Fisheries and Oceans Canada | Pêches et Océans Canada
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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Response 2014/049

SHORT-TERM STOCK PROSPECTS FOR COD, CRAB AND SHRIMP IN THE NEWFOUNDLAND AND LABRADOR REGION (DIVISIONS 2J3KL)

Context

Bottom water temperatures off the East Coast of Newfoundland and Labrador (NL) have been increasing since the mid-1990s and are expected to remain high or continue to increase (more gradually) for more than a decade to about 2030, based on the Aquatic Climate Change Adaptation Services Program (ACCASP). While the return to a warm regime should be favourable for Atlantic Cod, there are other factors (e.g. abundance of a primary prey such as capelin) affecting stock growth and productivity. For Snow Crab, warm conditions are associated with low survival soon after settlement and weak subsequent recruitment. Effects of warming are most unclear for Northern Shrimp because recruitment dynamics are believed to be related to the match/mismatch of hatching with the spring algal bloom, which likely involves multiple factors interacting with temperature.

Given current environmental predictions and the implications for these resources, Fisheries and Aquaculture Management Branch asked Science Branch to provide an overview of the prospects of these stocks over the next 3-5 years. Consequently, a DFO Science Response Process (SRP) was undertaken on 20, 21 and 28 August, 2014.

The objectives of this process were:

- report on the confidence of the environmental modelling from ACCASP that supports the expectations that bottom water temperatures are to remain high or continue to increase over the next decade, but more particularly, over the next 3-5 years;
- report on other key environmental attributes (e.g. algal blooms) considered to be important in cod-crab-shrimp dynamics;
- review trends in capelin and other important prey items;
- review scenarios for possible biomass trends to 2019 in key resources in the NL Region - Divisions 2J3KL - (specifically crab, shrimp and cod), to support economic analysis and discussions with industry in various consultation processes. Scenarios should be considered in terms of Optimistic, Pessimistic and Likely outcomes for these stocks under a warming environment regime.

With very limited new analyses the meeting attained a consensus view of the resource prospects, based mostly on the most recent stock assessments and information previously peer-reviewed. The process also identified the main uncertainties and their potential consequences on resource prospects.

This Science Response Report results from the Science Response Process of 20, 21 and 28 August, 2014 on the review of the Short-term Stock Prospects for Cod, Crab and Shrimp in the NL Region (Divisions 2J3KL).

Background

Environment

The environment is always changing. The recent long-term warming trend in the climate system is driven by an increase in temperature associated with both climate change and the warm phase of the Atlantic Multi-decadal Oscillation (AMO). A suite of associated changes (e.g. slowing down of the Labrador Current, reduction in ice coverage, more frequent extreme weather events) can have important effects on the ecology of the marine ecosystem (e.g. timing of blooms) which impact all trophic levels.

The warm ecosystem will almost certainly affect long-term changes in commercial species. However, short term (3-5 years) effects are less clear because of unknown responses to annual variation in the thermal regime.

Fish community

The NL marine ecosystem underwent a regime shift in the early to mid-1990s, which included the collapse of historically dominating groundfishes, and key forage species like capelin. Shellfish became the dominant functional group in the ecosystem.

Since the mid to late 2000s signals of a change in community structure started to emerge. Shellfish started to decline, and traditional groundfishes began to increase. Capelin also has shown improvements in comparison to the very low levels observed in the 1990s. Recent trends suggest that the system may be reverting back to a groundfish-dominated fish community, but the future structure of that ecosystem will not necessarily be similar to that of the previous groundfish-dominated ecosystem.

Analysis and Response

Environmental and Lower Trophic-Level Trends

The recent warming trend in the climate system is most likely driven by an increase in temperature associated with both global climate warming and the warm phase of the Atlantic Multi-decadal Oscillation (AMO) (Fig. 1). The current warm phase of the AMO is expected to continue for another 1-2 decades before transitioning back to the cool phase.

Global rise in air temperatures have led to a general increase in regional sea surface and bottom temperatures since early to mid-1990s. In addition, extent of sea ice and the cold shelf water mass (cold intermediate layer) has been in decline since the early 1990s. The long-term trend indicates continuation of a warm regime. Although short-term projections of ocean climate conditions remain highly uncertain due to variability associated with large-scale atmospheric forcing, it will likely be above or close to normal in the next 3-5 years.

The composite index is a measure of the overall state of the Northwest Atlantic ocean climate system with positive values representing warm-salty conditions and negative values representing cold-fresh conditions. The overall composite index clearly defines the cold/fresh conditions of the 1970s, 1980s and early 1990s, the recent warming and freshening trend that peaked in 2006 and the 3 years of relatively cooler conditions of 2007-09 (Fig. 2). In 2010 the composite index increased sharply to the 2nd highest in the 63-year time series. In 2011 it was very similar to 2010, the 4th highest in 63 years but in 2012 it had decreased to the 8th highest.

