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Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2018/024

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

Snow Crab (Chionoecetes opilio)

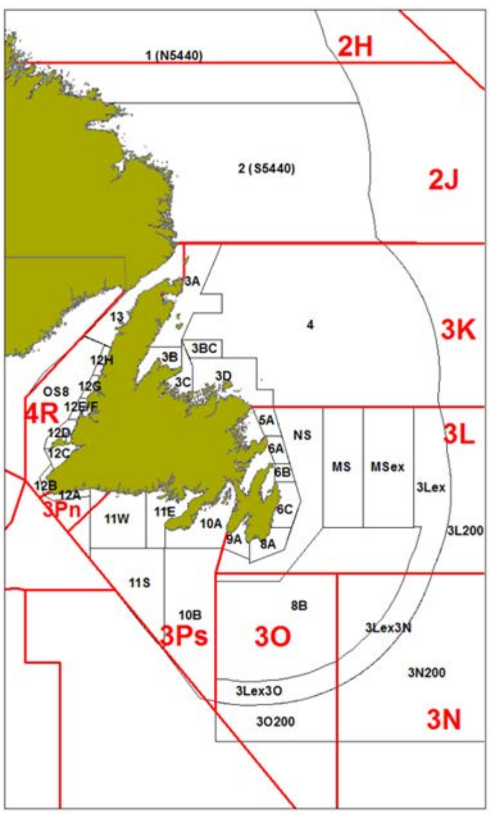

Figure 1: NAFO Divisions (red lines), Newfoundland and Labrador Snow Crab Management Areas (black lines).

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.*

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 toward ensuring the reproductive potential of the resource remains protected.

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 2,500 license holders across several vessel fleets under enterprise allocation in 2018. All fleets have designated trap limits, quotas, trip limits, fishing areas, and season dates. A vessel monitoring system (VMS) was fully implemented in the offshore fleets in 2004, which comprises the majority of landings.

Stock status is assessed annually within each Northwest Atlantic Fisheries Organization (NAFO) Division. Resource status is evaluated based on trends in exploitable biomass indices, recruitment prospects, fishery catch per unit of effort (CPUE), and mortality indices. Data are derived from multi-species bottom trawl surveys in Divs. 2HJ3KLNOP, an industry-Fisheries and Oceans Canada (DFO) collaborative trap survey in all divisions, DFO inshore trap surveys in Divs. 3KLPs, fishery data from logbooks, observer catch-effort data, as well as biological sampling from multiple sources.

This Science Advisory Report is from the February 20–21, 2018 Newfoundland and Labrador Snow Crab Assessment. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada Science Advisory Schedule] as they become available.

SUMMARY

Divisions 2HJ3KLNOP4R

- **Landings** most recently peaked at 53,500 t in 2009 and have since gradually declined to 34,000 t in 2017, their lowest level in two decades. Overall **effort** has remained at four to five million trap hauls in each of the past six years.
- Overall catch per unit of effort (**CPUE)** was at a two-decade low in 2017 with most divisions at or near historical lows.
- Despite a modest increase in 2017, the trawl survey **exploitable biomass** index has remained at its lowest observed level for the past three years. Meanwhile, the trap survey index has been at its lowest observed level in the past two years.
- Overall **recruitment** into the exploitable biomass has been very low in recent years and survey data suggest **recruitment** available to the 2018 fishery will remain low in most divisions. However, survey and environmental data suggest modest increases in **recruitment** could occur in some divisions over the next two to four years.
- **Total mortality** in exploitable crab has increased to be at or near time-series highs in recent years in all divisions.
- Status quo removals would maintain two-year average **exploitation rate indices** near or above long-term median levels in all divisions. New time-series highs would occur in Divisions 3L Inshore, 3LNO Offshore, and 4R3Pn.
- The relatively low level of **residual biomass** (old-shelled adult crab) at all sizes in all divisions in recent years is concerning given it is generally associated with low CPUE and high levels of discards in the fishery. Increasing **recruitment** potential in some divisions, coupled with a low **residual biomass** suggests that wastage of soft-shelled pre-recruits could become more problematic in the fishery in the next few years.

Divisions 2HJ

- **Landings** have remained at 1,700 t for the past four years while **effort** has remained at its lowest level in two decades.
- **CPUE** has remained near the decadal average in recent years, reflecting trends throughout the division.
- The **exploitable biomass** index has changed little during the past decade with the exception of a 2014 spike.
- **Recruitment** into the **exploitable biomass** has changed little during the past decade with the exception of a 2014 spike. The 2017 trawl and trap surveys suggest **recruitment** will remain unchanged in 2018.
- The **exploitable biomass** has consisted largely of incoming **recruits** for the past six years (75%), with few old-shelled crab. This suggests high **mortality** of large adult male crab.
- **Total mortality** in exploitable crab has been at or near its highest level in recent years. The **exploitation rate index** has been above the long-term average for the past two years. Status quo removals in 2018 would maintain the two-year average **exploitation rate index** at a relatively high level.

Division 3K

- **Landings** declined by 66% since 2009 to a time-series low of 5,450 t in 2017. **Effort** has been maintained near a two-decade low for the past five years.
- **CPUE** has been low for the past seven years reflecting trends in most management areas.
- The post-season trawl survey **exploitable biomass index** increased in 2017 from a historic low in 2015-16. Although the post-season trap survey(s) index has remained near a historical low for the past three years slight improvements were seen in some nearshore management areas in 2017.
- **Recruitment** increased from time-series lows in both the post-season trawl and trap survey(s) from 2016 to 2017. The 2017 trawl and trap surveys suggest **recruitment** should increase in 2018.
- The **exploitable biomass** has consisted largely of incoming **recruits** throughout the time-series (50-75%), with few old-shelled crab. This suggests high mortality of large adult male crab.
- **Total mortality** in exploitable crab has been at or near its highest level in recent years. The **exploitation rate index** has been at a decadal high during the past two years. Status quo removals in 2018 would decrease the **exploitation rate**, with the two year average index being below the time-series median level.

Divisions 3LNO Offshore

- **Landings** declined by 26% from 2016 to 18,050 t in 2017, the lowest level in two decades. **Effort** expanded rapidly from 1992 to the mid-2000s and has oscillated at a similar level since.
- Overall **CPUE** most recently peaked near a time-series high in 2013 and has since declined by 41% to its lowest level since 1992. Substantial declines have occurred in all management areas in recent years, although catch rates remain relatively high in the central portions of the division.
- The **exploitable biomass index** remains at or near time-series lows in both the trawl and trap surveys.
- Overall **recruitment** into the **exploitable biomass** has been at or near time-series lows in both the trawl and trap surveys in the past two years. This reflects low levels throughout all management areas. No major increases in the **exploitable biomass** are expected in 2018.
- **Total mortality** in exploitable crab has been steadily increasing since 2009 to be at or near its highest level in most recent years. The **exploitation rate index** increased by a factor of five from 2014 to 2017. Status quo removals in 2018 would maintain the two year average **exploitation rate index** at a historic high.

Division 3L Inshore

- **Landings** declined by 29% from a historical high in 2015 to 6,000 t in 2017. **Effort** has nearly doubled since 2013 to a historical high in 2017.
- Overall **CPUE** has declined by 56% since 2013 to its lowest level in 28 years. There have been strong declines throughout the division in recent years.
- The post season trap survey **exploitable biomass index** has declined by 73% since 2012, reaching a time-series low in 2017. The 40% overall change from 2016 to 2017 reflects declines to time-series lows in all management areas.
- Overall **recruitment** has steadily declined for the past three years to a time-series low in 2017. **Recruitment** indices from Fisheries and Oceans Canada (DFO) and collaborative post-season (CPS) trap surveys in all management areas were at or near their lowest levels in 2017. No major improvements in biomass available to the fishery are expected in the short-term.
- The overall trap survey-based **exploitation rate index** has increased from 2013 to a time-series high in 2017. Maintaining status quo removals would increase the two-year average **exploitation rate index** to an exceptionally high level in 2018, with all management areas reaching or remaining near time-series highs.
- The scenario of a depleted **exploitable biomass** coupled with low **recruitment** prospects and high **exploitation rate indices** suggests minimal potential for improvements in the short term.

Subdivision 3Ps

- **Landings** declined from a recent peak of 6,700 t in 2011 to a time-series low of 1,200 t during the past two years. **Effort** has declined by 44% since 2014 to be near its lowest level in two decades. The TAC has not been taken in eight years.
- **CPUE** has steadily declined since 2009 to a record low in the past two years, reflecting precipitous declines throughout the major fishing areas of the Subdivision in recent years.
- The in-season trawl survey **exploitable biomass** index was at a time-series low in 2016 but improved slightly in 2017. However, the post-season trap survey index suggests considerable improvements in the **exploitable biomass** throughout the major fishing grounds.
- Overall **recruitment** into the **exploitable biomass** has been at its lowest observed level in recent years but increased slightly in 2017.
- Prospects for **recruitment** into the **exploitable biomass** in 2018 have improved from the lowest levels experienced in recent years. Survey data of pre-recruit abundance suggest improving prospects for the next few years.
- In 2017, **total mortality** in exploitable crab was high but the **exploitation rate index** declined sharply to a relatively low level. Assuming the **exploitable biomass** remains at the current level, status quo removals would result in an **exploitation rate index** near the long-term median in 2018.
- Discards comprised half the catch in the past two years. This is concerning as fishing under elevated **mortality** levels on small and pre-recruit crab could impair reproductive capacity or yield from forthcoming **recruitment**.

Divisions 4R3Pn

- **Landings** have steadily declined since a recent peak in 2013. Meanwhile, **effort** has remained at a low level.
- **CPUE** has declined since 2013 to below the long-term median, reflecting trends throughout all major fishing areas.
- The trap survey **exploitable biomass index** most recently peaked in 2012 and has since declined to a time-series low in 2017, reflecting trends in all surveyed areas.
- **Recruitment** into the **exploitable biomass** has been very low for the past four years. Survey data from 2017 suggest no improvements are expected in 2018.
- The overall **exploitation rate index** has increased since 2013, reflecting trends in all surveyed areas. Status quo removals would elevate the two-year average **exploitation rate index** to an exceptionally high level in 2018, with all surveyed management areas reaching new time-series highs.
- The scenario of a low **exploitable biomass** and **CPUE**, coupled with an approaching pulse of pre-recruit crab in crab management area (CMA) 12EF suggests that excessive fishing in 2018 could be detrimental to yield in subsequent years due to associated high soft-shell mortality.

Ecosystem Perspective

- The snow crab **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.
- Ecosystem conditions in the Newfoundland and Labrador (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.
- **Predation** on snow crab has 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.

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 multiple times each year 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 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) that likely enhance their mating ability. 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 about 8-11 years of age, generally earlier in warm areas 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 crab failing to recruit to the fishery. However, the positive effect of cold water on early survival is overall stronger than the negative effect on size-at-terminal molt in regulating biomass.

Adult legal-sized males remain new-shelled throughout the remainder of the year of their terminal molt. They are not considered to contribute to the exploitable biomass until they harden and meat content in their shells becomes high. A recent study showed that following a molt it takes approximately 9-12 months for the meat content to progress to a near-full stage in large male snow crab. Males may live a maximum of about 6-8 years as adults after the terminal molt.

