations were identified as stations surveyed in 7 of the past 10 years. A stratification scheme, developed for the previous assessment, was used for estimating biomass indices. The survey also includes small-meshed traps, deployed on select stations, to provide data on recruitment prospects.

Total annual mortality rates in any given year t (A_t) were calculated as a 2-period moving average of stage-specific biomass indices of exploitable crab:

$$A_t = 1 - \frac{B_{old}\,(t)}{\left(B_{new}(t-1) + B_{old}(t-1)\right)}$$

where,

B_{new} = recruitment (shell conditions soft, new)

B_{old} = residual (shell conditions intermediate, old, very old)

t-1 = denotes survey of previous year

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. Natural mortality rates are unknown.

Resource Status

Landings & Effort

In AD 2HJ, landings have remained near 1,700 t for the past five years (Fig. 6) while effort has remained consistent (Fig. 7). In AD 3K, landings have remained relatively low for the past three years (6,000 t in 2018) while effort has been maintained near a two-decade low for the past six years. In AD 3L Inshore, landings declined by 56% from a time series high in 2015 to 3,700 t in 2018. The 2018 landings were 16% below the TAC. Effort remained at a time series high in 2018. In AD 3LNO Offshore, landings declined by 43% from 2016 to 14,000 t in 2018 because of reductions in the TAC, to the lowest level in two decades. Effort expanded rapidly from 1992 to the mid-2000s and has oscillated at a similar level since. In AD 3Ps, landings increased from decadal lows to 1,900 t in 2018, exceeding the TAC, which was set at 1,792 t. Effort has declined by 60% since 2014 to be near its lowest level in two decades. Finally, in AD 4R3Pn, landings have steadily declined since a recent peak in 2013 and were 250 t in 2018. Meanwhile, effort in AD 4R3Pn has remained at a low level.

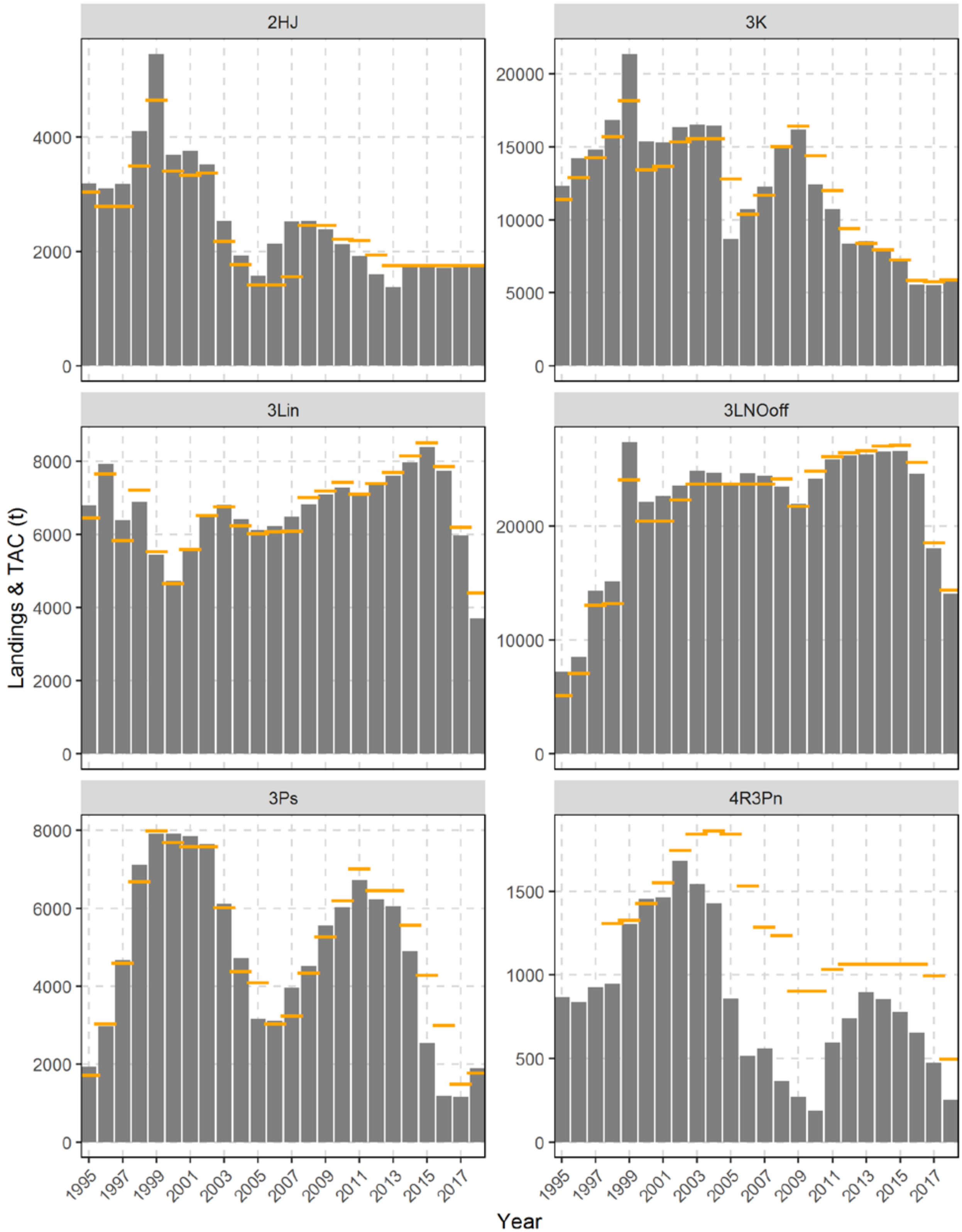

Figure 6: Annual landings and TAC by Assessment Division (1999-2018).

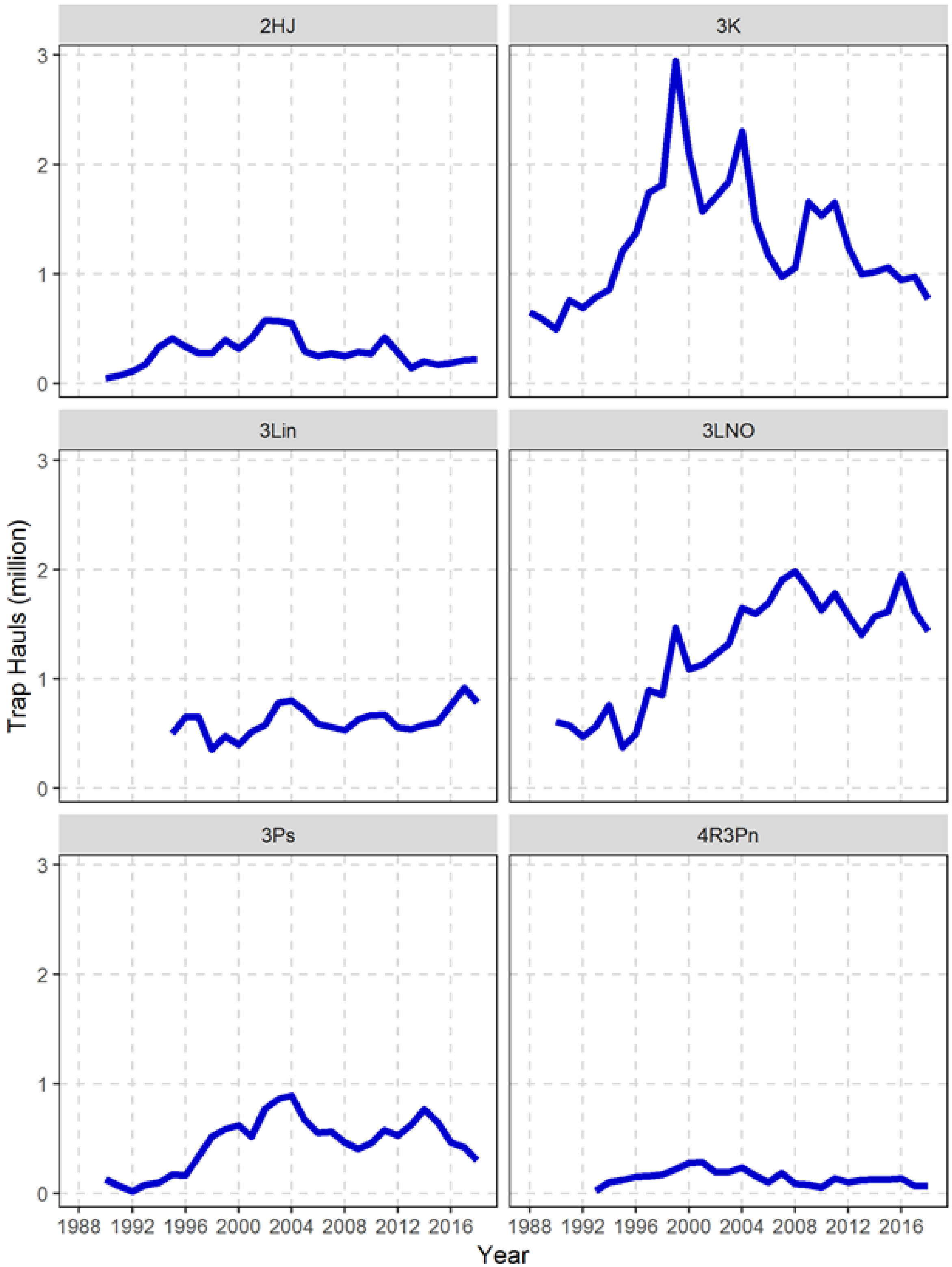

Figure 7: Annual effort (trap hauls) by Assessment Division.