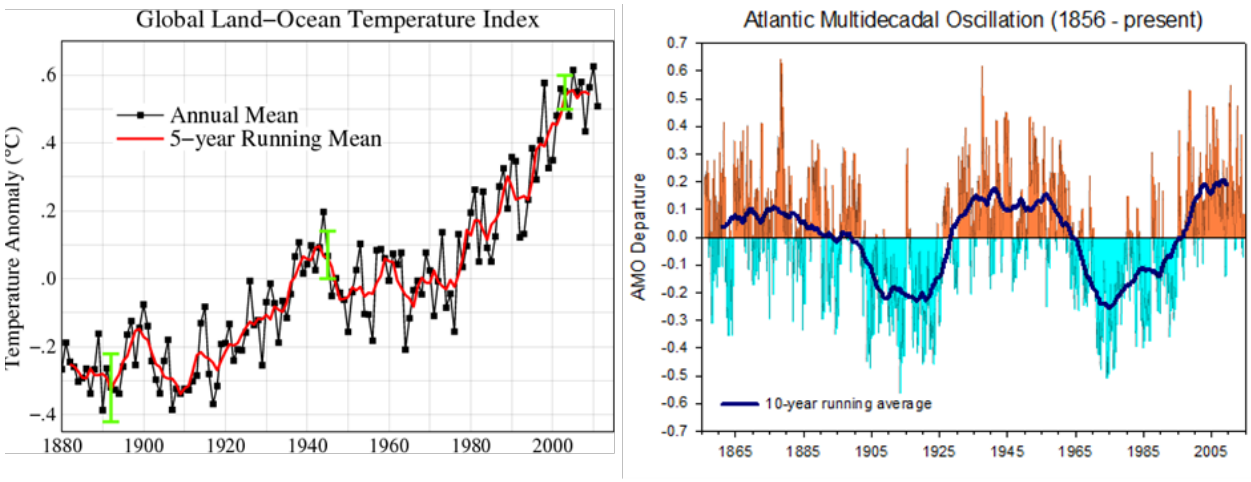

Figure 1. Global land-ocean temperature index (left panel) based on Hansen, J. et al. 2006. Atlantic Multi-Decadal Oscillation (right panel) after Enfield, D. B.; Cid-Serrano, L. 2010.

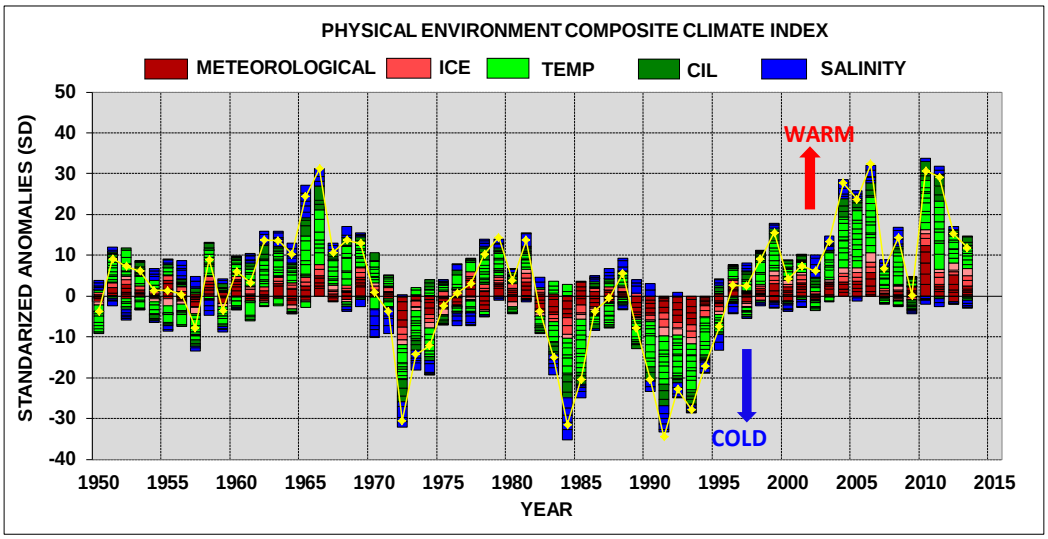

Figure 2. Composite climate index derived by summing the standardized anomalies of NAO, air temperature, ice, water temperature and salinity and CIL areas from several locations in the Northwest Atlantic. From Colbourne, E. et al. 2013.

Analysis of satellite ocean colour data has detected shifts toward earlier timing and more intense spring blooms. These trends are expected to continue under the current warm regime. Recent changes have also been noted in timing and abundance of key zooplankton taxa that may also be indicative of changes in overall productivity.

Large-scale environmental trends and climate projections indicate global surface air temperature has increased ~ 0.2°C per decade in the past 30 years. Short-term statistical projections show that limited change from current conditions is expected until about 2015 - 2020 for both sea surface and bottom temperature based on patterns of variation in projected air temperature (Fig. 3). Projections from a Canadian Regional Climate Model indicate that a long term increase of approximately 0.3°C/decade can be expected.

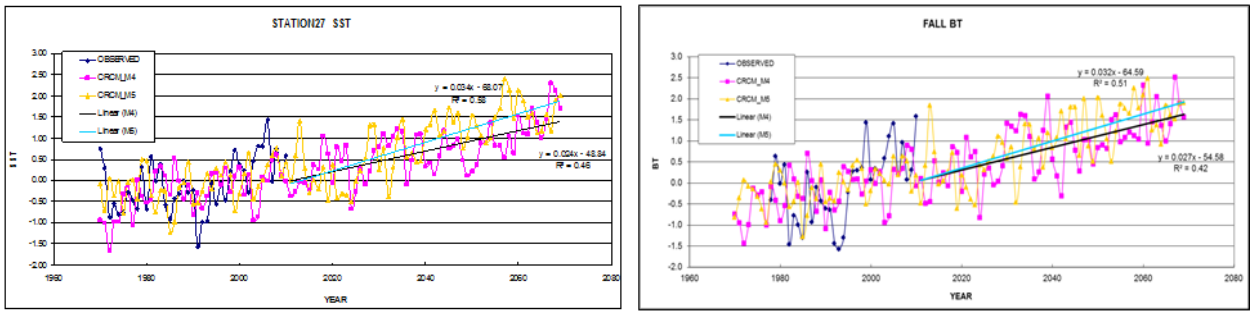

Figure 3. Reconstructed sea surface temperature (SST) anomalies (°C) at Station 27 (left panel) and fall bottom temperature (BT) over the Newfoundland and Labrador Shelf (right panel) based on the simulated air temperature anomalies at St. John's and Cartwright respectively. The straight lines are the linear fits to the SST and BT projections over 2011-2070. From Han, G. et al. 2013.

Ecosystem structure and trends

The NL Shelf marine ecosystem is organized in two major functional components, the northern Newfoundland and Labrador shelf and the Grand Bank proper, with the northern Grand Bank (nominally NAFO Div. 3L) acting as a transition zone between these two major regions (NAFO 2010, 2013). The marine ecosystem in NAFO Divs. 2J3KL mostly corresponds to the northern component, but also includes the transition into the Grand Bank ecosystem.