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, while smaller crab are common on harder substrates. Some crab also undertake a migration in late winter or spring for mating and/or molting. Although the dynamics of spring migrations are not fully understood, they are generally from deep to shallow areas. The Snow Crab diet includes 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 soft-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 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 2,500 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. A protocol was initiated in 2004 that results in closure of localized areas when soft-shelled crab exceed 20% of the legal-sized catch. In Divs. 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 69,000 t in 1999, largely due to expansion of the fishery to offshore areas. They decreased by 20% to 55,500 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 declined to 34,000 t in 2017.

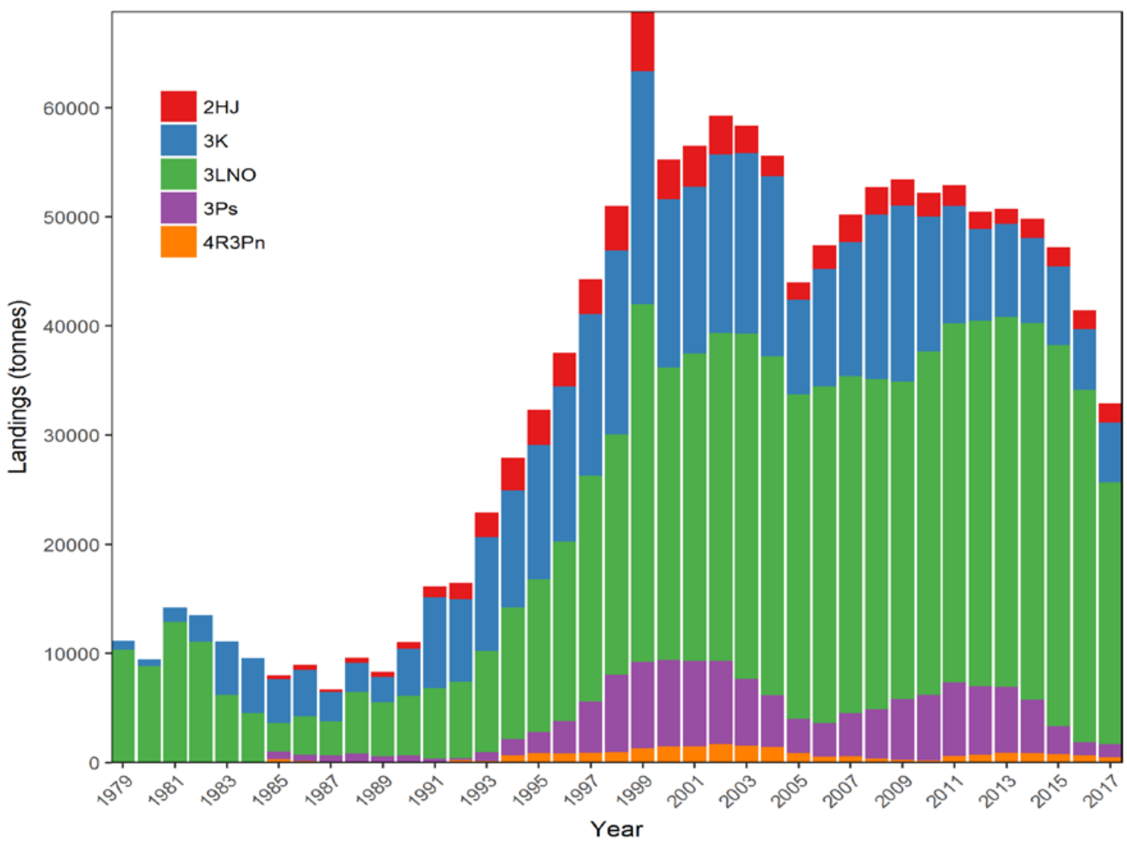

Figure 2: Annual landings by NAFO Division.

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

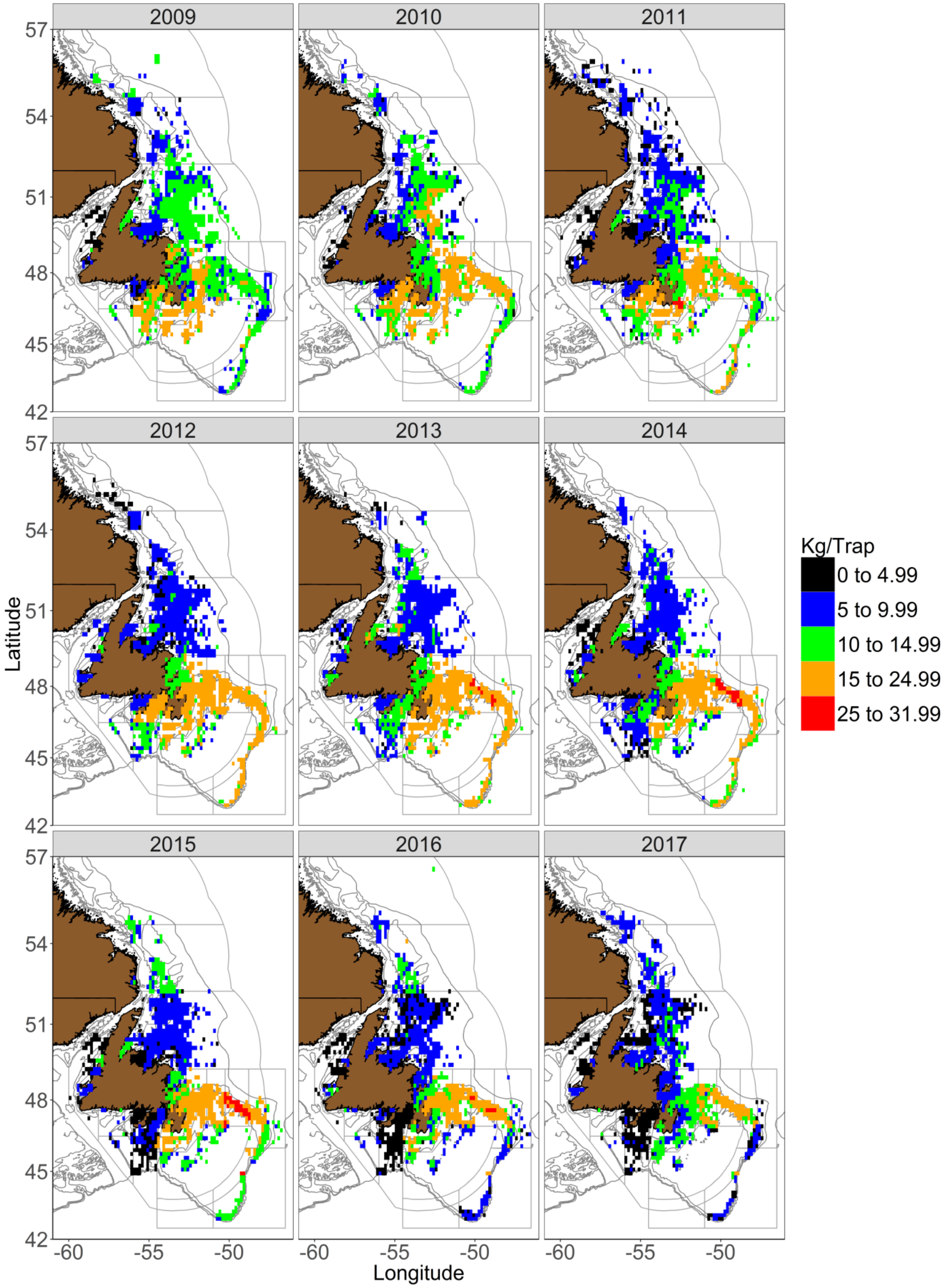

Figure 3: Locations of fishery sets and catch rates (kg/trap) from logbooks (2009-17).

Overall effort has remained at four to five million trap hauls in each of the past six years (Fig. 4).

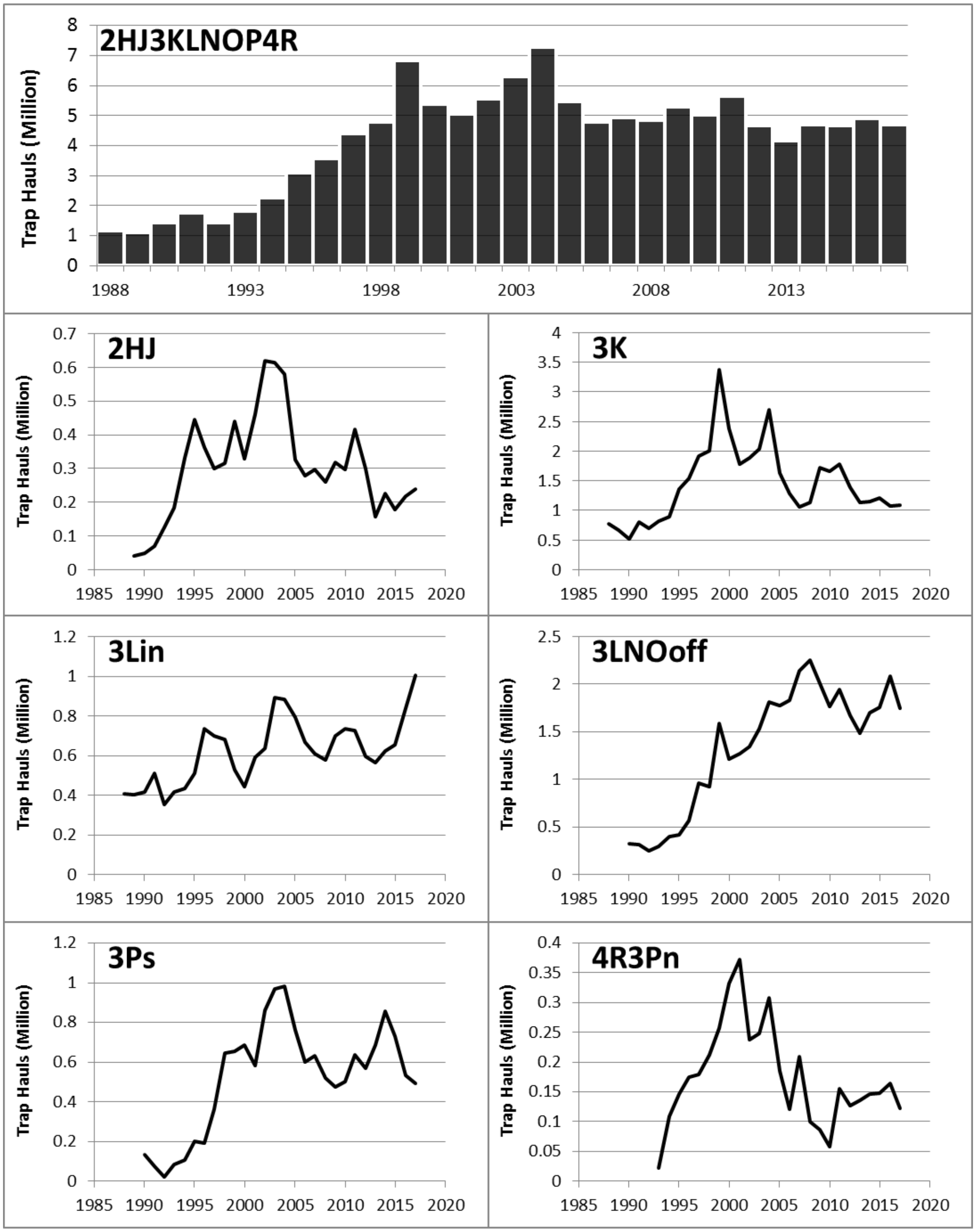

Figure 4: Annual effort overall and by assessment division.