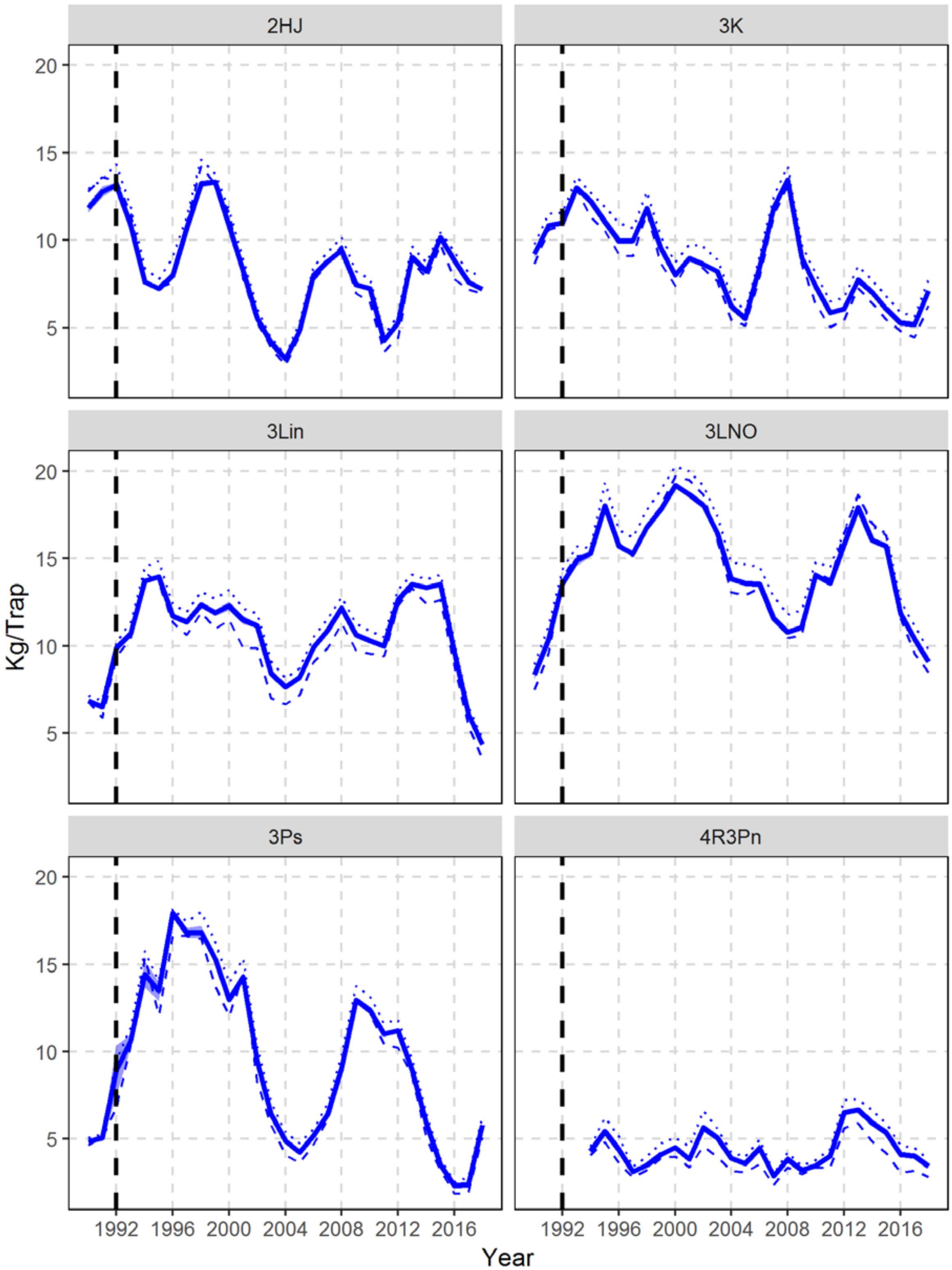

Figure 8: Fishery CPUE (kg/trap) by Assessment Division. Solid line is standardized CPUE and band is 95% confidence intervals. Dotted lines are raw means and hashed lines are raw medians. Vertical dashed line represents the beginning of the cod moratorium in most ADs.

CPUE

Fishery CPUE trends lag behind survey biomass trends by 1-2 years in all ADs, thus the fishery is typically delayed in reflecting stock status. In AD 2HJ, standardized CPUE has remained near the decadal average in recent years (Fig. 8). In AD 3K, it increased in 2018 from a time series low in 2017, but remains below the time series average. In AD 3L Inshore, CPUE has declined by 68% since 2013 to below 5 kg/trap, its lowest level in the time series. In AD 3LNO Offshore, it most recently peaked near a time series high in 2013 and has since declined by 49% to its lowest level since 1992. In AD 3Ps, standardized CPUE increased from time series lows in 2016 and 2017 to more than 5 kg/trap in 2018. Finally, in AD 4R3Pn, it has declined since 2013 to below the long-term average.

Exploitable Biomass

Multi-species trawl surveys indicate that the exploitable biomass was highest at the start of the survey series (1996-98) (Fig. 9). It declined from the late 1990s to 2003 and then varied without trend until 2013. From 2013 to 2016, it declined by 80%. Despite modest increases in the past two years, the trawl survey exploitable biomass index has remained at its lowest level for the past four years. Meanwhile, the trap survey index has declined by nearly 60% in the last two years to a time-series low (Fig. 10). The lack of residual crab in the exploitable biomass in recent years is concerning and in-part reflects a relatively high level of exploitation occurring on the stock coupled with a prolonged period of poor productivity.

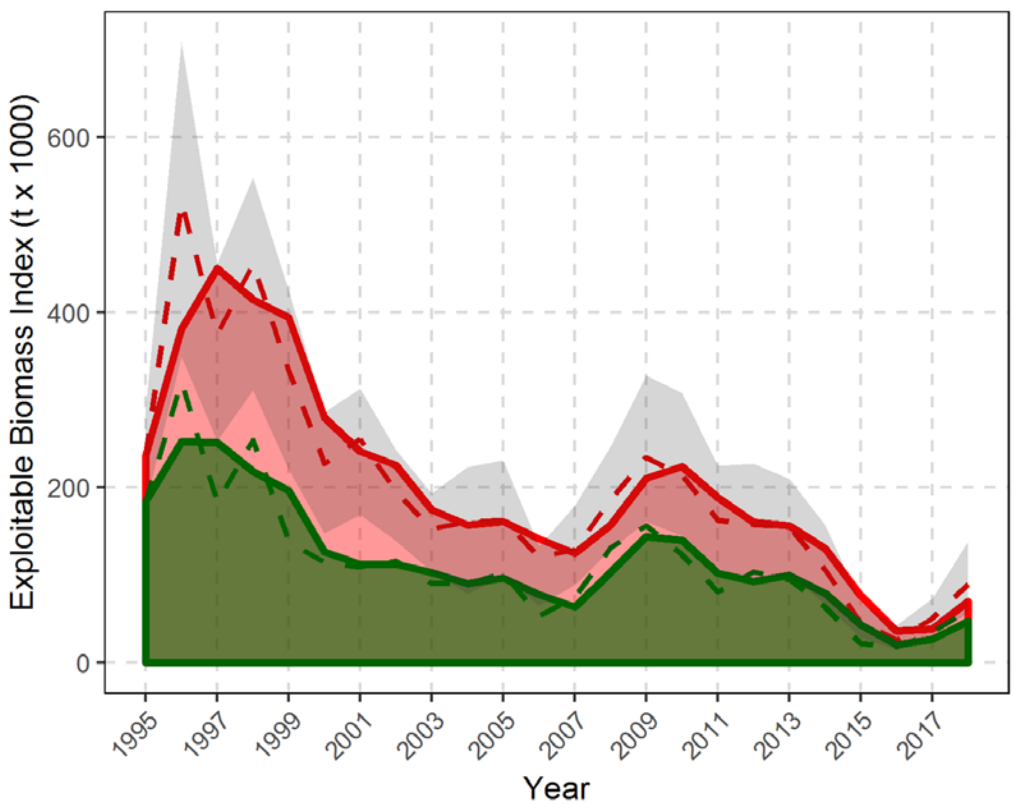

*Figure 9: Trawl survey exploitable biomass indices (t * 1000) by shell condition for Divisions 2HJ3KLNOPs. Soft and new-shell crab represent recruitment (green) and intermediate and old-shell crab represent residual biomass (red). Dashed lines shows annual estimates and solid lines are two year moving average estimates. Shaded 95% confidence intervals apply to annual estimates.*

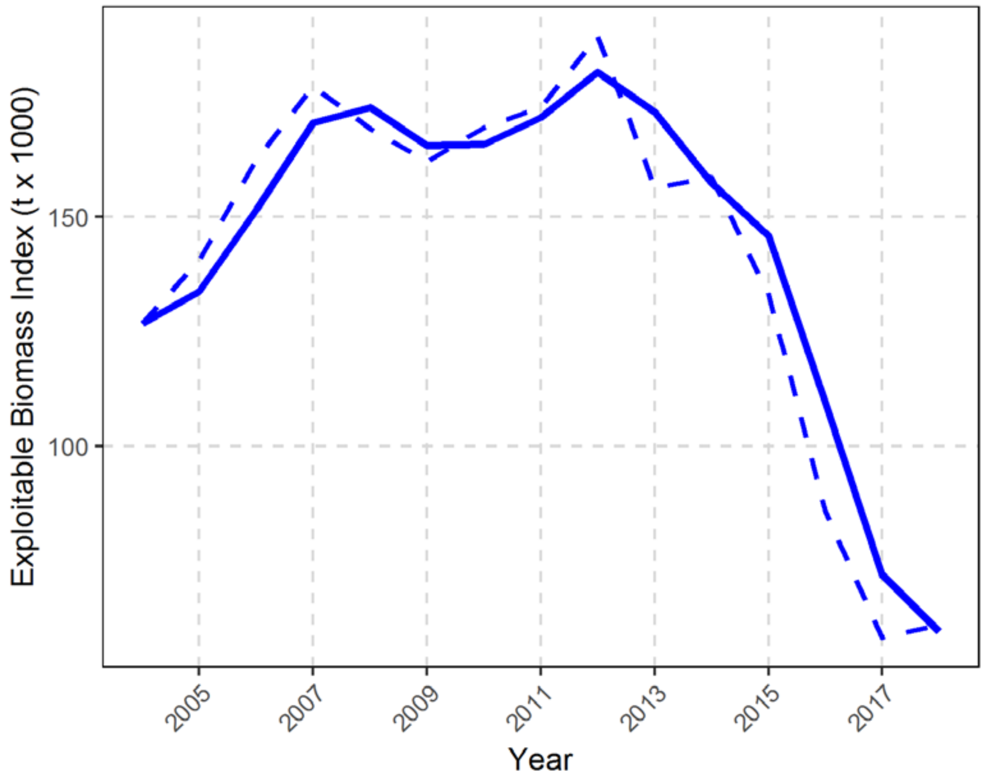

*Figure 10: Trap survey exploitable biomass indices (t * 1000) by shell condition for Divisions 2HJ3KLNOPs. Dashed line shows annual estimate and solid line is two year moving average estimate.*

In AD 2HJ, the exploitable biomass index has changed little during the past 15 years (Figs. 11-12). A modest increase in 2018 reflects an increase in residual biomass. Despite consistency across the two surveys, stock status interpretation is compromised by incomplete trap surveys in the past two years (Fig. 12). In AD 3K, despite localized improvements, the post-season trawl and trap survey exploitable biomass indices have remained near time-series lows for the past five years. In AD 3L Inshore, the exploitable biomass is severely depleted. The post-season trap survey exploitable biomass index remained near a time-series low in 2018. CMAs 6B and 6C (Fig. 1) had total catch rates of approximately 1 kg/trap in the 2018 surveys. In AD 3LNO Offshore, the trawl-derived exploitable biomass index showed a modest increase in 2018, but both it and the trap-derived exploitable biomass index remain at or near time-series' lows. In AD 3Ps, the in-season trawl survey exploitable biomass index was at a time-series low in 2016, but has improved during the past two years. The post-season trap survey index suggests an increase in the exploitable biomass throughout the major fishing grounds. Finally, in AD 4R3Pn, the exploitable biomass is severely depleted, with few residual crab in the population. The trap survey exploitable biomass index most recently peaked in 2012 and declined to a time series low in 2017. The index increased slightly in 2018, reflecting localized improvements in CMA 12EF (Fig. 1).