The fish community in Div. 2J3KL was historically dominated by groundfish species (e.g. piscivores like Atlantic cod, large benthivores like American plaice, medium benthivores like yellowtail and witch flounders, plankpiscivores like redfish) (Fig. 4), with capelin as its core forage-fish species. Anthropogenic impacts (e.g. overfishing, climate change), in conjunction with changing environmental conditions (e.g. AMO) led to a regime shift in the early-mid 1990s (Buren et al. 2014a), which involved significant changes in community structure. The fish community became dominated by shellfish species like Northern Shrimp, while traditional groundfish species and capelin declined to very low biomass levels (Figs. 4 and 5).

Between the mid-1990s and early 2000s, the fish community showed a relatively stable structure, with shellfish (mostly Northern Shrimp) dominating the overall biomass (Fig. 4). During this period, and with capelin at very low levels, Northern Shrimp became a key forage species for core fish predators. The cod diet was dominated by shrimp, and the fraction of shrimp in the turbot diet increased (Dawe et al., 2012).

By the mid-late 2000s the community structure started to change. Fish functional groups began to show increases in biomass, and shellfish started to decline (Fig. 4). Although showing positive trends, historically-dominating groundfishes (e.g. Atlantic Cod, American Plaice) and capelin remain well below their pre-collapse levels, while Northern Shrimp is at or below the biomass levels observed in the mid-1990s (Fig. 4).

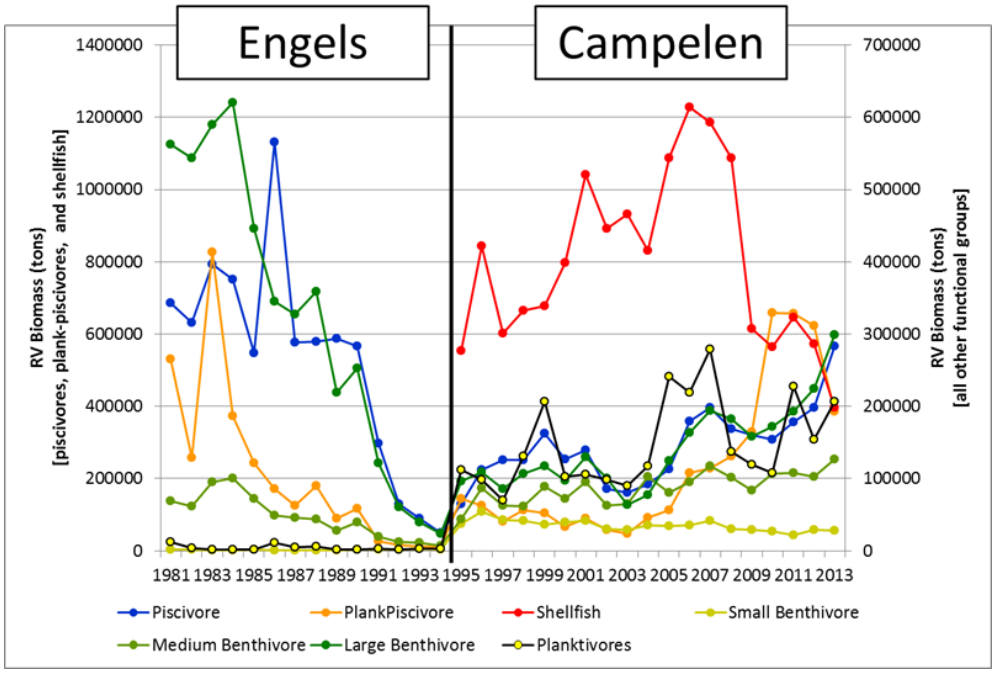

Figure 4. Trends in the Research Vessel (RV) Biomass index by fish functional groups in core strata of NAFO Divs. 2J3KL from the DFO Fall RV survey. Index values are not comparable between earlier (Engels gear) and later (Campelen gear) periods - denoted by the vertical line - due to the lack of conversion factors for most species in the survey. The Shellfish functional group includes Pandalus shrimp and Snow Crab, but its signal is heavily dominated by shrimp; reliable RV survey data for these species are only available since the introduction of the Campelen gear in the survey.

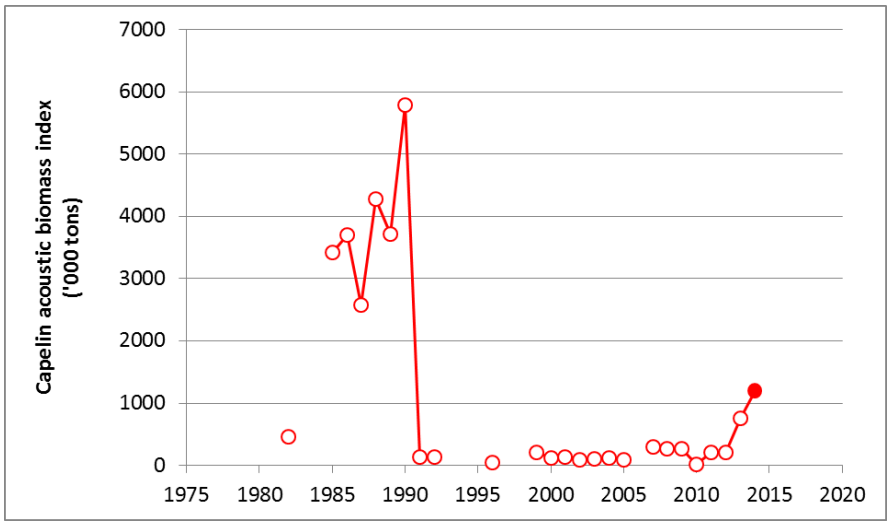

Figure 5. Trend in the capelin acoustic biomass index from DFO spring capelin survey; the data point corresponding to 2014 is still preliminary.