Fishery CPUE is typically highest in Divs. 3LNO, adjacent to the southeast portion of the island of Newfoundland and extending east across the Grand Bank (Fig. 3). Overall, CPUE was at a two-decade low in 2017 (Fig. 5) with most divisions at or near historical lows (Fig. 6).

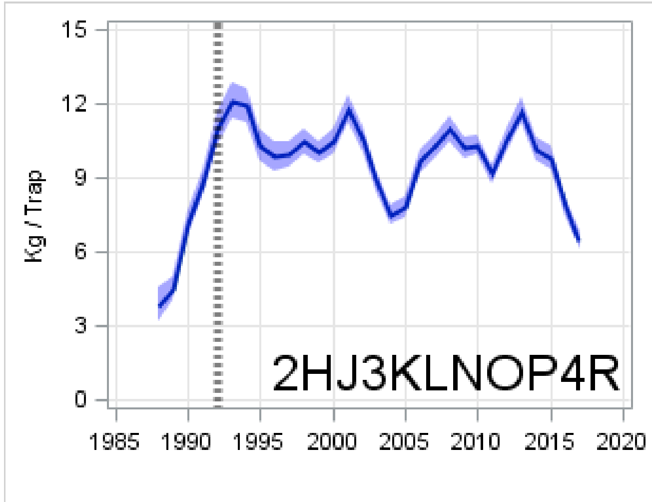

Figure 5: Standardized CPUE (kg/trap). Solid line is predicted CPUE and band is 95% confidence intervals. Vertical dashed line represents the beginning of the cod moratorium.

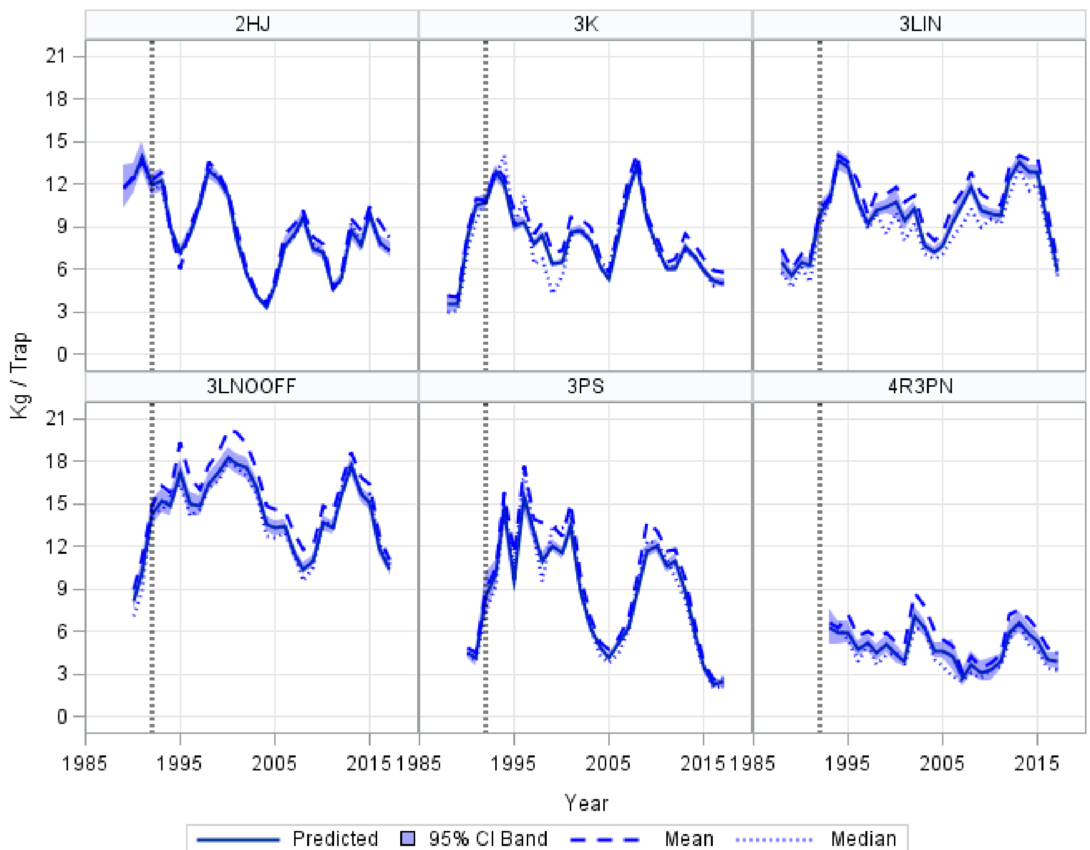

Figure 6: Standardized CPUE (kg/trap) by assessment division. Solid line is predicted CPUE and band is 95% confidence intervals. Vertical dashed line represents the beginning of the cod moratorium.

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; fall Industry-DFO collaborative trap surveys in Divs. 2HJ3KLOP4R; DFO inshore trap surveys in Divs. 3KLPs; fishery data from logbooks; and observer catch-effort data.

Bottom temperature data from multi-species trawl surveys were used to derive thermal habitat indices (<2°C bottom temperatures) toward inferring mid- and long-term recruitment prospects.

The resource is assessed at the NAFO Division level as the crab management areas are too small to conform to biologically meaningful units. 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 of synchrony among broad-scale resource trends and management area boundaries extending over NAFO division lines. 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 in part to conform to management boundaries.

Generally, more data are available for offshore than inshore areas in most divisions. Trawl survey data are often only available 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 compared to inshore 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 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 in the year 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 Div. 3L Inshore and Divs. 4R3Pn, no trawl survey is conducted, so the CPS and DFO trap survey(s) exploitable biomass index is used. The DFO surveys have occurred for several decades while the CPS survey was initiated in 2003. These surveys provide the most recent data available for the annual assessment in these divisions.

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 are also 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 survey, raw Ogmap exploitable and pre-recruit 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 up by a common Q calculated as the ratio of annual trawl survey biomass to Delury logbook biomass in each division. 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 adults (immediate pre-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 recruit to 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 (about 12-30 mm CW) may indicate recruitment prospects approximately 6-8 years later, depending on NAFO division. Longer-term recruitment prospects are inferred from the thermal habitat index, with the relationship between extent of cold bottom water and CPUE being positive and operating at lags of about 6-10 years depending on division (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 crab. These core stations were identified as stations surveyed in seven of the last 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 three period moving average of stage-specific biomass indices of exploitable crab with the biomass of new and old-shelled crab in the preceding survey divided by the biomass of old-shelled crab in the current survey representing survival.

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

Landings most recently peaked at 53,500 t in 2009 and have since gradually declined to 34,000 t in 2017, their lowest level in two decades (Fig. 2).

In Divs. 2HJ, landings have remained at 1,700 t (Fig. 7) for the past four years while effort has remained at its lowest level in two decades (Fig. 4). In Div. 3K, landings declined by 66% since 2009 to a time-series low of 5,450 t in 2017. In Divs. 3LNO Offshore, landings declined by 26% from 2016 to 18,050 t in 2017, the lowest level in two decades. In Div. 3L Inshore, landings declined by 29% from a historical high in 2015 to 6,000 t in 2017. In Subdiv. 3Ps, landings declined from a recent peak of 6,700 t in 2011 to a time-series low of 1,200 t during the past two years, while in Divs. 4R3Pn, landings have steadily declined since a recent peak in 2013.

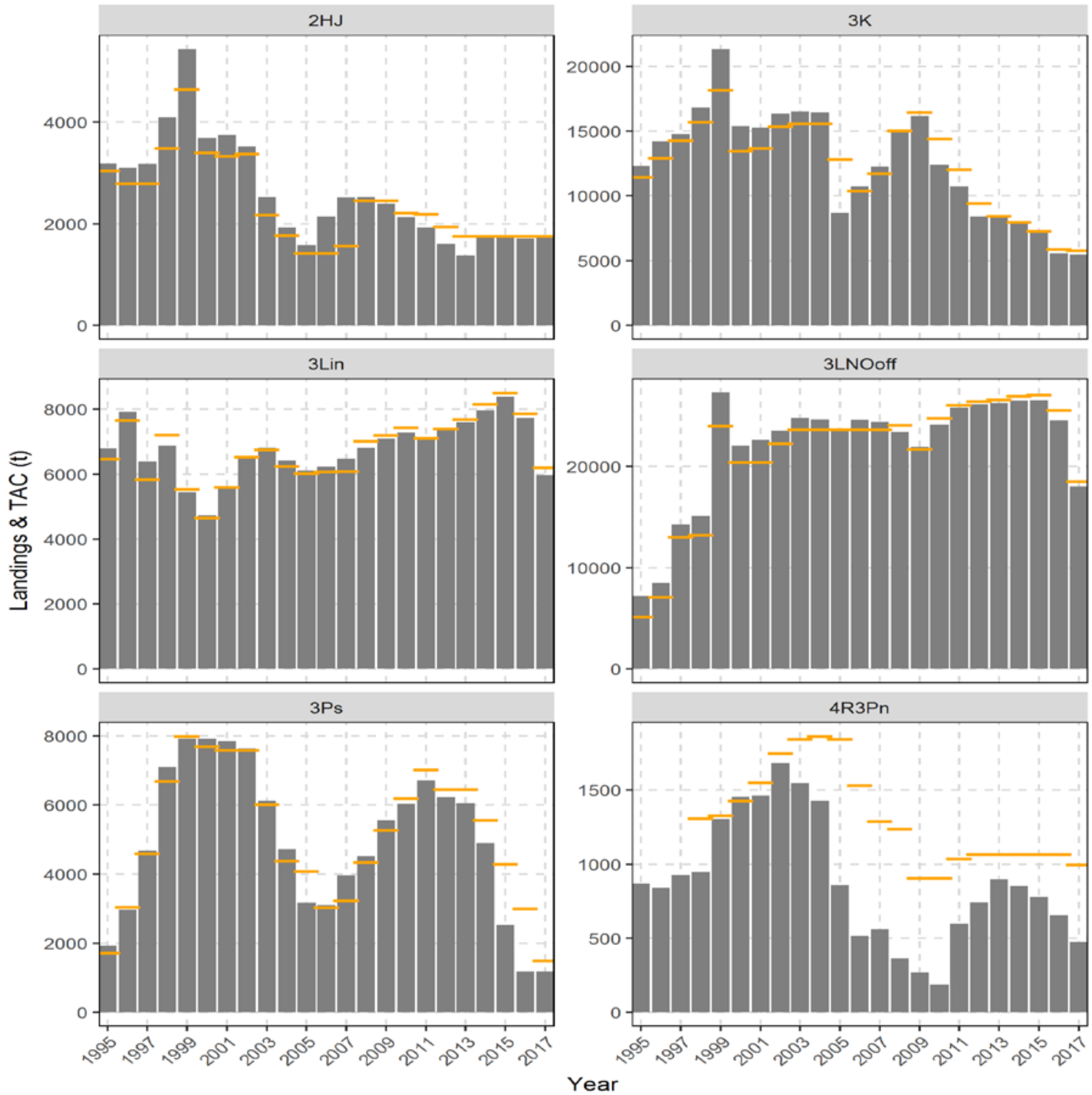

Figure 7: Annual landings (bars) and TAC (yellow lines) by assessment division.