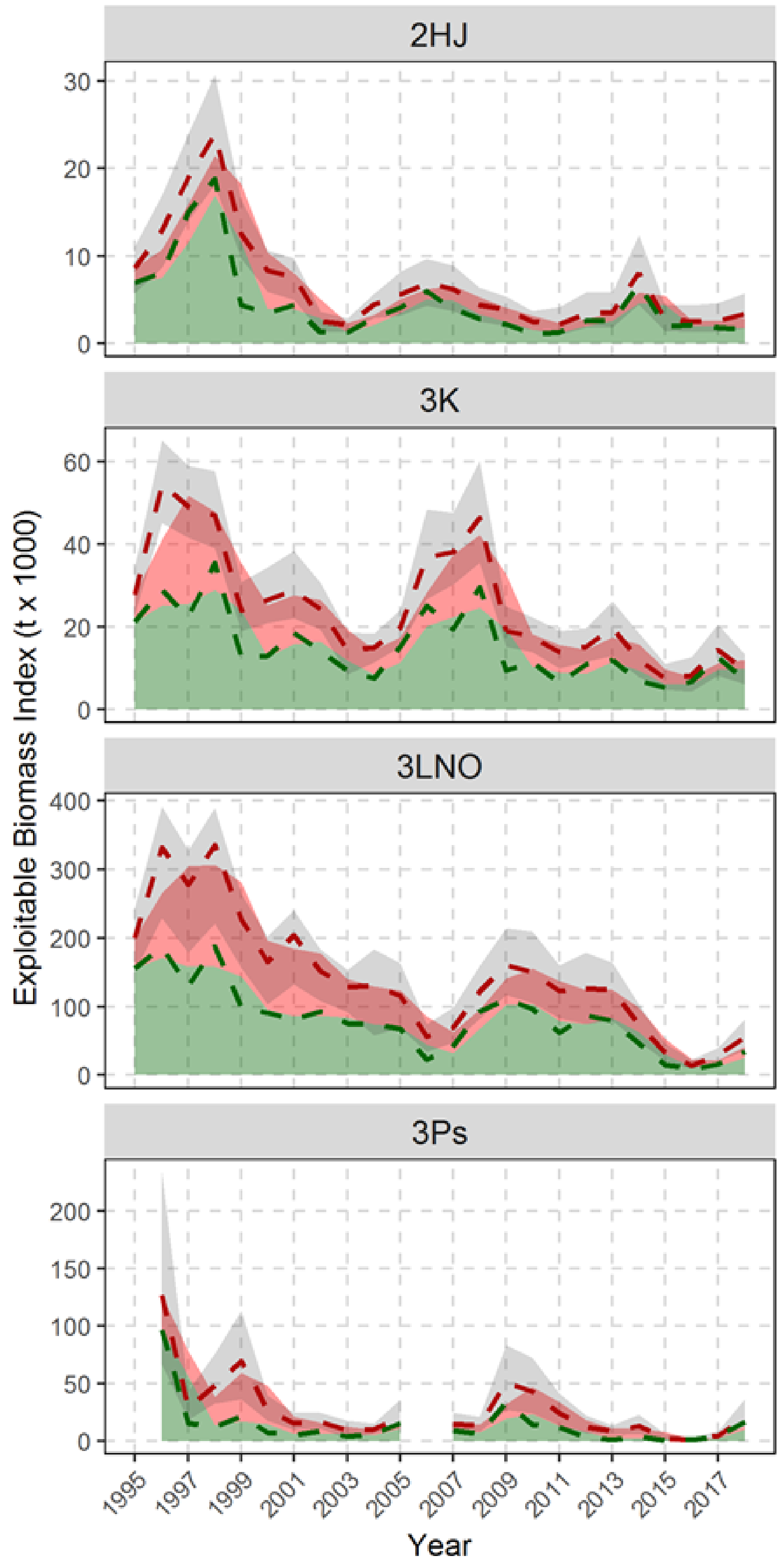

*Figure 11: Trawl survey exploitable biomass indices (t * 1000) by shell condition for trawl-surveyed Assessment Divisions. Soft and new-shell crab represent recruitment (green) and intermediate and old-shell crab represent residual biomass (red). Dashed lines shows annual estimates and solid lines are two year moving average estimates. Shaded 95% confidence intervals apply to annual estimates.*

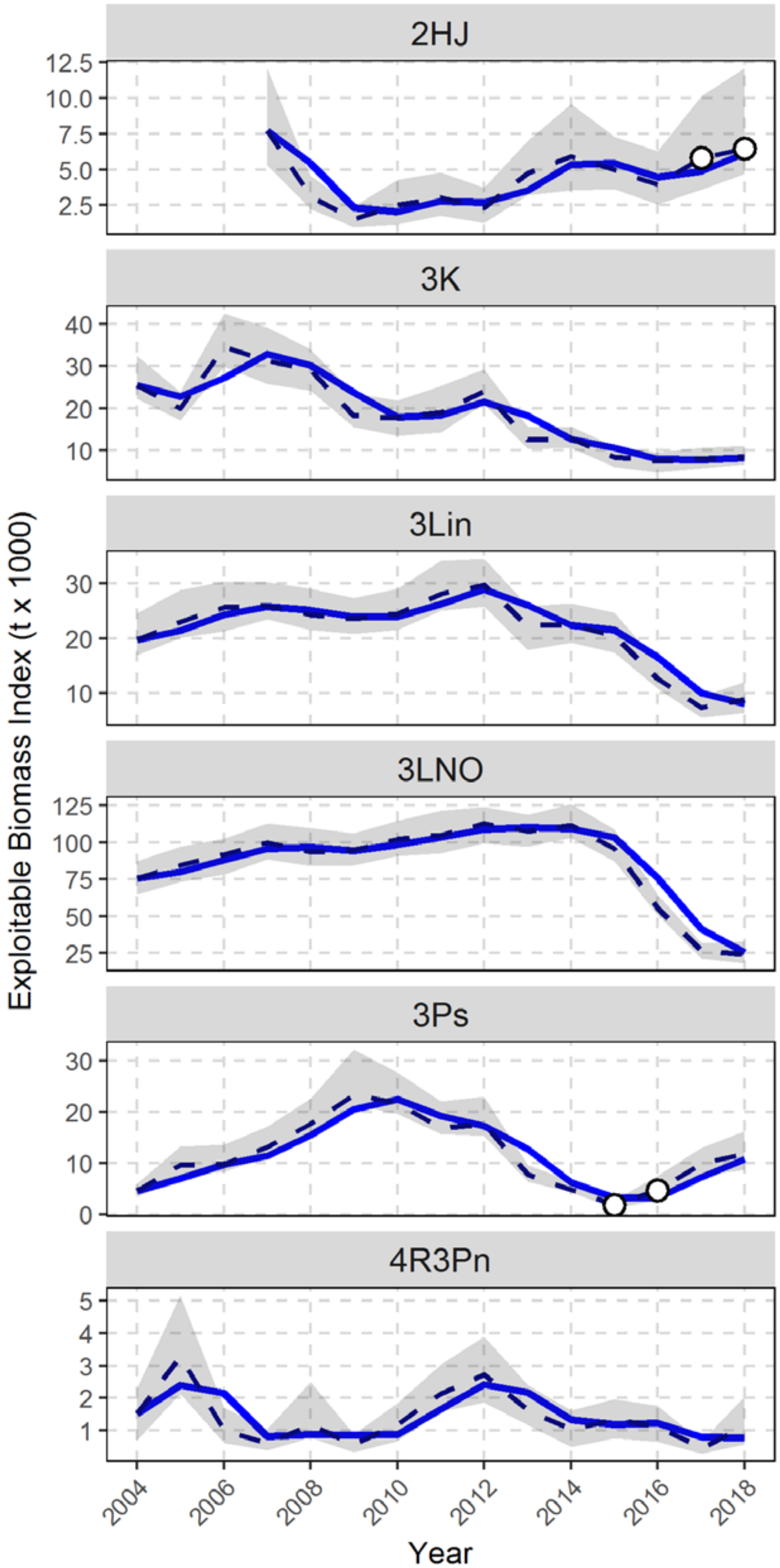

*Figure 12: Trap survey exploitable biomass indices (t * 1000) by Assessment Division. Dashed line shows annual estimate and solid line is two year moving average estimate. White dots depict incomplete surveys.*

Mortality

Total mortality in exploitable crab was very high in all ADs during 2015-16 (Fig. 13). In AD 2HJ, total mortality remained high in 2017 but declined slightly in 2018. In AD 3K, total mortality in exploitable crab has remained at its highest level during the past four years. In AD 3LNO Offshore, total mortality declined from its highest observed level in 2016 to a relatively low level in 2018. Finally, in AD 3Ps, total mortality in exploitable crab has varied considerably throughout the times series but was low in 2018. The high variability in the total mortality index in AD 3Ps likely reflects the shell condition-based methodology, with a spring survey potentially compromising the efficacy of the subjective shell condition classifications.