Associated with these trends, the total food consumption by fish functional groups that include key groundfish predators (i.e. piscivores, medium and large benthivores, and plankpiscivores) has been increasing since the mid-2000s (NAFO, 2013). Regarding diet composition, key groundfishes are showing a decrease in shrimp, and an increase in capelin in their diets in

recent years (Fig. 6). This suggests that the trend towards an increased role of invertebrates in the diet observed in the mid-1990s and earlier 2000s may be starting to reverse.

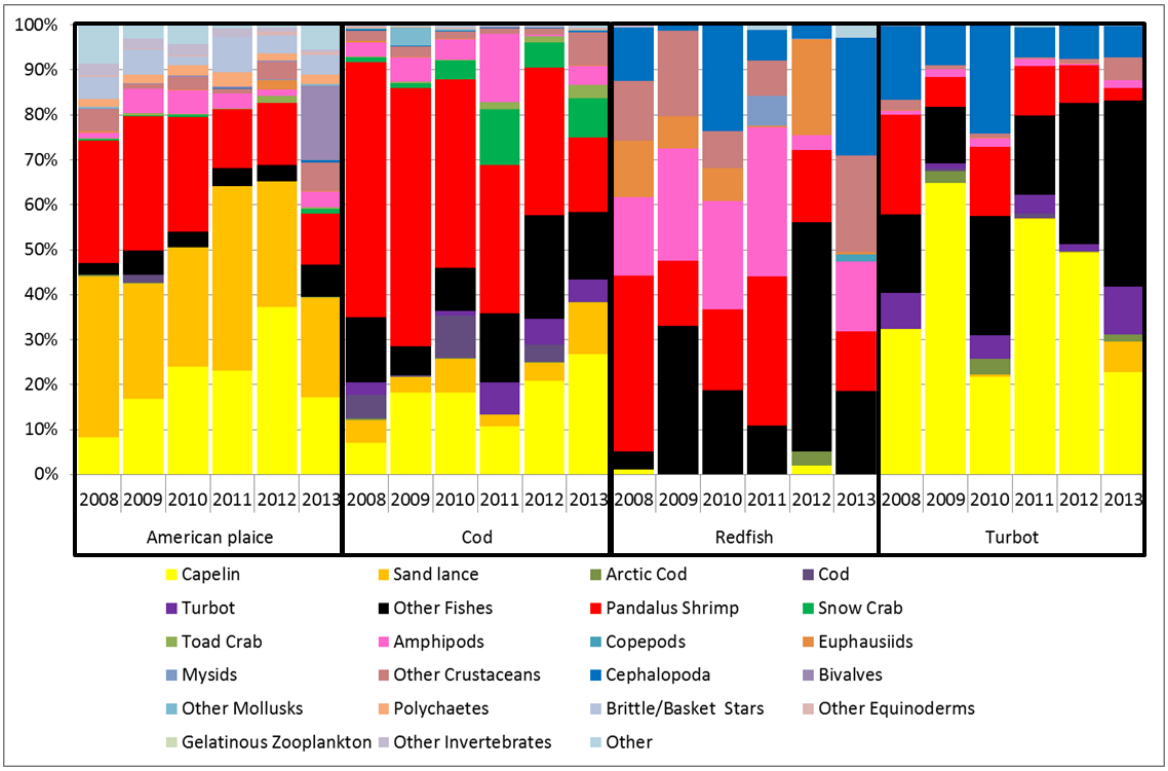

Figure 6. Diet composition of key groundfish species in 2008-2013 in NAFO Divs. 2J3KL based on stomach contents collected during DFO Fall RV surveys.

In terms of ecosystem regulation, sea ice dynamics are important drivers of the spring phytoplankton bloom (Wu et al., 2007). The timing of the bloom has an influence on Northern Shrimp phenology (Koeller et al., 2009), and it has been correlated with shrimp production rates (Fig. 7). Sea ice retreat, through its influence in triggering the spring bloom and cascading effects on zooplankton availability, has also been found to be an important modulator of capelin dynamics (Buren et al., 2014a), while capelin availability has been identified as a significant driver in northern cod dynamics (Buren et al., 2014b). Overall, ecosystem production seems to be, at least in recent decades, mainly regulated by bottom-up processes. This implies that current trends in the climate system and lower trophic levels would be expected to impact overall ecosystem productivity, where capelin availability emerges as a key factor in determining productivity of upper trophic levels.

If current trends persist, it could be expected that the fish community in NAFO Divs. 2J3KL would return to a groundfish-dominated structure. It remains uncertain how similar this emerging structure will be to the historical ecosystem, in terms of both species composition and overall biomass levels, or at what rate these changes would occur.

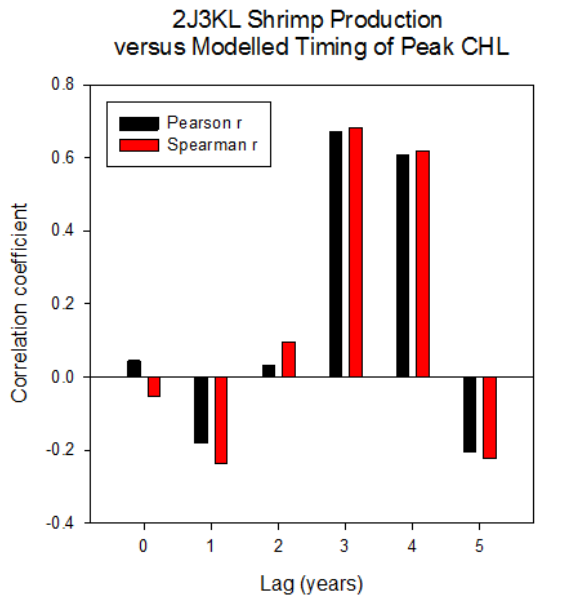

Figure 7. Lagged correlations between shrimp production rate in Div. 2J3KL and the timing of the peak of the spring phytoplankton bloom (peak chlorophyll –CHL- from model output). Correlations were explored with both parametric (Pearson r) and non-parametric (Spearman r) correlation coefficients.