Effort

Effort has remained at four to five million trap hauls in each of the past six years and has been broadly distributed in recent years (Figs. 3, 4).

In Divs. 2HJ, effort has remained at its lowest level in two decades (Fig. 4). In Div. 3K, it has been maintained near a two-decade low for the past five years. In Divs. 3LNO Offshore, effort expanded rapidly from 1992 to the mid-2000s and has oscillated at a similar level since then. In Div. 3L Inshore effort nearly doubled since 2013 to a historical high in 2017. In Subdiv. 3Ps, effort has declined by 44% since 2014 to be near its lowest level in two decades, and in Divs. 4R3Pn, effort has remained at a relatively low level (~ 125,000-160,000 traps) in recent years.

CPUE

Overall CPUE was at a two-decade low in 2017 (Fig. 5) with most divisions at or near historical lows (Fig. 6). In Divs. 2HJ, CPUE has remained near the decadal average in recent years, reflecting trends throughout the division. In Div. 3K, it has been low for the past seven years reflecting trends in most management areas. In Div. 3L Inshore, CPUE has declined by 56% since 2013 to its lowest level in 28 years. This reflects strong declines throughout the division in recent years. In Divs. 3LNO Offshore, CPUE most recently peaked near a time-series high in 2013 and has since declined by 41% to its lowest level since 1992. Substantial declines have occurred in all management areas in recent years, although catch rates remain relatively high in the central portions of the division. In Subdiv. 3Ps, CPUE has steadily declined since 2009 to a record low in the past two years, reflecting precipitous declines throughout the major fishing areas of the Subdivision in recent years. In Divs. 4R3Pn, CPUE has declined since 2013 to below the long-term median, reflecting trends throughout all major fishing areas.

Exploitable Biomass

Multi-species trawl surveys indicate that the exploitable biomass was highest at the start of the survey series (1995-98) (Fig. 8). It declined from the late 1990s to 2003 and then varied without trend until 2013. From 2013 to 2016 it declined by 80%. Despite a modest increase in 2017, the exploitable biomass index has remained at its lowest observed level for the past three years.

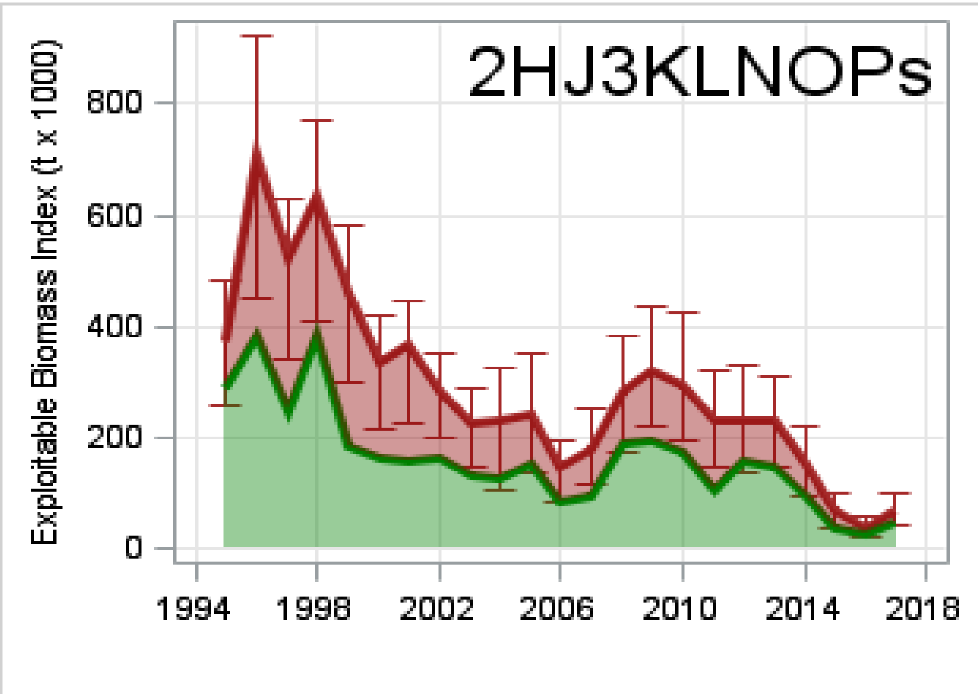

*Figure 8: Trawl survey exploitable biomass indices (t * 1000) by shell condition for Divisions 2HJ3KLNOPs. Soft and new-shell crab represent recruitment (green) and intermediate and old-shell crab represent residual biomass (red).*

Recent trends in exploitable biomass indices from trawl and trap surveys vary between Divisions (Figs. 9, 10). In Divs. 2HJ, the exploitable biomass index has changed little during the past decade with the exception of a 2014 spike. The exploitable biomass has consisted largely of incoming recruits for the past six years (75%), with few old-shelled crab. In Div. 3K, the post-season trawl survey exploitable biomass index increased in 2017 from a historic low in 2015-16.

Although the post-season trap survey(s) index has remained near a historical low for the past three years slight improvements were seen in some nearshore management areas in 2017. The exploitable biomass has consisted largely of incoming recruits throughout the time-series (50-75%), with few old-shelled crab. This suggests high mortality of large adult male crab. In Div. 3L Inshore, the post season trap survey exploitable biomass index has declined by 73% since 2012, reaching a time-series low in 2017. The 40% overall change from 2016 to 2017 reflects declines to time-series lows in all management areas. In Divs. 3LNO Offshore, both the trawl and trap surveys show considerable spatial contraction in high catch rates of exploitable crab in recent years. The exploitable biomass index remains at or near time-series lows in both the trawl and trap surveys. In Subdiv. 3Ps, the in-season trawl survey exploitable biomass index was at a time-series low in 2016, but improved slightly in 2017. However, the post-season trap survey index suggests considerable improvements in the exploitable biomass throughout the major fishing grounds. In Divs. 4R3Pn, the trap survey exploitable biomass index most recently peaked in 2012 and has since declined to a time-series low in 2017, reflecting trends in all surveyed areas.

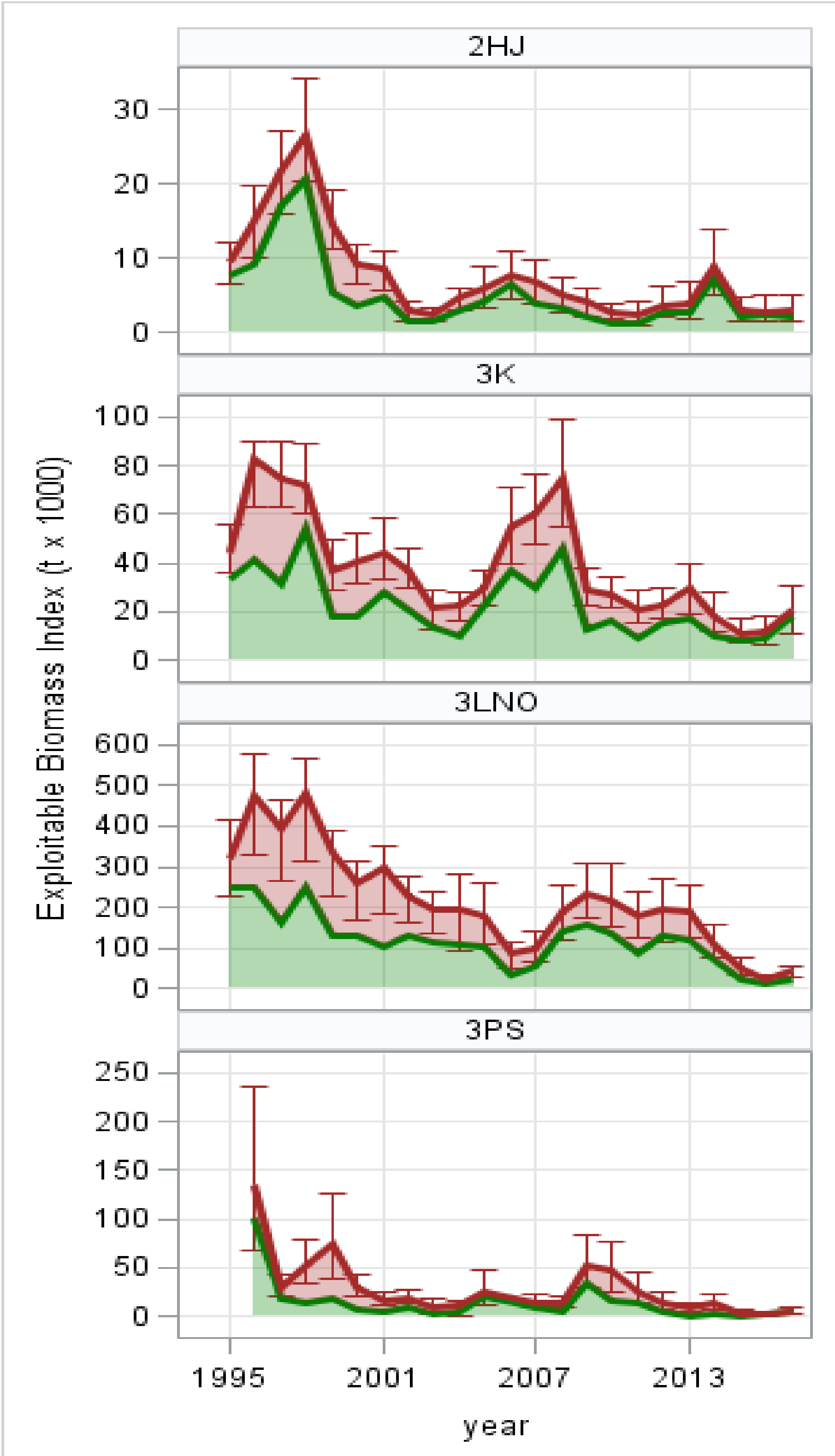

*Figure 9: Trawl survey exploitable biomass indices (t * 1000) by shell condition and assessment division. Soft and new-shell crab represent recruitment (green) and intermediate and old-shell crab represent residual biomass (red).*