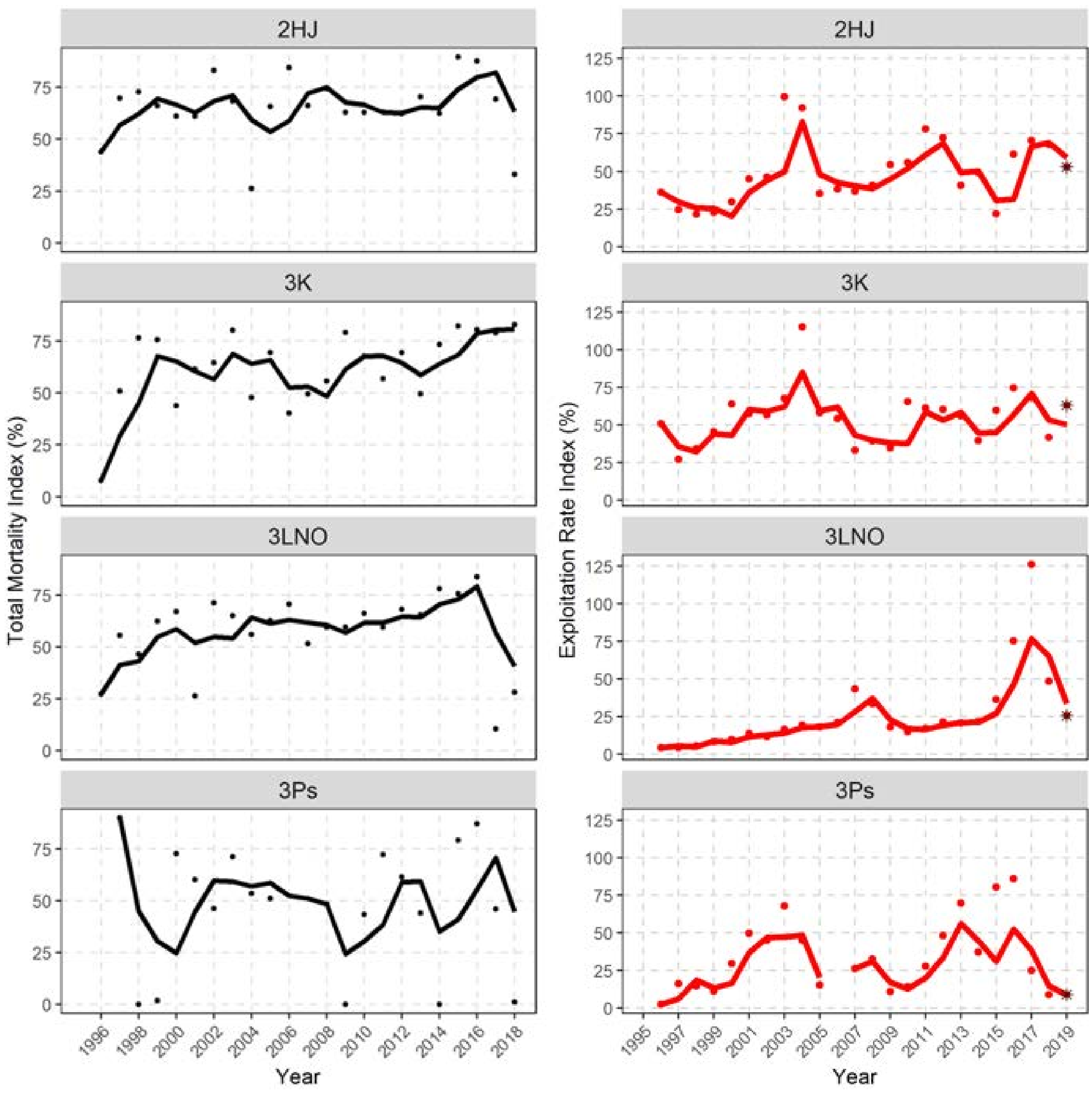

Figure 13: (Left panels) Trends in the annual (circles) and two year moving average (solid line) total annual mortality index (%) of exploitable crab by Assessment Division. Note if annual mortality index was <0 it was plotted as 0 for presentation. (Right panels) Trends in the annual (circles) and two year moving average exploitation rate index (solid line) (%) by Assessment Division; 2019 stars depict annual projected exploitation rate indices under status quo removals in the 2018 fishery.

Trends in total mortality generally reflect those of fishing-induced mortality, as measured by exploitation rate indices. ADs currently experiencing notable recovery in the exploitable biomass (3LNO Offshore, 3Ps) are associated with reduced total mortality rates and associated reductions in exploitation rates while ADs remaining at low levels with little signs of recovery (2HJ, 3K) are associated with persistent high total mortality and exploitation rates. Evidence suggests that reducing exploitation rates constitutes an effective strategy toward promoting recovery of the exploitable biomass. This is further bolstered by the presence of stronger residual components to the exploitable biomass in less heavily exploited areas.

In AD 2HJ, the exploitation rate index has been above the long-term average for the past three years (Fig. 13). Status quo removals in 2019 would decrease the exploitation rate index, but it would remain at a relatively high level. In AD 3K, the exploitation rate index declined from a decadal high to near time-series average levels in 2018. Under status quo removals in 2019 the exploitation rate index would be unchanged. In AD 3LNO Offshore, the exploitation rate index increased by a factor of five from 2014 to 2017, and remained high in 2018. The exploitation rate index would decline to near the long-term average with status quo removals in 2019. In AD 3Ps, the exploitation rate index was near its lowest observed level in the time series in 2018 and status quo removals would result in the exploitation rate index being near a time-series low in 2019.

There are no trawl-based biomass indices available in ADs 3L Inshore and 4R3Pn from which to calculate exploitation rate indices. Accordingly, the shorter time series of trap surveys are used as the basis. In AD 3L Inshore, the overall trap survey-derived exploitation rate index has increased since 2013 and remained at its highest observed level in 2018. Status quo removals would maintain the exploitation rate at a time series high in 2019. In AD 4R3Pn, The overall exploitation rate index declined to below the long-term average in 2018. Status quo removals in 2019 would result in little change to the exploitation rate index.

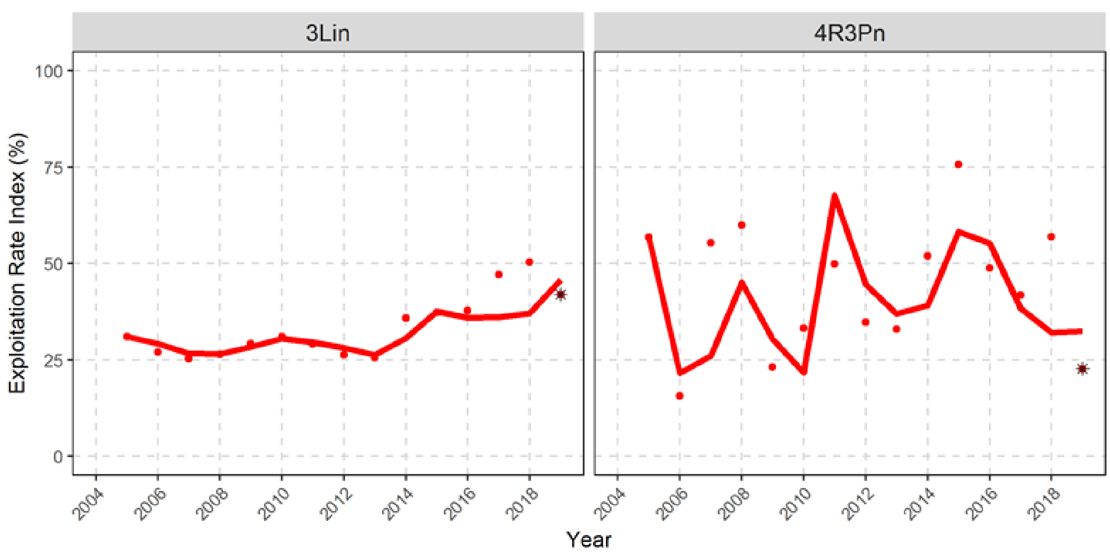

Figure 14: Trends in the annual (circles) and two year moving average trap-based exploitation rate indices (solid line) (%) by Assessment Division; 2019 stars depict annual projected exploitation rate indices under status quo removals in the 2018 fishery.

Recruitment

Overall recruitment into the exploitable biomass has been very low in recent years and will remain low in 2019 (Fig. 9). In most ADs, the exploitable biomass is presently dominated by incoming recruits. In AD 2HJ, recruitment into the exploitable biomass has changed little during the past 15 years (Fig. 11). The 2018 trawl and trap surveys suggest recruitment will remain unchanged in 2019. This suggests little change in fishery prospects for 2019. In AD 3K, the post-season trawl and trap survey indices of recruitment into the exploitable biomass have remained near time-series lows for the past five years (Fig. 11), suggesting little prospects for improvements in the fishery in 2019. In AD 3LNO Offshore, recruitment into the exploitable biomass has been at or near time-series lows in both the trawl (Fig. 11) and trap surveys in the past three years, but increased slightly in 2018. This suggests better prospects for the 2019 fishery. In AD 3Ps, recruitment into the exploitable biomass was near a decadal high in 2018 (Fig. 11), with the exception of Fortune Bay. The marked improvement in recruitment into the AD 3PS exploitable biomass strongly suggests the 2019 fishery should perform well.

For ADs where no trawl surveys occur the assessment found that in AD 3L Inshore recruitment into the exploitable biomass steadily declined to a time-series low in 2017 and that recruitment indices from DFO and CPS trap surveys remained near their lowest levels in 2018. This suggests a continuation of a depleted exploitable biomass and a poor performing fishery in that AD in 2019. In AD 4R3Pn, recruitment into the exploitable biomass was low from 2014 to 2017, but survey data from 2018 suggest localized improvements may occur in 2019, particularly in CMA 12EF.