Snow Crab

Current Status

It is currently not possible to estimate absolute biomass. Survey indices suggest that the overall Div. 2J3KLNO exploitable biomass has changed little in recent years. However, it declined by about 74% in Div. 2J from 2006-2011 (Fig. 8), while landings declined by 37%. Similarly, it declined by about 68% in offshore Div. 3K from 2008-2013 (Fig. 8), while landings declined by 50%. In contrast, the exploitable biomass has increased in Div. 3LNO (Fig. 8). As a result Div. 3LNO has accounted for an increasing percentage of the overall 2J3KLNO exploitable biomass in recent years, from about 40% in 2008 to 75% in 2013. Div. 3NO is included in the Div. 3LNO management unit, but most of the Snow Crab resource is within Div. 3L.

The offshore Div. 3LNO trawl survey exploitable biomass index has been highly variable, declining by almost an order of magnitude over a decade from the start of the survey series to 2006 (Fig. 9). The post-season trap and trawl surveys do not agree, with the trap survey exploitable biomass index declining by almost half over 4 years to 2008 (Fig. 8). It is believed that the trend in the trap survey index better reflects the trend in the exploitable biomass because it is supported by the increasing fishery performance during that time (Figs. 8 and 9). The trap survey suggests that the Div. 3LNO exploitable biomass has almost doubled since 2008 (Fig. 8). Meanwhile, landings have been maintained at a constant high level (about 24,000-29,000 t) over the past two decades.

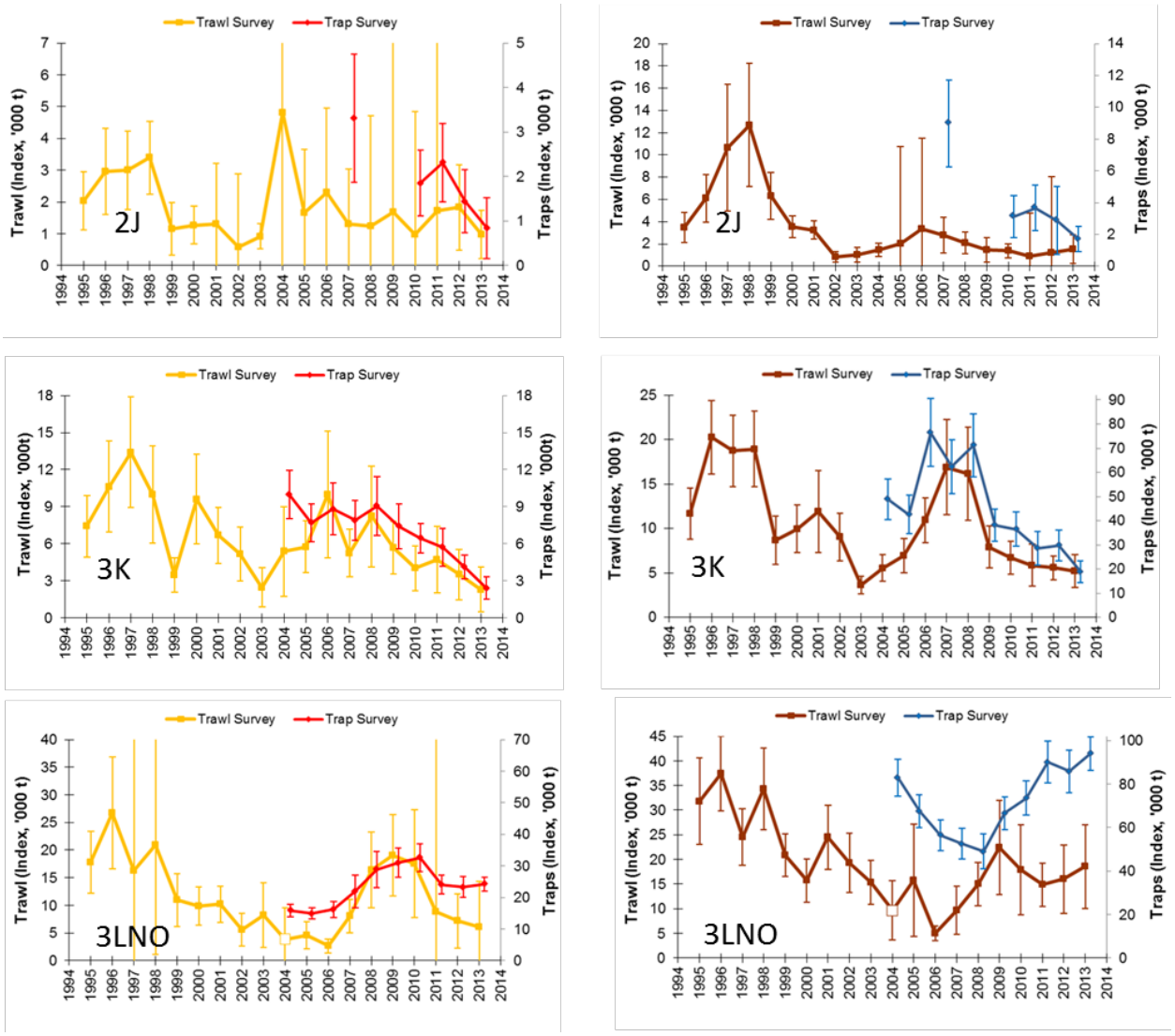

Figure 8. Pre-recruit (left panels) and exploitable (right panels) biomass indices from trawl and trap surveys in each division.

Prospects for the next 5 years based on current status and trends.

The exploitable biomass has already declined to a very low level in Div. 2J3K, and recruitment prospects remain poor (Fig. 8). Accordingly, overall changes within the next 5 years will be driven by changes in Div. 3LNO.