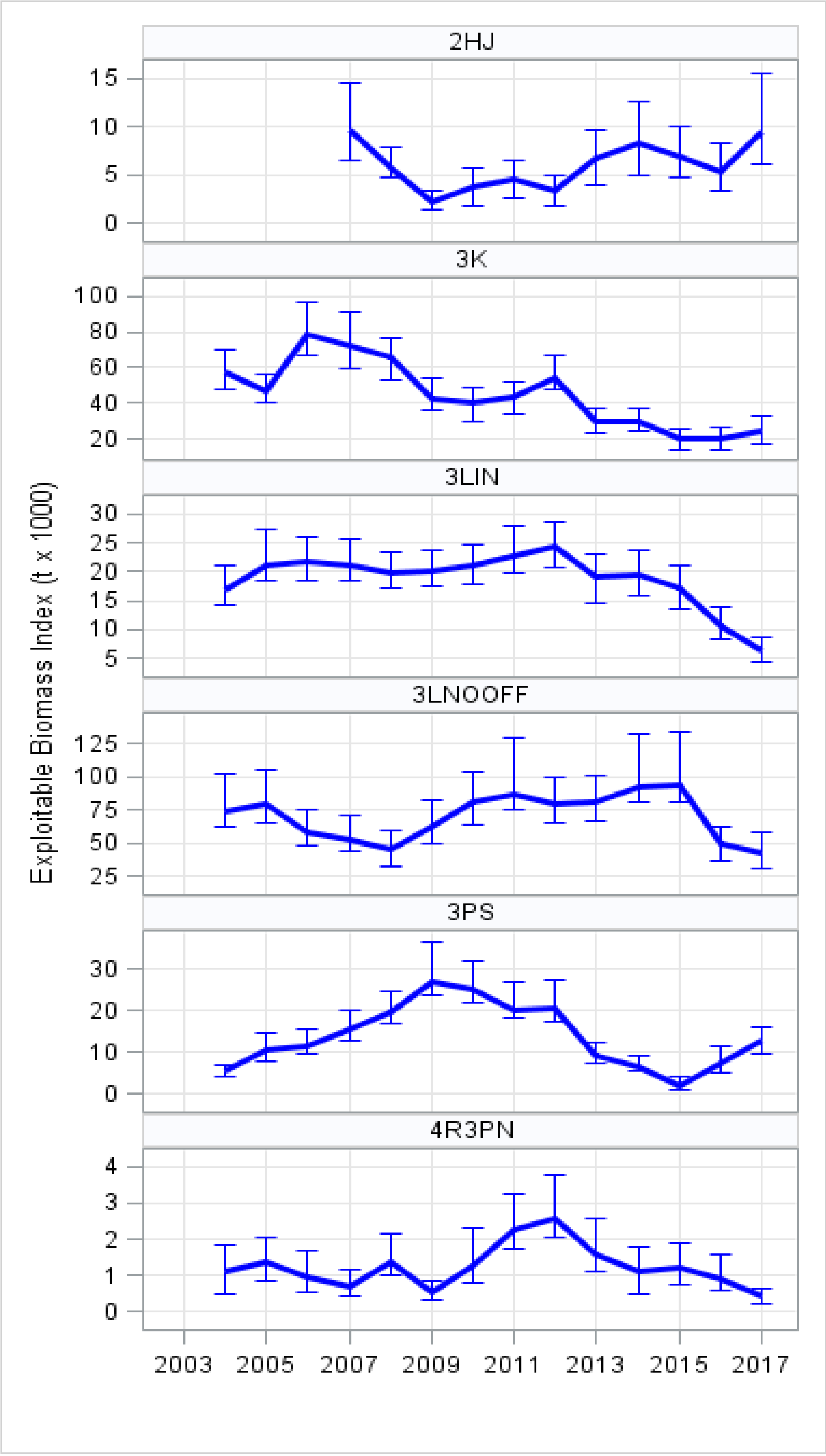

Figure 10: Trap survey exploitable biomass indices by assessment division.

Mortality

Total mortality in exploitable crab has increased to be at or near time-series highs in recent years in all divisions (Fig. 11).

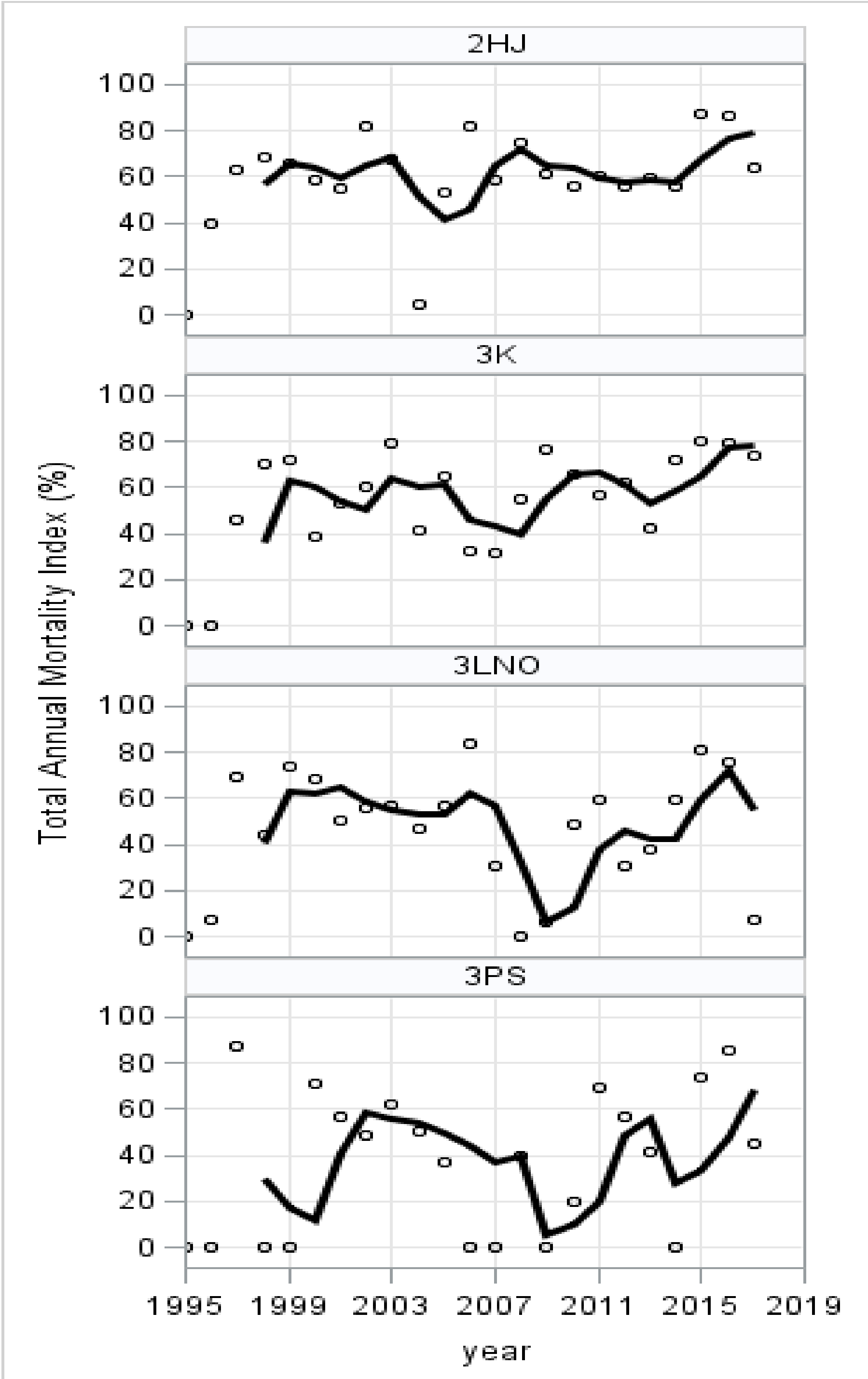

Figure 11: Trends in the annual (circles) and three-year moving average (solid line) total annual mortality index (%) of exploitable crab by assessment division. Note if annual mortality index was <0 it was plotted as 0 for presentation.

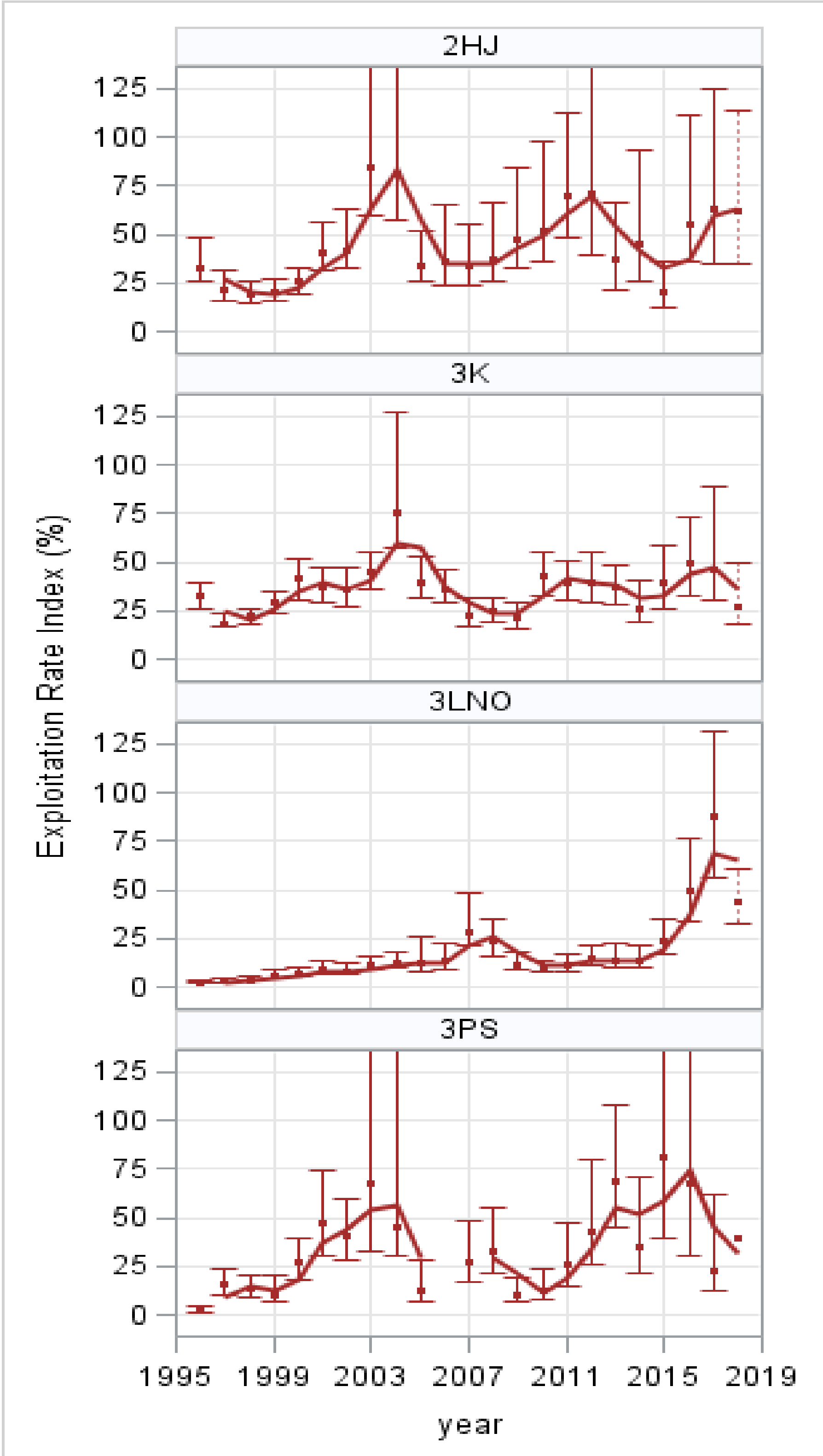

Figure 12: Trends in trawl survey-based exploitation rate indices; annual (circles) and two-year moving average exploitation rate index (solid line) (%) by assessment division; 2018 points depict projected exploitation rate indices under status quo removals in the 2018 fishery.