Pre-recruit abundance indices for trawl and trap surveys provide an index of recruitment prospects for the next two to four years. In reality however, the proportion of the 65–94 mm CW adolescents measured by these surveys that reach the exploitable biomass depends on several factors including mortality and the size at which crab terminally molt. The overall abundance of pre-recruits in the stock has remained at or near its lowest observed level of eight consecutive years. This largely reflects trends in the largest AD (3LNO Offshore). Nonetheless, both surveys are suggesting the potential for localized improvements of recruitment into the exploitable biomass in forthcoming years. Most notably, in AD 3Ps the survey data of pre-recruit abundance suggest short-term prospects are positive relative to the recent 2013-16 low period (Figs. 15-16). Spatially, the distribution of pre-recruit crab appears concentrated on the major fishing grounds of the AD. Further potential for localized improvements of recruitment are suggested by increased abundance of pre-recruits in the trap surveys in AD 3L Inshore, AD 3LNO Offshore, and AD 4R3Pn. The assessment found that these localized aggregations were most pronounced in CMAs 6A, 8B, 9A, and 12EF. The scenario of low or depleted exploitable biomass levels in each these ADs coupled with increased potential of recruitment into the biomass suggests soft-shell crab incidence may be high in the fishery in these areas over the next couple of years if measures to ensure efficient transition of these crab into the exploitable biomass are not taken.

Ecosystem Perspective

The thermal habitat index (defined as the areal extent of <2°C bottom water) has returned to near-average conditions in all divisions in recent years (Fig. 17). More broadly, annual anomalies of the NAO atmospheric index have been favourably positive for the past seven years. Overall, broad-scale climate indices appear favourable for improved recruitment to occur in most major areas of the stock range over the next few years.

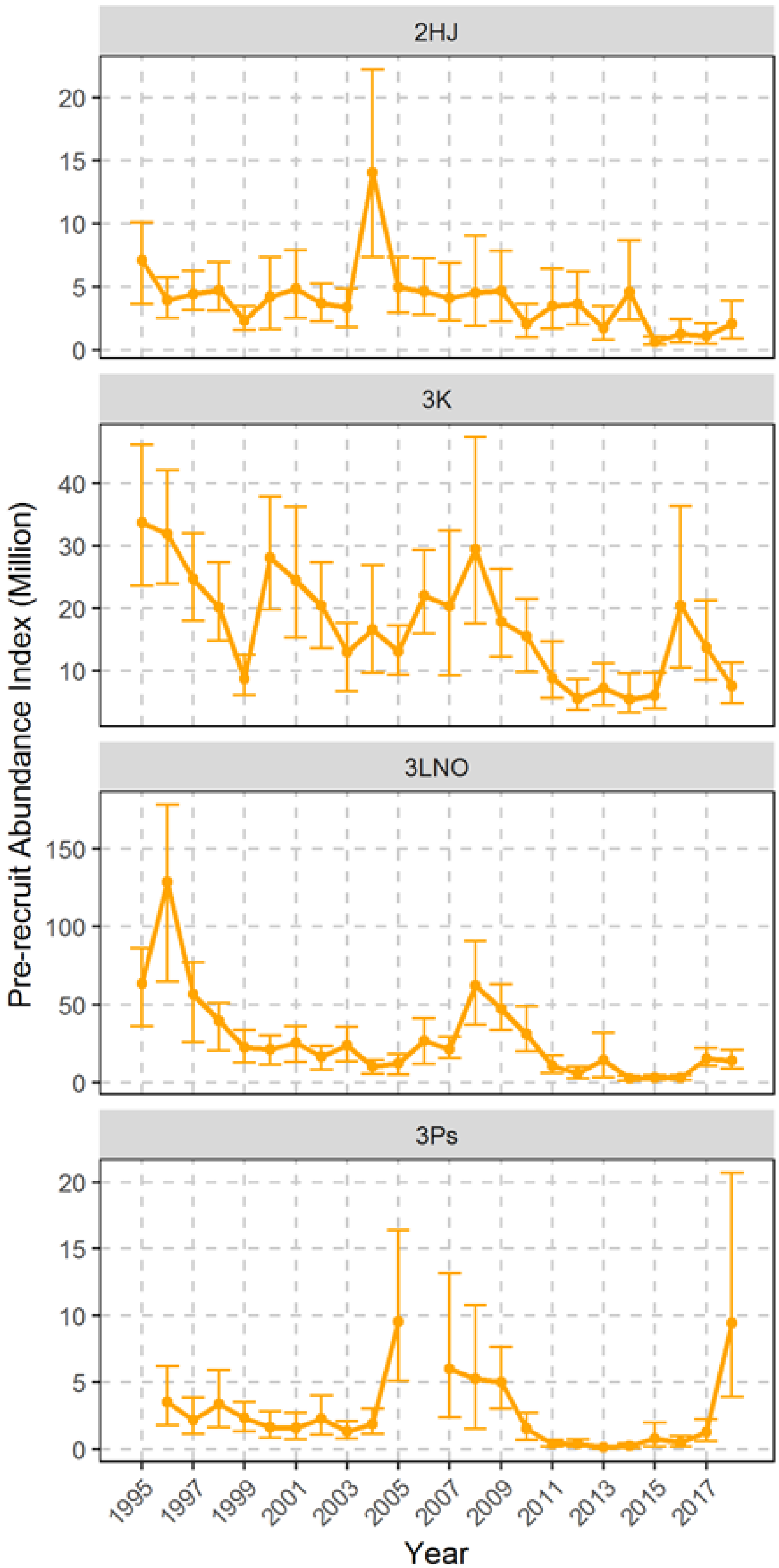

*Figure 15: Overall trawl survey pre-recruit biomass index (t * million) by Assessment Division.*

Figure 16: Annual CPUE (#/trap) of pre-recruits from small-mesh traps at core stations in the CPS trap survey by Assessment Division (2004-18).

Figure 17: Snow Crab thermal habitat indices by Assessment Division and year (1980-2018).

Since the collapse of most of the finfish community in the early-1990s, the Snow Crab resource appeared to have largely been under bottom-up temperature control for much of the past two decades (Mullowney et al. 2014). However, at present it is becoming apparent that the level of small crab in the population and short-term recruitment prospects are below those that occurred under similarly cold regimes of the past. The resource was most productive throughout the 1990s but productivity has been declining for the past two decades including under the recent favourably cooling oceanographic regime. This suggests other factors such as top-down forcings from heavy exploitation or increased predation have increased in importance.

Predation indices were unable to be updated for the present assessment. However, up until 2017 it had been observed that predation on Snow Crab had been high in recent years, associated with low availability of core forage species like capelin and shrimp. However, there was a sharp decline in predation on Snow Crab in 2017 (Fig. 18). Given that the regulating effect of predation is thought to be most important on small to intermediate-sized crab (Chabot et al. 2008), a delay would be expected between the time the predation index increases and crab become available to the fishery. Any dampening effects of predation could now plausibly be manifest in pre-recruit abundance indices, which are low relative to historic norms in most major ADs (Fig. 16).

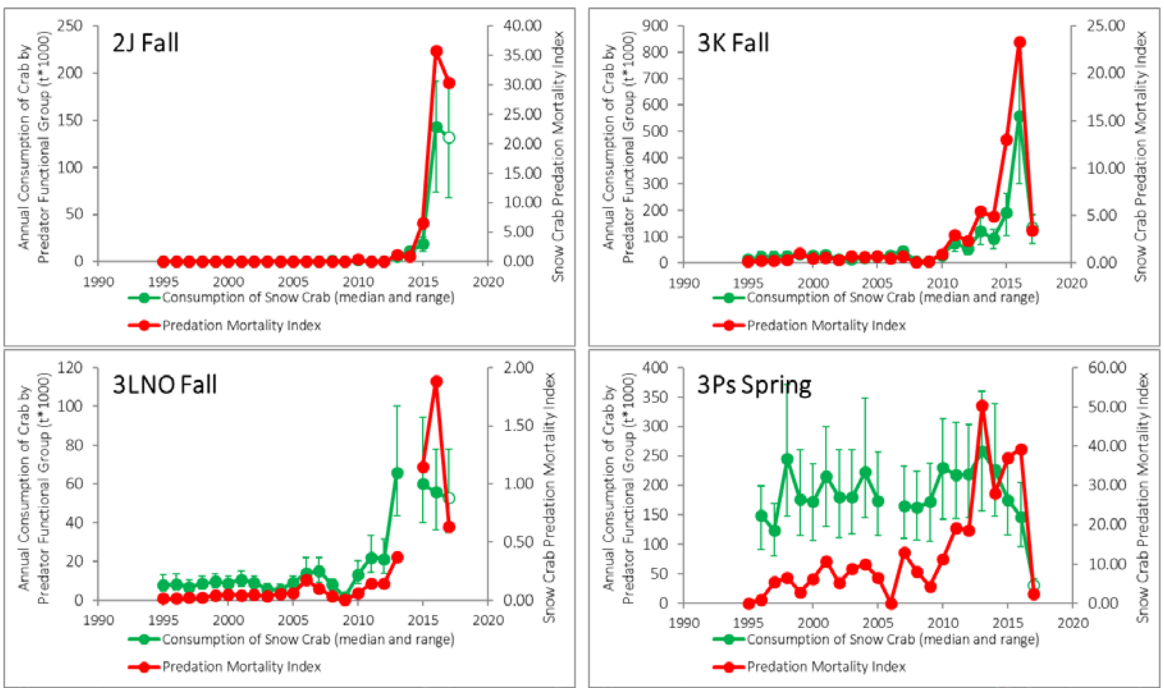

Figure 18: Consumption of Snow Crab by predators by assessment division. Green represents estimated consumption and red is an index of predation mortality. Solid symbols in 2017 denote preliminary data.

With respect to overall ecosystem productivity, ecosystem conditions in the NL Bioregion are indicative of an overall low productivity state. Current total shellfish and finfish biomass is at a level similar to that observed in the mid-1990s. However, shellfish make up a much lower proportion of that biomass. The concerns of low ecosystem productivity extend into the bases of the food-web, with of an overall low productivity at the lower trophic levels (phytoplankton and zooplankton) in recent years (Fig. 19) and changes in zooplankton community structure that may impact the transfer of energy to higher trophic levels.