The exploitable biomass is expected to decline in Div. 3LNO (and Div. 2J3KLNO overall) over the next 5 years. Biological data from several sources indicate that recruitment will likely decrease in the short term. A recent recruitment pulse, reflected in a 2009-2010 peak in pre-recruit biomass indices from both surveys (Fig. 8) has now fully recruited to the exploitable biomass. Pre-recruits are small males that will molt and recruit to the exploitable biomass within 2-3 years. There is no evidence of any increase in the pre-recruit biomass indices in the past three years (Fig. 8). There has also been no increase in the abundance index of very small (<40 mm carapace width (CW)) males, suggesting no apparent recruitment pulse within the next five years (Mullowney et al., 2014a).

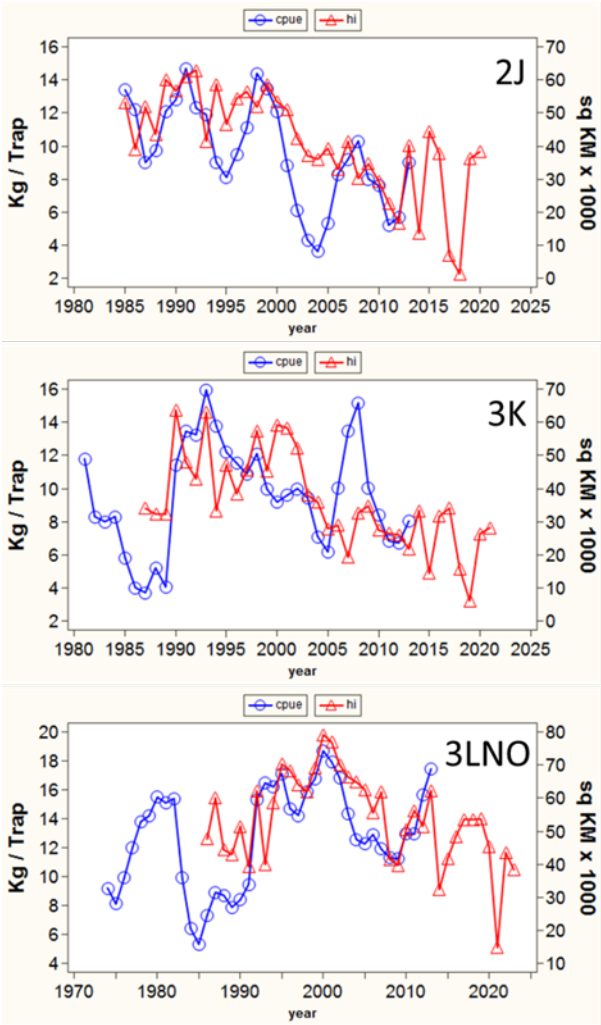

Figure 9. Fishery CPUE versus snow crab habitat index by Division. Habitat indices shifted forward by 7 years in Div. 2J, 8 years in Div. 3K, and 10 years in Div. 3LNO represent projections of future CPUE. The habitat index is the bottom area covered by coldest water of < 2 C in Div. 2J3K and < 1 C in Div. 3LNO.

Cold conditions during early life history are associated with increased fishery CPUE and survey biomass indices 6-10 years later (Fig. 9) (Marcello et al., 2012). Biomass and recruitment have historically shown long-term oscillations, related to trends in thermal regime (DFO 2014a). The recent warm oceanographic regime (reflected in low habitat index values) suggests weak recruitment in the long term (Fig. 9). However the nature, magnitude and duration of the expected decline in Div. 3LNO are unknown.

Major Uncertainties and Potential Consequences on Stock Prospects

Low and annually variable capture efficiency of crabs by the survey trawl makes it difficult to interpret inter-annual changes in biomass indices. This annual variability is thought (in part) to result in annual fluctuations and co-variation in pre-recruit and exploitable biomass indices, especially in Div. 3LNO (Fig. 8) where the trawl is most inefficient due to a hard bottom type. Trawl efficiency also declines as crab size decreases. Uncertainty is further increased by low precision of annual biomass indices, as reflected by broad confidence intervals (Fig. 8).

There is also uncertainty in predicting recruitment from the trap-based pre-recruit index because it includes an unknown and variable portion of terminally molted (adult) crabs that will never recruit to the fishery. The capture efficiency of pre-recruits is annually variable due to competition with larger and adult crabs for baited traps. The trap survey pre-recruit index in Div. 3LNO (Fig. 8) has become increasingly dominated by old-shelled (likely adult) crabs in recent years.

The ocean climate indices have varied considerably over the past decade, introducing uncertainty beyond the short term. However, the overall trend is warming, with record warm conditions in 2011 (Fig. 9).

Unknown levels of future fishing mortality (landings and handling mortality) introduce uncertainty. Other sources of mortality, including predation, bottom trawl fisheries, seismic exploration, and disease are likely to have relatively little impact on short-term changes in the exploitable biomass (Mullowney et al., 2014b).

A most severe 5-year decline in the Div. 2J3KLNO exploitable biomass could result from an immediate and steady decline in overall recruitment, especially in Div. 3LNO, due to progressive warming. This decline would be exacerbated if the current level of fishery removals is maintained.

A least severe 5-year decline could result from some delay in the start of the decline in Div. 3LNO and/or some annual variability in overall recruitment and exploitable biomass due to variability in ocean climate in recent years (Fig. 9). The decline in exploitable biomass would be moderated if fishery removals are reduced.

Northern Shrimp

Current Status

The Northern Shrimp resource is managed by Shrimp Fishing Areas (SFAs), which do not conform exactly to NAFO Divisions. SFA 5 (Div. 2HJ) is dominated by Div. 2H and it includes only a minor portion of the overall Div. 2J3KL resource. Most of the overall resource resides in SFA 6 (Div. 2J3K, Fig. 10). The fishable biomass indices have declined substantially since 2006 (Fig. 10). The rate of decline increased from north (SFA 5) to south (SFA 7; Div. 3L). The SFA 5 fishable biomass index decreased by 48% from 147,000 t in 2012 to 76,000 t in 2013 and is presently at the pre-2000 level. The SFA 6 fishable biomass index decreased by 68% from 670,000 t in 2006 to 212,000 t in 2013, the lowest level in the time series. The SFA 7 fishable biomass index decreased by 92% from 238,000 t in 2007 to 18,000 t in 2013, near the lowest level in the time series (Orr and Sullivan, 2014).