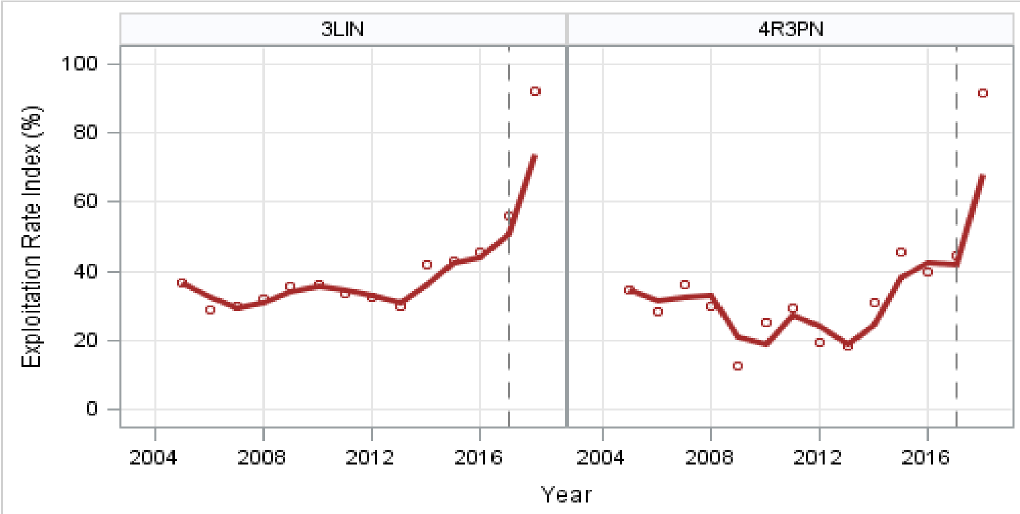

Figure 13: Trends in trap survey-based exploitation rate indices; annual (circles) and two-year moving average exploitation rate index (solid line) (%) by assessment division; 2018 points depict projected exploitation rate indices under status quo removals in the 2018 fishery.

In Divs. 2HJ, the exploitation rate index has been above the long-term average for the past two years (Fig. 12). Status quo removals in 2018 would maintain the two-year average exploitation rate index at a relatively high level. Historically, exploitation rates above 50% in the index in Divs. 2HJ have been associated with high levels of soft-shell discards. In Div. 3K, the exploitation rate index has been at a decadal high during the past two years. Status quo removals in 2018 would decrease the exploitation rate, with the two year average index being below the time-series median level. In Divs. 3LNO Offshore, the exploitation rate index increased by a factor of five from 2014 to 2017. Status quo removals in 2018 would maintain the two-year average exploitation rate index at a historic high. In Subdiv. 3Ps, the exploitation rate index declined sharply to a relatively low level in 2017. Assuming the exploitable biomass remains at the current level, status quo removals would result in an exploitation rate index near the long-term median in 2018.

In Div. 3L Inshore, the trap survey-based exploitation rate index has increased from 2013 to a time-series high in 2017 (Fig. 13). Maintaining status quo removals would increase the two-year average exploitation rate index to an exceptionally high level in 2018, with all management areas reaching or remaining near time-series highs, with several CMAs reaching rates in excess of 80%. In Divs. 4R3Pn, the overall exploitation rate index has increased since 2013, reflecting trends in all surveyed areas. Status quo removals would elevate the two-year average exploitation rate index to an exceptionally high level in 2018, with all surveyed management areas reaching new time-series highs (>60%).

Recruitment and Outlook

Overall recruitment into the exploitable biomass has been very low in recent years (Fig. 8) and survey data suggest recruitment available to the 2018 fishery will remain low in most divisions (Fig. 9). However, survey and environmental data suggest modest increases in recruitment could occur in some divisions over the next two to four years (Figs. 14-16). In Divs. 2HJ, recruitment into the exploitable biomass has changed little during the past decade with the exception of a 2014 spike (Fig. 9). The 2017 trawl and trap surveys suggest recruitment will remain unchanged in 2018. In Div. 3K, recruitment increased from time-series lows in both the post-season trawl and trap survey(s) from 2016 to 2017. The 2017 trawl and trap surveys suggest recruitment should increase in 2018. In Divs. 3LNO Inshore, overall recruitment has steadily declined for the past three years to a time-series low in 2017. Recruitment indices from DFO and CPS trap surveys in all management areas were at or near their lowest levels in 2017. No major improvements in biomass available to the fishery are expected in the short term. In Subdiv. 3Ps, recruitment into the exploitable biomass has been at its lowest observed level in recent years but increased slightly in 2017. Prospects for recruitment into the exploitable biomass in 2018 have improved from the lowest levels experienced in recent years. Survey data of pre-recruit abundance suggest improving prospects for the next few years. Finally, in Divs. 4R3Pn, recruitment into the exploitable biomass has been very low for the past four years. Survey data from 2017 suggest no improvements are expected in 2018.

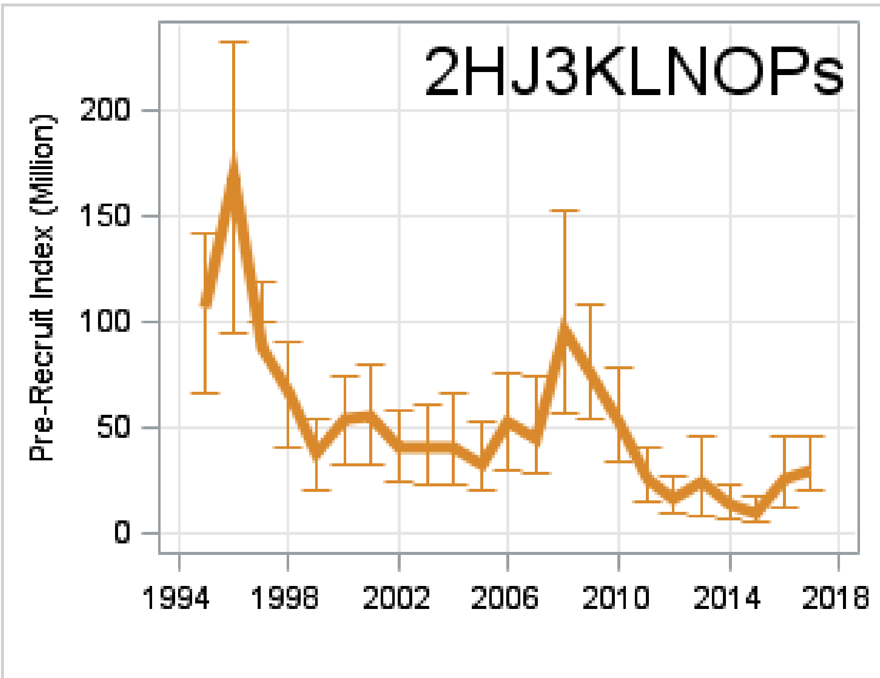

Figure 14: Trawl survey pre-recruit abundance index (million) for Divisions 2HJ3KLNOPs. Pre-recruits defined as 65-95 mm CW adolescent males.

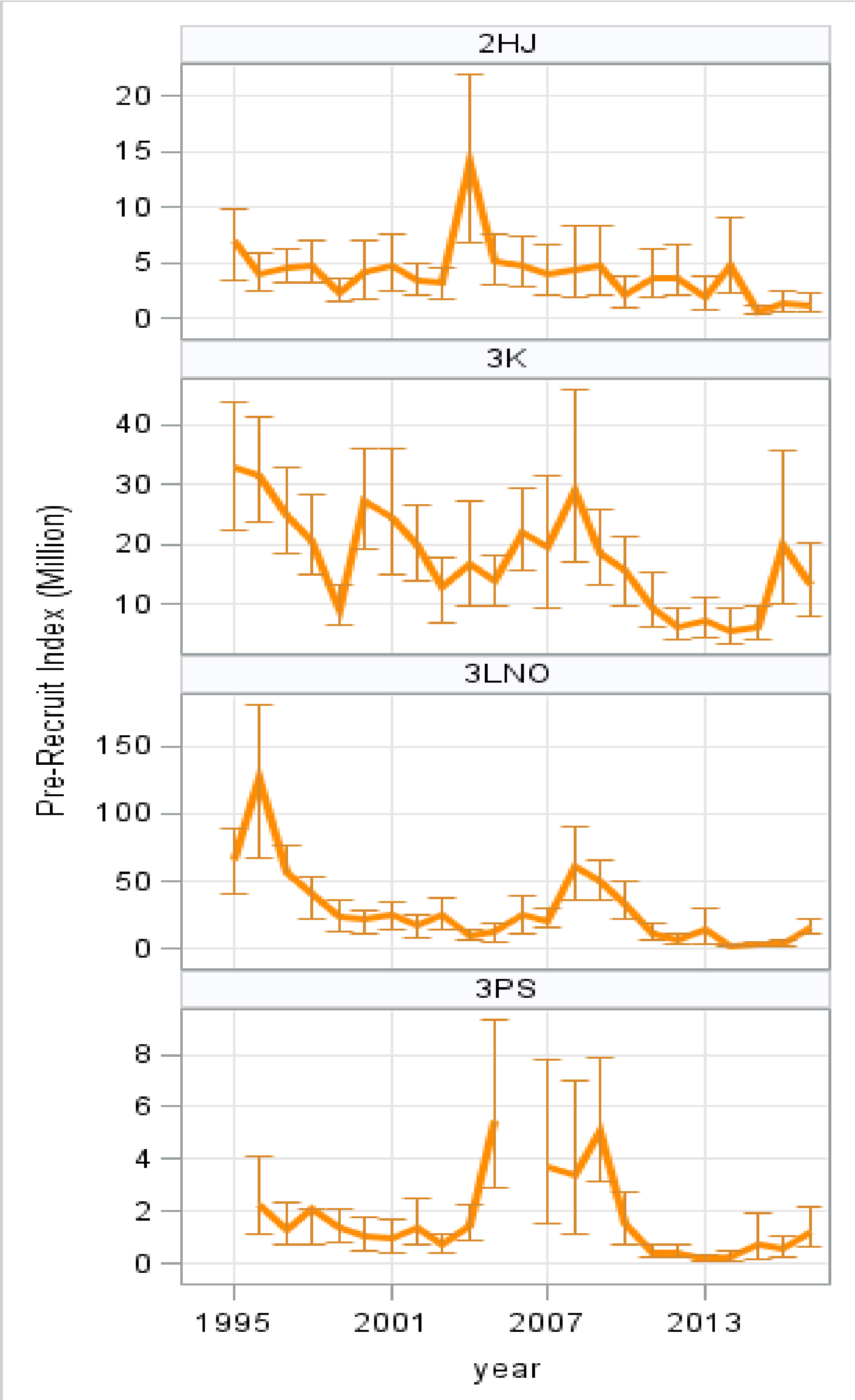

Figure 15: Trawl survey pre-recruit abundance index (million) by assessment division. Pre-recruits defined as 65-95 mm CW adolescent males.