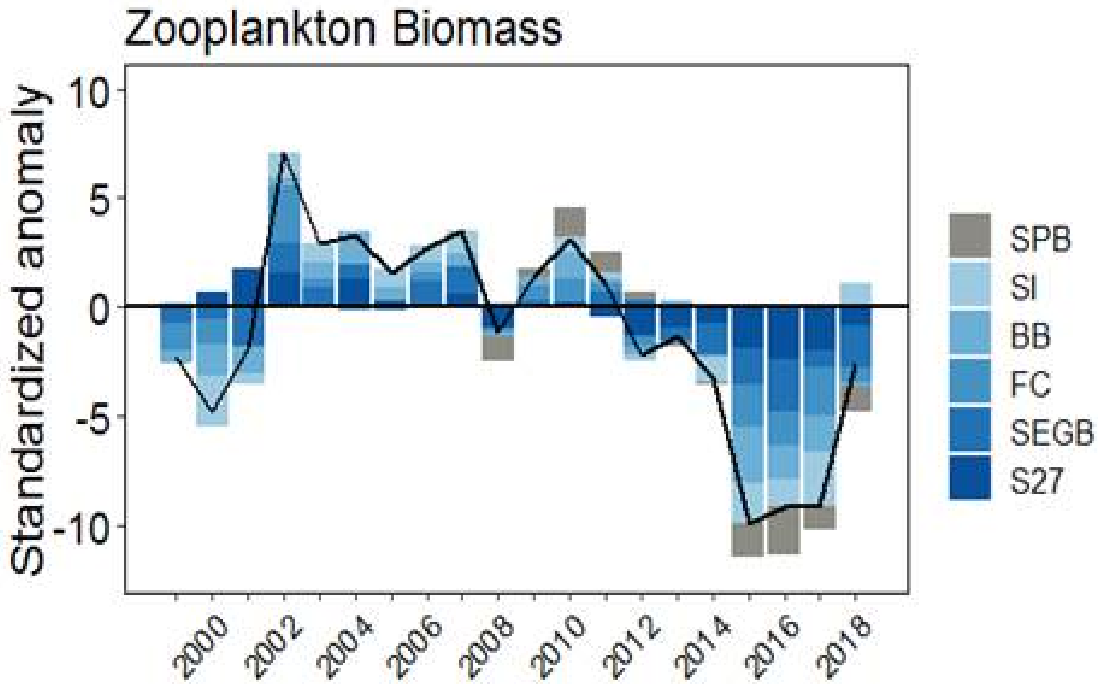

Figure. 19: Annual standardized anomalies of total zooplankton biomass for the Atlantic Zone Monitoring Program (AZMP) oceanographic sections [St. Pierre Bank (SPB); Southeast Grand Bank (SEGB); Flemish Cap (FC); Bonavista Bay (BB); and Seal Island (SI)], and for the high frequency sampling Station 27 (S27). The black line represents the annual cumulated anomalies. Time series for SPB section covers the period 2008-2018 only and is therefore not included in cumulated anomalies.

Outlook

Although a small pulse of young crab (i.e. < 50 mm CW) has emerged in some divisions in recent years (i.e. ADs. 2HJ and 3K), overall, virtually all population components are at low levels relative to historical levels in all divisions (Fig. 20). Most data suggest that overall, short, medium, and long-term prospects appear relatively weak.

Compounding potential issues of a low productivity state is that recruitment levels that already appear modest relative to historic highs are likely to be further moderated by intrinsic growth responses of males. A sharp decline in size-at-maturity (i.e., size-at-terminal molt) has occurred in all major ADs in recent years (Fig. 21). In all examined ADs, the size at which 50% of the males have terminally molted has been near or below 60 mm CW. These are sizes more typically associated with terminal molt in female crab. Explicit reasons for this growth response in males is not known, but both bottom-up (temperature, nutrition) and top-down (fishing, predation) influences, or a combination of several factors, could be causalities. The emergence of this phenomenon will be important to monitor moving forward as persistence of it could lead to genetic change in the species over the long-term or to offsetting consequences such as sperm limitation in females in the short-term.

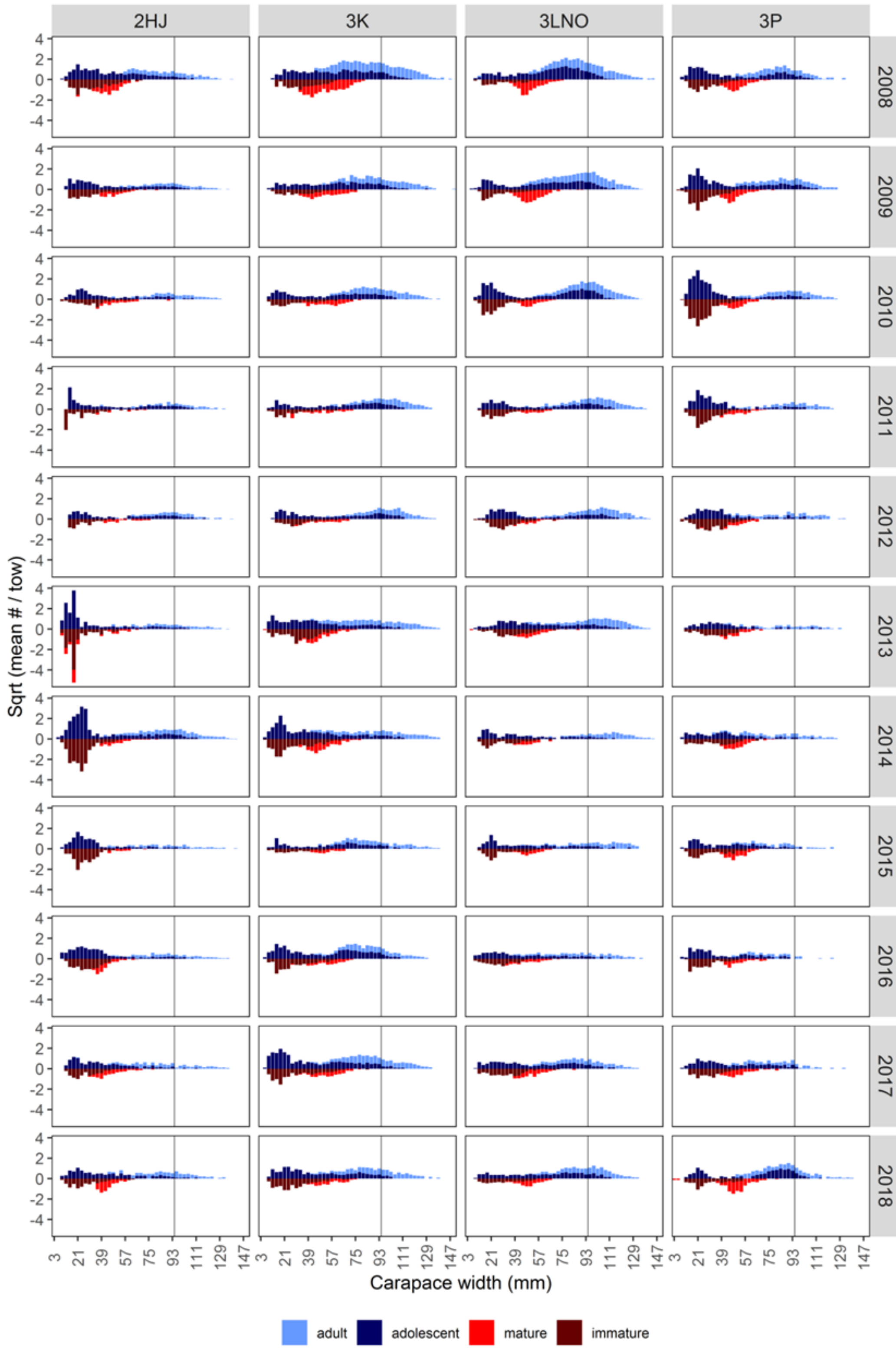

Figure 20: Abundance indices by carapace width for juveniles plus adolescent males (dark blue), adult males (light blue), immature females (dark red), and mature females (red) from spring (Subdiv. 3Ps) and fall (Divs. 2HJ3KLNO) trawl surveys. Dashed vertical line is legal-size. Data standardized by vessel.

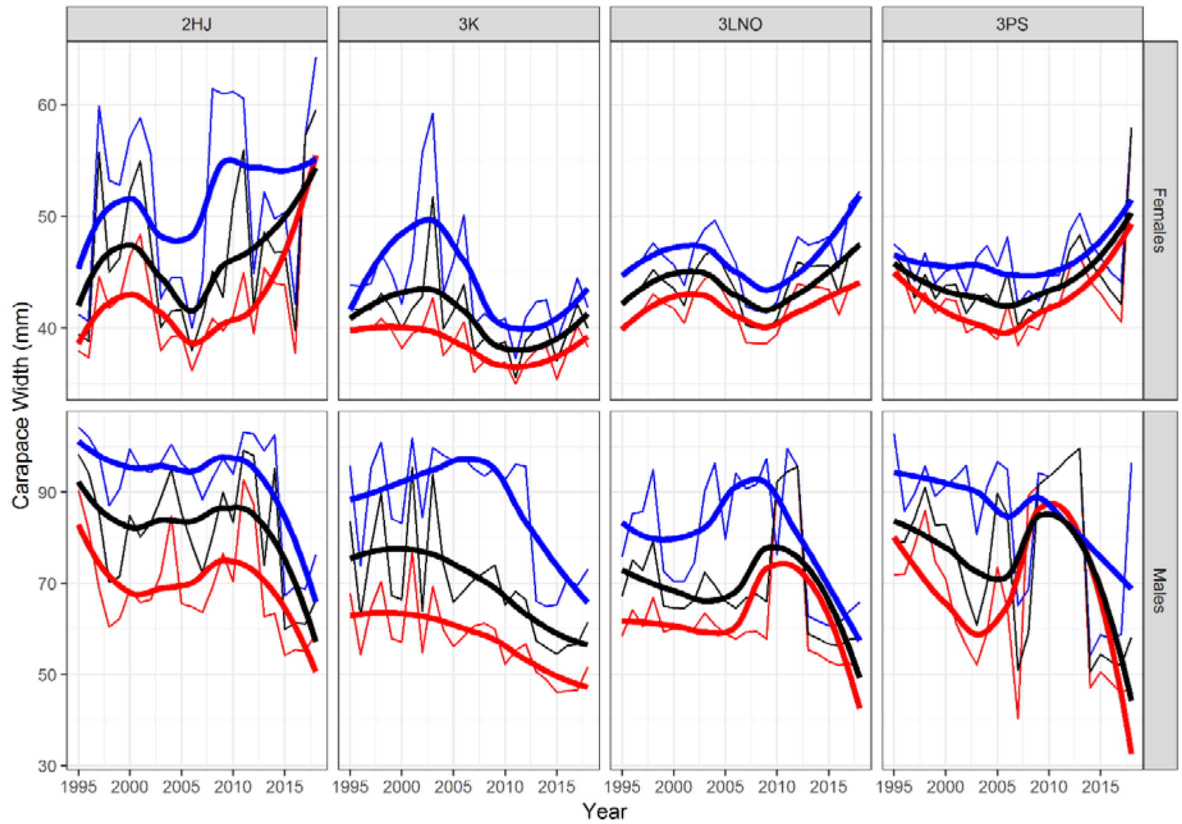

Figure 21: Size of female (top) and male (bottom) 1/3 (red), 50% (black), and 2/3 (blue) size at maturity in each Assessment Division. Thin lines represent annual estimates from GAM. Thick lines represent a smoothed line through annual estimates.