Female spawning stock biomass (SSB) is a part of the fishable biomass and is used to determine the status of the resource within the precautionary approach framework. The SFA 5 resource is currently estimated to be in the healthy zone, with a 33 % chance of being in the cautious zone. The SFA 6 SSB is at its lowest level in the time series and remains in the cautious zone, but well below the 2012 point. NAFO Scientific Council considers that the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for the biomass limit reference point or B_{lim} (approximately 19 000 t) for Northern Shrimp in Div. 3LNO (SCS Doc., 04/12). The SFA 7 resource has declined since 2007, and in 2012 the SSB point estimate was marginally above the B_{lim} level, with a 43% chance of being below B_{lim}. Preliminary data indicate the SSB was below the B_{lim} level in 2013.

A preliminary analysis of the shrimp annual surplus production rate in NAFO Divs. 2J3KL indicated that it has been reduced since the mid-2000s, particularly in the southern area (Div. 3L) (Fig. 11).

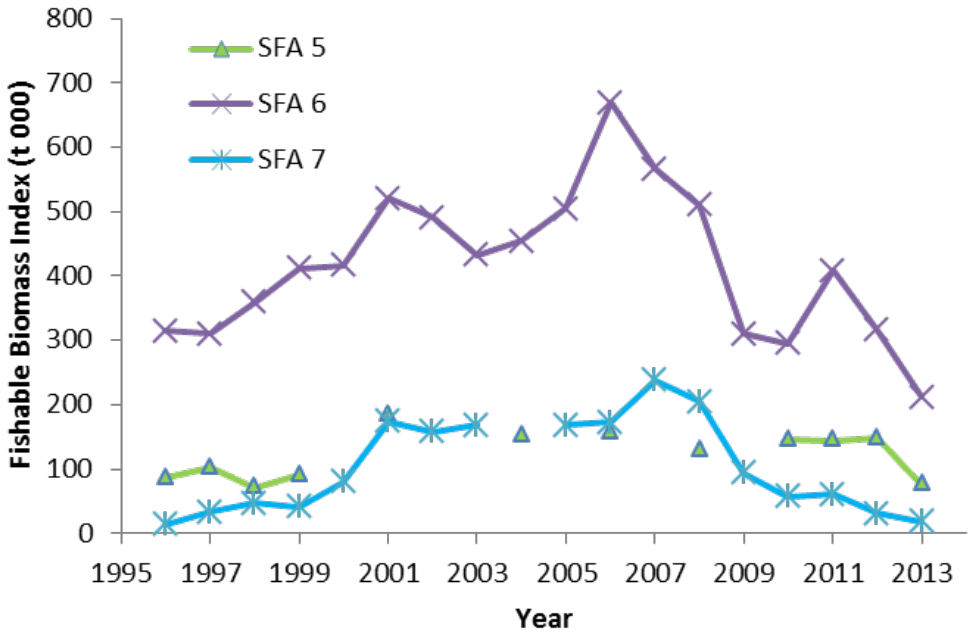

Figure 10. Northern Shrimp fishable biomass index within SFAs 5 – 7 from fall Canadian multi-species bottom trawl survey data, 1996-2013.

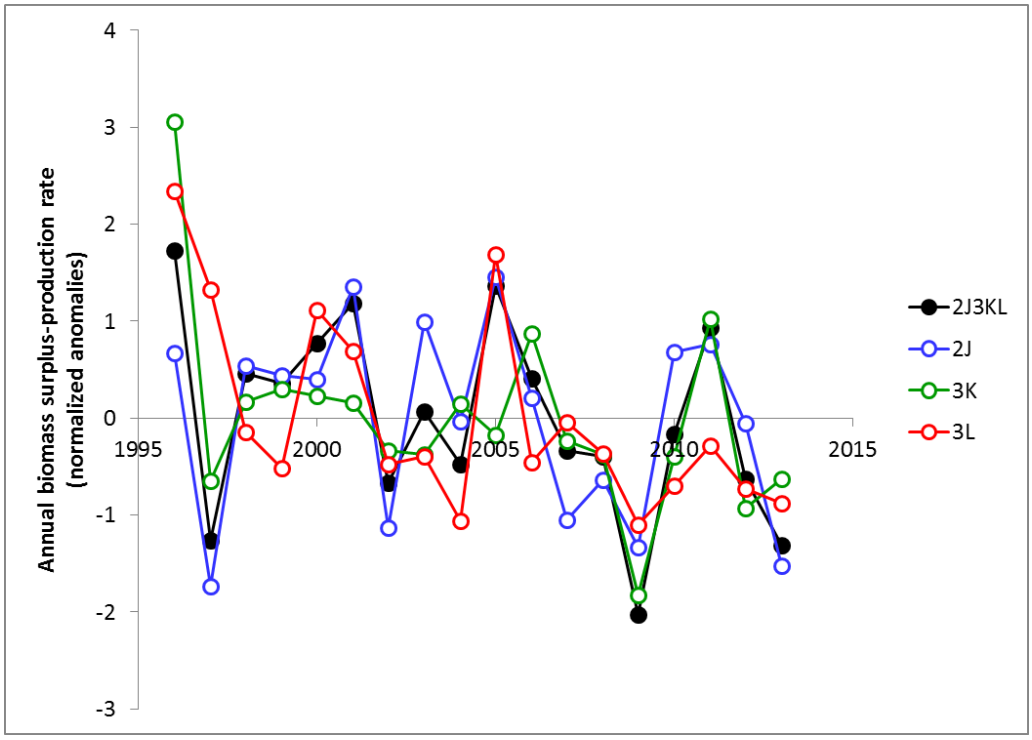

Figure 11. Annual surplus-production rate of shrimp calculated for NAFO Divs. 2J3KL overall, and by each individual NAFO division. This plot shows the normalized anomalies (i.e. mean=0, standard deviation =1) for each series; the base index is derived from RV fall survey and reported fishery catch data.