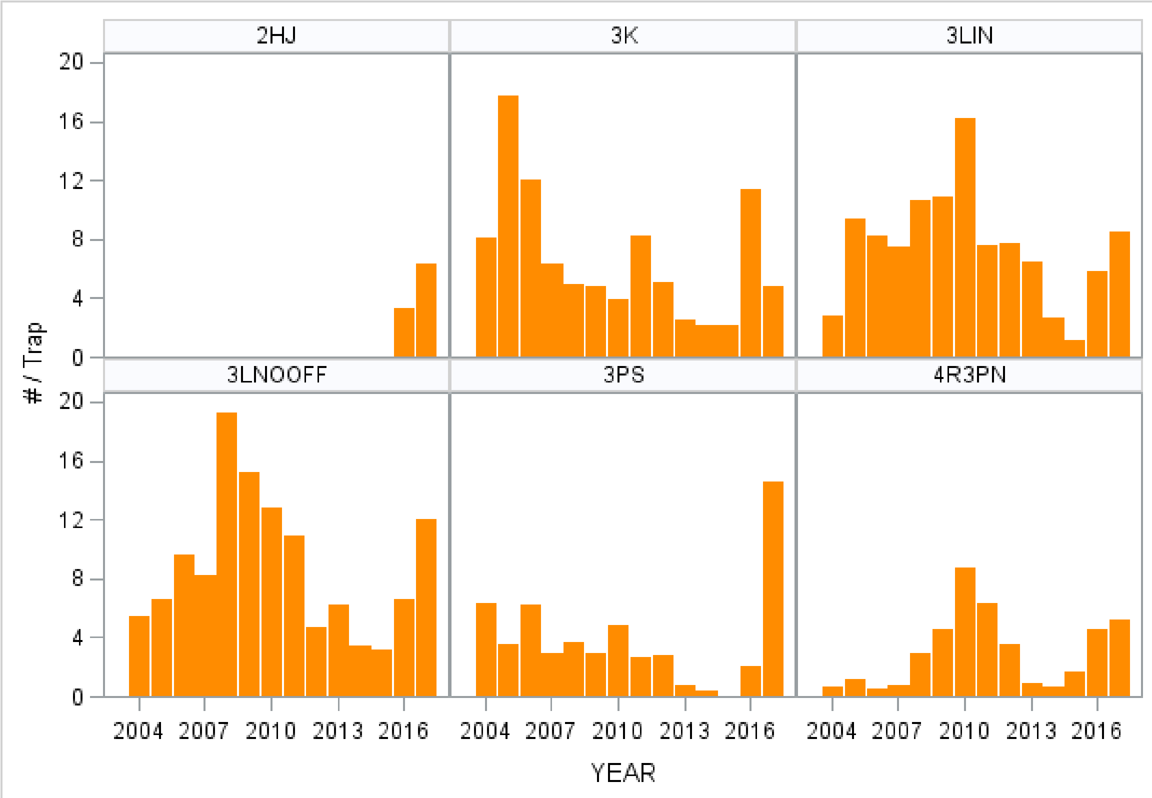

Figure 16: Annual CPUE (#/trap) of pre-recruits from small-mesh traps at core stations in the CPS trap survey by assessment division (2004-17).

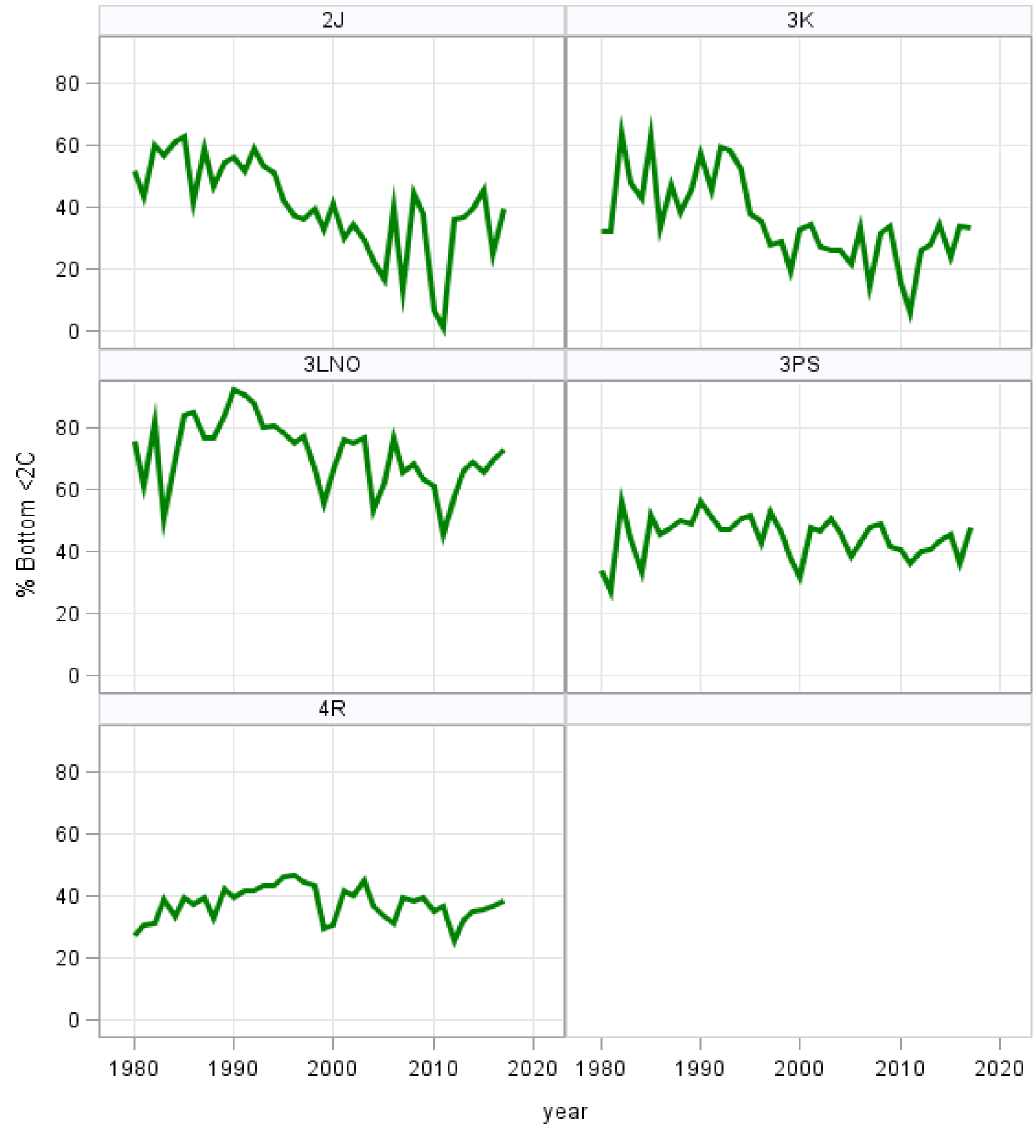

Figure 17: Snow Crab thermal habitat indices by assessment division.

The Snow Crab thermal habitat index (defined as the areal extent of <2°C bottom water) suggests improving conditions, with the return to near-average conditions in all divisions in recent years (Fig. 17).

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).

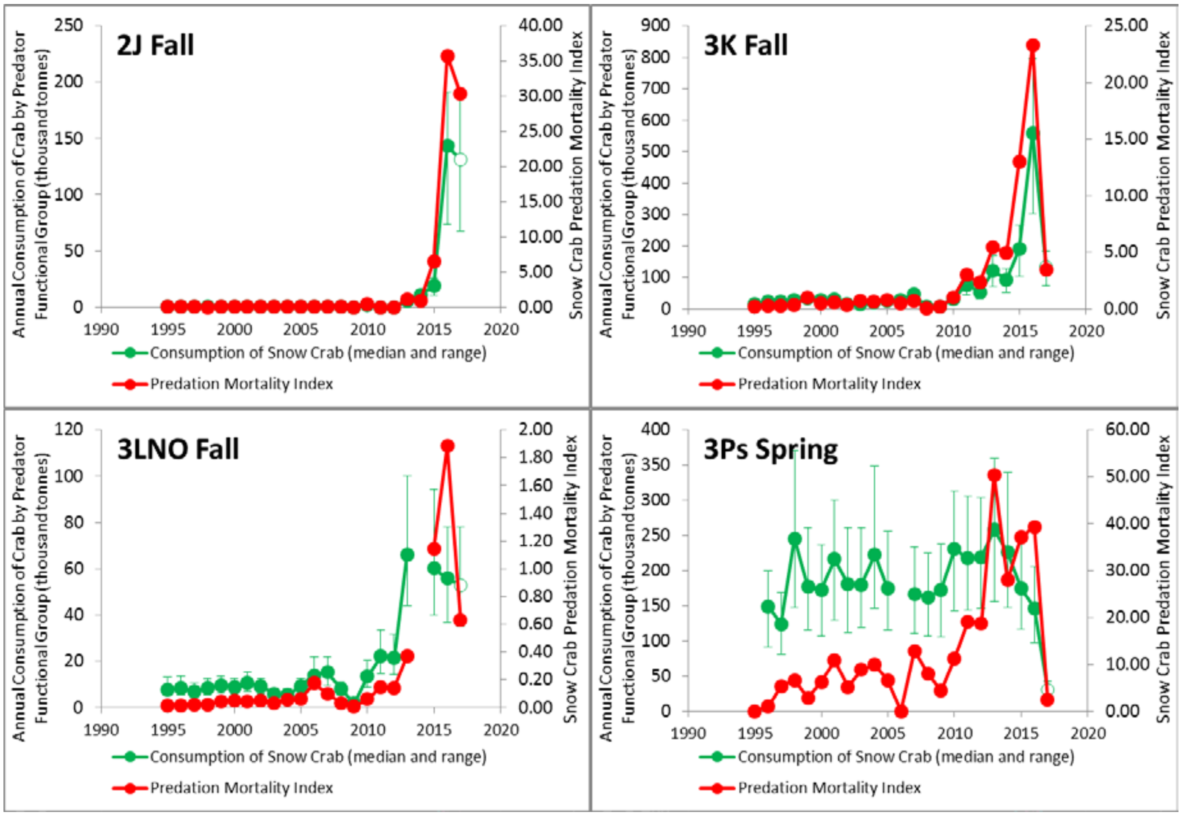

Figure 18: Consumption of Snow Crab by predators by assessment division. Green represents estimated consumption and red is an index of predation mortality. Solid symbols in 2017 denote preliminary data.

Ecosystem Perspective

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.

Trends in predation mortality suggest that this factor may be an important driver for Snow Crab in Southern Newfoundland (Subdiv. 3Ps), and may become one in other areas. Predation mortality on Snow Crab has increased since the late-2000s and early-2010s in most divisions (Fig. 18), and shows important differences in magnitude across ecosystem units. Southern Newfoundland (Subdiv. 3Ps) has predation levels an order of magnitude higher than other areas. Still, predation mortality in the Grand Bank (Divs. 3LNO) and Newfoundland Shelf (Divs. 2J3K) has coarsely increased five-fold over the last four to five years.