Precautionary Approach

DFO Science has proposed a Precautionary Approach (PA) Framework for the NL Snow Crab resource and fishery (Mullowney et al. 2018). The established parts of the framework include the Limit Reference Points (LRPs), differentiating the critical from cautious zones, and the Upper Removal Reference (URR). Harvest Control Rules (HCRs) and Upper Stock References (USRs) have been proposed but not adopted into the framework. Accordingly, proposed USRs presented in this assessment are tentative. The proposed overarching HCR for the framework is that the stock is considered to be in the lowest zone of the three metrics examined, which include female egg clutches, fishery CPUE, and fishery discards. The framework uses generalized additive models, peer-reviewed at the present assessment, to project forward one year anticipated fishery CPUE and discard rates.

In 2019 most ADs are projected to fall within the provisional cautious zone of the proposed Precautionary Approach Framework (Fig. 22). AD 3L Inshore would be in the critical zone. These projections assume status-quo landings.

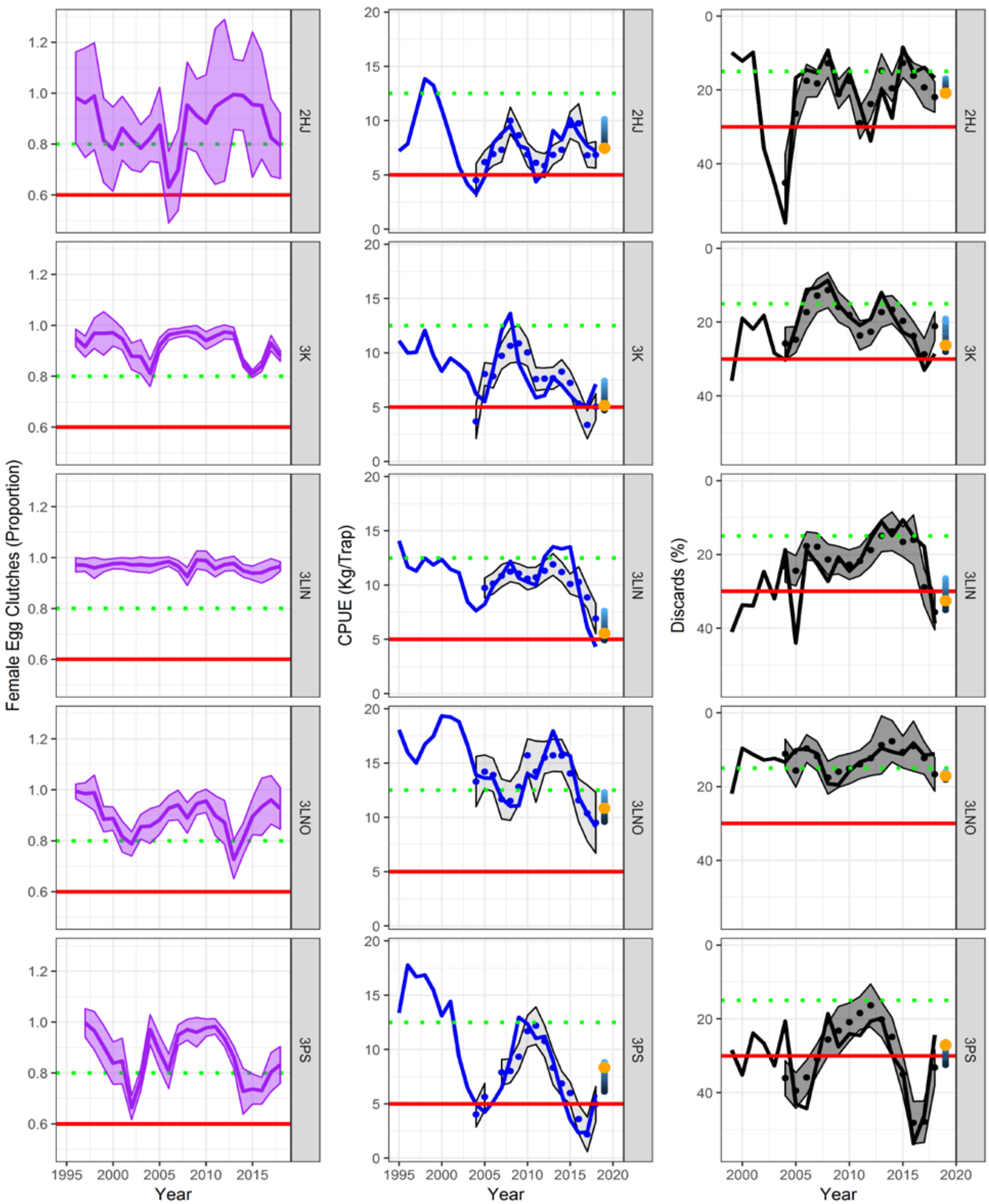

Figure 22:Trends in proportion of females with full egg clutches (left), CPUE (middle), and % discards (right), in relation to proposed Precautionary Approach. Shaded areas represent 95% confidence (egg clutches) or prediction (CPUE and discards) intervals. Points represent raw values. Orange points represent predicted values under status quo landings. Vertical blue shades in 2019 are the predicted values under varying levels of ERI (light to dark blue: ERI = 0 – 60%).

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 because post-season surveys are the most recent available sources of information to inform the stock assessment and available recruitment into the biomass for the forthcoming fishery has generally been fully realized at that point in time (i.e. typically autumn).

Surveys

Interpretation of trends in exploitable biomass and pre-recruit abundance indices from surveys is highly uncertain if the survey was incomplete such as in AD 2HJ trap surveys in the past two years. 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 abundance index because it and the exploitable biomass index often 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 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 biomass indices and pre-recruit catch rates from trap surveys are also affected by annual variation in catchability of crabs. There is uncertainty in interpreting trends from the CPS survey because it has 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.

For the present assessment, all biomass estimates were smoothed as two-year moving averages to partially account for such inconsistencies in annual survey performance.

Small-meshed traps are included in sampling by the CPS trap survey at 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 historically 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.

Crab movements across divisional boundaries may affect the extent to which distributions during timing of various surveys are reflected in subsequent fisheries or the extent to which modes of growth progression can be followed from one year to the next. In the present assessment, there is evidence presented of a large redistribution of exploitable crab out of AD 3K and into AD 2HJ during the past year. Such issues have the potential to greatly affect stock status interpretations at small spatial scales such as the CMAs used to manage the fishery.

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). In the present assessment it was demonstrated that unusually high proportions of adolescent males in AD 3Ps were observed to be skip-molters in

2012 and 2013, thus progression of the current recruitment pulse to legal-size was delayed relative to the generation time of previous pseudo-cohorts in this AD.

Long-Term Recruitment

There is high uncertainty about the reliability of qualitatively relating recent climate events to long-term recruitment potential. Strong direct linkages of future biomass to climate forcings such as the NAO (Colbourne et al. 2011) could fail if additional factors such as excessive fishing or high predation affect recruitment and yield. Moreover, under greenhouse gas-forced warming, there is uncertainty regarding whether such long-term oscillations will persist as they have in the past or how they will interact with additional forcings.

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 so the associated CPUE and effort values are potentially biased and considered preliminary. Overall, for the current assessment, approximately 70% or more of the 2018 logbooks were available for each AD. The reliability of the logbook data can be 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.

Fishery catch rates are standardized in a mixed model incorporating fishing day and soak time to account for potential inaccuracies, but other factors remain that can potentially bias their utility as indices of relative biomass.

There are concerns regarding the utility of the observer data from at-sea sampling during the fishery due to low and spatio-temporally inconsistent coverage, especially in ADs. 2HJ, 3L Inshore and 4R3Pn. These concerns introduce 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. Total mortality estimation relies on shell-condition classifications, and such classifications may be especially difficult during spring surveys. An exploitation rate index is estimated for ADs 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.

Ecosystem Change

Prolonged warming up until approximately 2010-12 in waters surrounding most of NL promoted a general loss of productivity in cold water crustaceans such as Snow Crab and Northern Shrimp (*Pandalus borealis*) and some recovery in pelagic and groundfish species. However, bottom conditions have since cooled. The extent of community reorganizations resulting from such instability and change is unknown. Ultimately, if temperatures continue to warm as expected under greenhouse gas scenarios, the prognosis for Snow Crab would be poor. However, rates, extent, and even direction of future climate and community changes in the marine shelf ecosystem are highly uncertain. Moreover, it is uncertain the extent to which current low levels of zooplankton in the ecosystem will resonate through the food-web to affect future Snow Crab success.

CONCLUSIONS AND ADVICE

Assessment Division 2HJ

The exploitable biomass has consisted largely of incoming recruits for the past fifteen years with few residual crab in the population. This suggests high mortality of large adult male crab. The exploitation rate index has been high throughout most of the time series relative to other ADs within NL as well as other fished snow crab stocks globally. Status quo removals in 2019 would maintain the exploitation rate index at a high level. A lower exploitation rate would be required to promote recovery of the exploitable biomass. Following the proposed PA the stock status would be projected to be in the provisional cautious zone in 2019 with no recovery toward the provisional healthy zone.