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 (Mullowney et al. 2014). The resource was most productive throughout the 1990s, but productivity has diminished coincident with warming over much of the past decade. Besides exerting a direct impact on early-life survival, a shift toward warmer conditions now appears to be affecting the Snow Crab resource indirectly, in the form of increased predation as finfish populations respond positively to warming. However, a return to average bottom temperatures in recent years in most divisions (Fig. 17) could favour increased productivity and recruitment in the near future, particularly if predatory finfish levels decline. Such potential improvements are lagged in relation to responses in the fishery, as temperature appears to most directly affect early life stages of crab and predation is generally on small crab below about 40 mm CW (Chabot et al. 2008).

Although a small pulse of young crab (i.e. <30 mm CW) has emerged in some divisions in recent years (i.e. Divs. 2HJ and 3K), overall, virtually all population components are at low levels relative to historical levels in all divisions (Fig. 19). Most data suggest that overall, short, medium, and long-term prospects appear relatively weak.

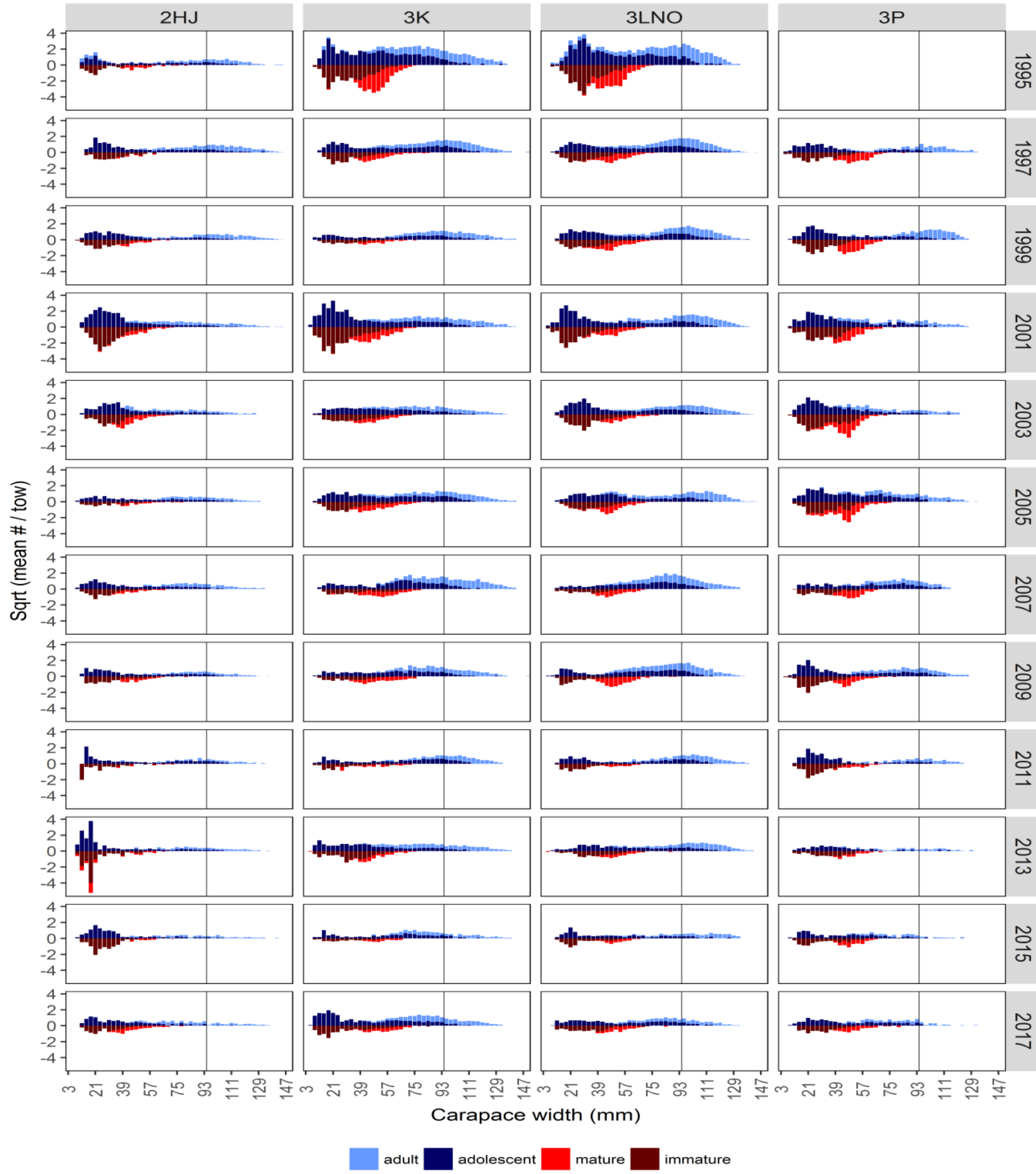

Figure 19: Abundance indices by carapace width for juveniles plus adolescent males (dark blue), adult males (light blue), immature females (dark red), and mature females (red) from spring (Subdiv. 3Ps) and fall (Divs. 2HJ3KLNO) trawl surveys. Dashed vertical line is legal-size. Data standardized by vessel.

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 biomass and pre-recruit abundance indices from surveys are highly uncertain if a survey was incomplete. Although incomplete surveys have not affected fall trawl data in recent years, the survey coverage levels have been reduced relative to historic norms due to vessel and logistical issues. One outcome of reduced coverage levels is that inshore areas are not routinely covered by the multispecies trawl surveys in some NAFO divisions, thus surveys fail to sample the stock as a whole.

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 in some divisions. 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 and pre-recruit catch rate indices from trap surveys are also affected by annual variation in catchability of crab. 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.

Small-mesh 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. Recent efforts to increase the number and distribution of small mesh pots in the survey have increased coverage in shallow-water small crab habitat. However, there remains uncertainty associated with 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 habitat indices as an indicator of future biomass (or CPUE), particularly under the scenario of changing oceanographic conditions, shifts in trophic control, and increasing exploitation rates. Bottom temperatures throughout the region warmed from the mid-1990s to about 2011-12, when they reached record highs in most divisions (Fig. 17). This warming was associated with low productivity in the stock and contributed to poor recruitment in recent years. However, bottom waters have since cooled back to near-average levels in all divisions, inferring improved prospects for increased productivity, which likely relates to increases in pre-recruit abundance in most divisions (Fig. 16). How long these improved (cooler) conditions will be sustained is unknown. The long-term trend is warming, but the trend is characterized by high levels of variability such as the recent cooling years. Continued warming in the long-term is inferred from multi-decadal oscillations in the ocean climate of the entire Atlantic Ocean that, until recent years, had been 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 as well as whether or not the NL shelves will respond to climate warming in the same fashion as other areas of the North Atlantic. Given uncertainties associated with future ocean climate, long-term recruitment prospects are ultimately unknown.

Fishery Indices

Logbook data provide the broadest coverage and therefore the most representative fishery performance index. 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 considered preliminary. Overall, for the current assessment, 84% of the 2017 logbooks were available. This is high, and the current trends in CPUE are considered reliable.

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. Fishery catch rate indices are standardized for time (week) and space (CMA) as well as soak time but other factors could affect catch rates to unknown degrees.

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 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 crab.

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 crab or fishing effort inside versus outside the limited survey areas. Total mortality indices can be affected by annual variation in trawl performance.

Ecosystem Change

Prolonged warming in waters surrounding most of Newfoundland and Labrador has 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 in recent years. However, the extent of community reorganization or change that will result in response to changing thermal conditions is unknown. The most recent years have been characterized by a high level of variability in ocean temperatures, which could slow or alter changes that have been occurring. Ultimately, if temperatures continue to warm, 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.

CONCLUSIONS AND ADVICE

Divisions 2HJ

The exploitable biomass has consisted largely of incoming recruits for the past six years (75%), with few old-shelled crab. This suggests high mortality of large adult male crab. The exploitation rate index has been above the long-term average for the past two years. Status quo removals in 2018 would maintain the two-year average exploitation rate index at a relatively high level.

Division 3K

The exploitation rate index has been at a decadal high during the past two years. Status quo removals in 2018 would decrease the exploitation rate, with the two year average index being below the time-series median level.

Division 3L Inshore

The overall trap survey-based exploitation rate index has increased from 2013 to a time-series high in 2017. Maintaining status quo removals would increase the two-year average exploitation rate index to an exceptionally high level in 2018, with all management areas reaching or remaining near time-series highs. The scenario of a depleted exploitable biomass coupled with low recruitment prospects and high exploitation rate indices suggests minimal potential for improvements in the short term.

Divisions 3LNO Offshore

The exploitation rate index increased by a factor of five from 2014 to 2017. Status quo removals in 2018 would maintain the two year average exploitation rate index at a historic high.

Subdivision 3Ps

In 2017, total mortality in exploitable crab was high but the exploitation rate index declined sharply to a relatively low level. Assuming the exploitable biomass remains at the current level, status quo removals would result in an exploitation rate index near the long-term median in 2018. Discards comprised half the catch in the past two years. This is concerning as fishing under elevated mortality levels on small and pre-recruit crab could impair reproductive capacity or yield from forthcoming recruitment.

Divisions 4R3Pn

The overall exploitation rate index has increased since 2013, reflecting trends in all surveyed areas. Status quo removals would elevate the two-year average exploitation rate index to an exceptionally high level in 2018, with all surveyed management areas reaching new time-series highs. The scenario of a low exploitable biomass and CPUE, coupled with an approaching pulse of pre-recruit crab in CMA 12EF suggests that excessive fishing in 2018 could be detrimental to yield in subsequent years due to associated high soft-shell mortality.

OTHER CONSIDERATIONS

Bitter Crab Disease

Bitter Crab Disease (BCD) is fatal to crab and 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 in small males is directly related to density (Mullowney et al. 2011) and was been relatively low in 2017 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

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. However, 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 crab 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) for the remainder of the season when a threshold level of 20% 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 a very large number of grids and low observer coverage, together with the decision to treat unobserved grids as if they had no problem. In addition, failure to consider small to moderate-sized samples as representative frequently resulted in failure to invoke the protocol even when it was clear that the level of soft-shelled crab had exceeded the threshold. Low catch rates in some areas actually serve to keep an area open as minimum sample sizes necessary to invoke a closure cannot be met. These shortcomings undermine the intent of the protocol. Measures should be taken to ensure adequate and representative observer coverage 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. In some divisions (3Ps, 4R3Pn) there has been the perception that additional quota would not be catchable resulting in incomplete surveys in particular years. Under the scenario of expected reduced exploitable biomass in many divisions, there are concerns the integrity of this survey could deteriorate.

Exploitation rate indices have been increasing to exceptionally high levels in the biggest and most important (highest abundance) areas in recent years (Divs. 3LNO Offshore, Div. 3L Inshore) and there are concerns that continuing to fish at these levels could serve to minimize any improvements in stock status and potentially affect the reproductive capacity of the stock.

Precautionary Approach

Fisheries and Oceans Canada is currently working toward a Precautionary Approach for NL Snow Crab that will address efficiencies of the fishery, as well as reproductive capacity.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 20-21, 2018 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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