Assessment Division 3K

The exploitable biomass has consisted largely of incoming recruits for the past five years with few residual crab in the population. This suggests high mortality of large adult male crab. Total mortality in exploitable crab has remained at its highest level during the past four years. The exploitation rate index has been high throughout most of the time series relative to other ADs within NL as well as other fished snow crab stocks globally. Status quo removals in 2019 would leave the exploitation rate index unchanged near the time-series average. A lower exploitation rate would be required to promote recovery of the exploitable biomass. Following the proposed PA the stock status would be projected to be in the provisional cautious zone in 2019 with potential to fall into the critical zone.

Assessment Division 3L Inshore

The exploitable biomass is severely depleted. In particular, CMAs 6B and 6C had total catch rates of approximately 1 kg/trap in the 2018 surveys. The exploitation rate index has increased since 2013 and has been at its highest level in the past two years. Status quo removals would maintain the exploitation rate index at a time series high in 2019. There are biological concerns surrounding excessive removals of large males in some areas in recent years. Further, a high incidence of soft-shell crab in the fishery in CMAs 6A and 9A is anticipated under a continuation of high exploitation. Following the proposed PA, the stock status would be in the critical zone in 2019. Lower exploitation rates would be required to prevent long-term serious harm to the resource and promote recovery in both severely depleted areas as well as those where recruitment potential is relatively strong.

Assessment Division 3LNO Offshore

The exploitable biomass has undergone modest recovery in the past two years but remains low relative to the time series. This has been associated with a decrease in exploitation rate and a reduced level of total mortality in exploitable crab. Status quo removals would decrease the exploitation rate index to near the long-term average in 2019. This is a level near which productive fisheries have historically occurred. However, following the proposed PA the stock status would be in the provisional cautious zone in 2019 and reductions in the exploitation rate may be required to promote a redirection of stock trajectory indices toward the provisional healthy zone.

Assessment Division 3Ps

The two-year average exploitable biomass index increased by a factor of four in 2019. This was associated with a reduction of the exploitation rate index to a time-series low in 2018. Total mortality in exploitable males is currently low and the residual biomass appears strong. Status quo landings would result in the exploitation rate index remaining near a time series low in 2019. Following the proposed PA, the stock status would be in the provisional cautious zone in 2019 with a steep trajectory toward the healthy zone. Most indications suggest that removals could be increased in 2019 with little risk of detrimental impacts to the resource.

Assessment Divisions 4R3Pn

The exploitable biomass is severely depleted, with few residual crab in the population. The exploitable biomass has been at a time series low in the past two years despite a decline of the exploitation rate index to below the long-term average in 2019. Status quo removals would render the exploitation rate index unchanged in 2019. A high incidence of soft-shell crab in the fishery in CMAs 12EF is anticipated under high exploitation. A lower exploitation rate in 2019 would be required to promote recovery of the resource.

OTHER CONSIDERATIONS

Bitter Crab Disease

Bitter Crab Disease (BCD) is fatal to crab and predominately occurs in new-shelled crab of both sexes. It 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 is most typical in small crab (Mullowney et al. 2011) although BCD has been unusually high in large males in AD 3K in the past three years.

Reproductive Biology

The percentage of mature females carrying full clutches of viable eggs has generally remained high throughout the time series wherever measured but localized declines in heavily fished areas have been observed in recent years. Fishery-induced mortality on mature males (including undersized males) could adversely affect insemination of females in the presence of high exploitation. A current study is investigating for the presence of sperm limitation in females associated with high exploitation rates of males in some areas in recent years.

Management Considerations

Conservation measures that exclude females and males smaller than 95 mm CW, including a portion of the adult (large-clawed) males, from the fishery are aimed to protect reproductive potential. Nevertheless, it remains unclear how the persistence of a severely depleted exploitable biomass may impact reproductive potential (e.g., sperm limitation, and reduced guarding time).

Fishery-induced mortality on non-exploitable crab 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 spatio-temporally variable observer coverage introduces high uncertainty in interpreting indices of biomass, recruitment, and mortality. Measures should be taken to ensure representative observer coverage 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. It closes localized areas (70 nM^2 grids in the offshore and 18 nM^2 in inshore areas of 3L and 3K, 3Ps, and 4R3Pn) for the remainder of the season when a threshold level of 20% (15% in some areas) of the legal-sized catch is soft-shelled. 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. An analysis at the present assessment showed that a high proportion of cells had no ability to invoke closure due to complete absence of observer coverage in a given year. This was further compounded by low sample sizes prohibiting adherence to closure thresholds when observer coverage was present. These shortcomings undermine the intent of the protocol. Measures should be taken to ensure adequate and representative observer coverage as well as adjust sample size thresholds to better quantify prevalence of soft-shelled crab in the fishery and therefore afford better protection to recruitment.

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 in AD 3Ps in 2015 and 2016 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 within other ADs such as 4R3Pn. In the future, under the scenario of expected low exploitable biomass in many ADs, there are concerns the integrity of this survey could further deteriorate. Finally, survey coverage has been poor in AD 2HJ in the past two years and issues were exacerbated by a failure of sea-going personnel to follow established sampling protocols. This survey is of great benefit to the stock assessment and deployment and sampling schemes should be strictly followed moving forward.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Allister Russell	Harvester
Andy Careen	Harvester
Ben Davis	DFO Science NL Region
Brett Favaro	Marine Institute
Brian Careen	Harvester
Brittany Beauchamp	DFO Science National Capital Region
Calvin Young	Harvester
Connie Korchoski	DFO Centre for Science Advice NL Region
Craig Taylor	Torngat Secretariat
Darrell Mullowney	DFO Science NL Region
Darren Sullivan	DFO Science NL Region
David Belanger	DFO Science NL Region

Name	Affiliation
David Small	DFO Resource Management Grand Falls Windsor
Derek Butler	Association of Seafood Producers
Derek Osborne	DFO Science NL Region
Don Stansbury	DFO Science NL Region, Emeritus
Dwight Petten	Harvester
Elizabeth Coughlan	DFO Science NL Region
Ellen Careen	DFO Resource Management NL Region
Eric Pedersen	DFO Science NL Region
Erika Parrill	DFO Centre for Science Advice NL Region
Erin Carruthers	FFAW
Frederic Cyr	DFO Science NL Region
Geoff Evans	DFO Science NL Region, Emeritus
Glen Newbury	Harvester
Hannah Murphy	DFO Science NL Region
Jenn Duff	DFO Communications NL Region
Julia Pantin	DFO Science NL Region
Katherine Skanes	DFO Science NL Region
Keith Watts	Torngat Fish Producers Corporation
Kevin Guest	DFO Communications NL Region
Krista Baker	DFO Science NL Region
Kristin Loughlin	DFO Science NL Region
Laura Wheeland	DFO Science NL Region
Laurie Hawkins	DFO Resource Management Corner Brook
Martin Henri	DFO Resource Management NL Region
Michael Hurley	DFO Science NL Region
Miranda McGrath	FFAW
Nancy Pond	Fisheries and Land Resources, Govt NL
Nelson Bussey	Harvester
Nicholas Le Corre	DFO Science NL Region
Rob Coombs	Nunatukavut Community Council
Sanaollah Zabihi-Seissan	DFO Science NL Region
Stephanie Boudreau	DFO Science Gulf Region
Tony Doyle	Harvester
Trevor Jones	Harvester
Wayne King	DFO Resource Management Goose Bay
William Coffey	DFO Science NL Region

SOURCES OF INFORMATION

This Science Advisory Report is from the February 19-21, 2019 2HJ3KLNOP4R 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.

Chabot, D., Sainte-Marie, B., Briand, K., and J.M. Hanson. 2008. Atlantic cod and Snow Crab predator-prey size relationship in the Gulf of St. Lawrence, Canada. Mar. Ecol. Prog. Ser. 363: 227-240.

Colbourne, E., Craig, J., Fitzpatrick, C., Senciall, D., Stead, P., and W. Bailey. 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.

Dawe, E.G., Parsons, D.G., and E.B. Colbourne. 2008. Relationships of sea ice extent and bottom water temperature with abundance of Snow Crab (*Chionoecetes opilio*) on the Newfoundland - Labrador Shelf. ICES CM 2008:B02, 18 p.

Dawe, E.G., Mullowney, D.R., Moriyasu, M., and E. Wade. 2012. Effects of temperature on size-at-terminal molt and molting frequency in Snow Crab (*Chionoecetes opilio*) from two Canadian Atlantic ecosystems. Mar. Ecol. Prog. Ser. 469: 279-296.

Evans, G.T., Parsons, D.G., Veitch, P.J., and D.C. Orr. 2000. A local-influence method of estimating biomass from trawl surveys, with monte carlo confidence intervals. J. Northw. Atl. Fish. Sci. Vol. 27: 133-138.

Foyle, T.P., O'Dor, R.K., and R.W. Elner. 1989. Energetically defining the thermal limits of the Snow Crab. J. Exp. Biol. 145: 371-393.

Marcello, L.A., Mueter, F.J., Dawe, E.G., and M. Moriyasu. 2012. Effects of temperature and gadid predation on Snow Crab recruitment: Comparisons between the Bering Sea and Atlantic Canada. Mar. Ecol. Prog. Ser. 469: 249-261.

Mullowney, D.R., Dawe, E.G., Morado, J.F., and R.J. Cawthorn. 2011. Sources of variability prevalence and distribution of bitter crab disease in Snow Crab (*Chionoecetes opilio*) along the Northeast Coast of Newfoundland. ICES J. Mar. Sci. 68: 463-471.

Mullowney, D.R., Dawe, E.G., Colbourne, E.B., and G.A. Rose. 2014. A review of factors contributing to the decline of Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*). Rev. Fish. Biol. Fish. 24: 639-657.

Mullowney, D., Baker, K., Pedersen, E., and D. Osborne. 2018. Basis for a precautionary approach and decision making framework for the Newfoundland and Labrador snow crab (*Chionoecetes opilio*) fishery. DFO Can. Advis. Sec. Res. Doc. 2018/054. IV + 66p.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Newfoundland and Labrador Region
Fisheries and Oceans Canada
PO Box 5667
St. John’s, NL, A1C 5X1

Telephone: 709-772-8892
E-Mail: DFONLCentreforScienceAdvice@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2019. Assessment of Newfoundland and Labrador (Divisions 2HJ3KLNOP4R) Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/041.

Aussi disponible en français :

MPO. 2019. Évaluation du crabe des neiges de Terre-Neuve-et-Labrador (Divisions 2HJ3KLNOP4R). Secr. can. de consult. sci. du MPO. Avis sci. 2019/041.