Reduced shrimp production rates were associated with the recent warming trend, early timing of the phytoplankton bloom, increasing biomass of predatory fishes, and fishing, with typical lags in the range of 2-4 years. The underlying mechanisms behind these associations are not fully understood.

Prospects for the next 5 years based on current status and trends

Shrimp is an important prey item for several groundfish species in NAFO Divs. 2J3KL, and became a key forage species after the decline in capelin biomass during the early 1990s. Predation pressure is one of the factors contributing to the decline of this resource, and given the current positive trend across several fish functional groups (Fig. 4), this pressure is likely to continue increasing.

Bottom temperatures have been increasing since the mid-1990s, reducing the available thermal habitat for this resource. Ocean warming may also be responsible for altering the timing of the blooms in lower trophic levels (e.g. spring phytoplankton bloom) (Zhao et al., 2013), which would be expected to have an impact on the early life stages of shrimp. Preliminary analysis showed that lower shrimp production rates are associated with earlier phytoplankton blooms.

As noted above, fishable biomass indices have decreased in SFAs 6 and 7 since 2007 and in SFA 5 since 2012. However, commercial catches were not reduced until at least 2010 in SFAs 6 and 7 and 2014 in SFA 5. Because levels of catch reductions do not match fishable biomass index reductions, recent exploitation rates have increased in SFAs 5-7.

The delayed response of shrimp production rate (by 2-4 years) to recent unfavourable changes in several factors implies that the fishable biomass would be expected to remain low or continue declining in the short term. This period of low or declining biomass may be extended if the trend in warm conditions and earlier spring phytoplankton blooms continues.

Major Uncertainties and Potential Consequences on Resource Prospects

The impact of predation depends upon the stock sizes of all predators and availability of alternative forage species, both of which are uncertain. If alternative forage species such as capelin continue to increase, they may become more dominant in the diet of predators, which could slow down the increasing predation pressure on shrimp.

The thermal regime has varied considerably over the past decade, introducing uncertainty. However, the overall trend is warming, with record warm conditions in 2011.

Unknown levels of future fishing mortality also introduce uncertainty.

A most severe 5-year decline in the Div. 2J3KL fishable biomass could result from further decline in shrimp production due to recent and future warm conditions, early phytoplankton blooms, increasing groundfish biomass and low capelin biomass. This decline would be exacerbated if fishery exploitation rates increase.

A least severe 5-year decline (or stability at the current low level) could result from some annual variability in overall recruitment and fishable biomass due to variability in the ocean climate in recent years, limited groundfish recovery, and increase in capelin biomass. The decline in exploitable biomass would be moderated if the exploitation rate is reduced.

Northern Cod

Current Status

The spawning stock biomass (SSB) index declined rapidly in the late 1980s and early 1990s and has been well below the LRP (=B_{lim}, or biomass Limit Reference Point; DFO, 2010) for

more than two decades (Fig. 12). The SSB index was low (<2% of the LRP) during 1993 to 2005 but shows an increasing trend after 2005. This trend has been linked to the increased availability of capelin (Buren et al. 2014b). The three-year average SSB index during 2011-13 represents 18% of the LRP.

The SSB from DFO RV surveys and sentinel catch rates (inshore) do not show a clear trend during 2008-2012 (DFO, 2013). Tagging results suggest that exploitation rates (% harvested) have been about 5% per annum. The lack of a clear upward trend in SSB indicates the stock has not been particularly productive during this period and has not generated much surplus production. However, on the positive side, survival has improved compared with the 1990s; older cod are now being observed offshore, the age structure has expanded, and the distribution of cod in the 2012 and 2013 DFO RV and Sentinel surveys shows some expansion northward in Divs. 3K and 2J.

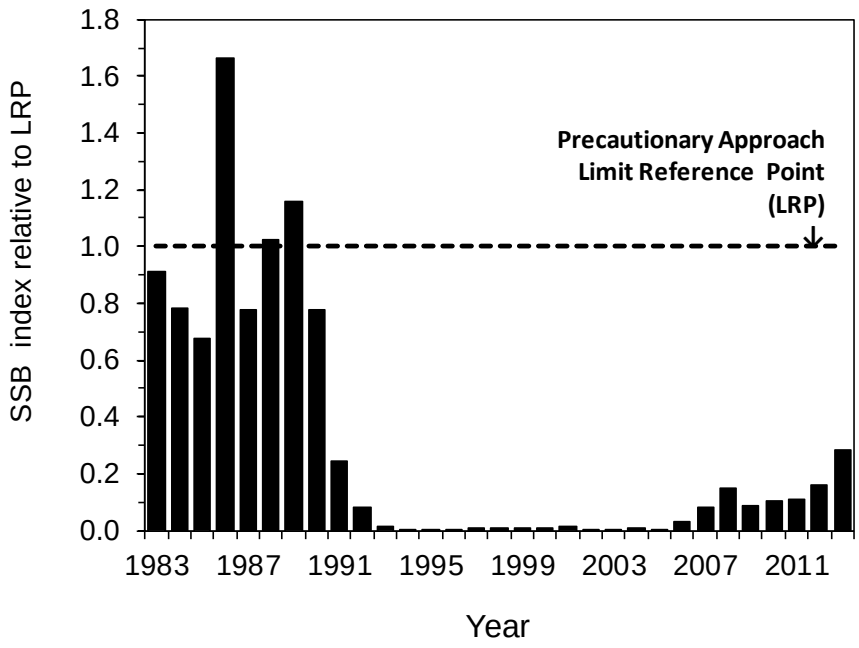

Figure 12. Cod spawning stock biomass (SSB) index from autumn research vessel surveys of NAFO Divs. 2J3KL.

The number of recruits (ages 3 and 4) in the autumn RV survey in the 1990s has consistently been much lower than during the 1980s, but improved slightly in year-classes produced from 2002 to 2009 (Fig. 13). Northern cod typically take about 5 years to reach maturity and recruits (ages 3-4) will contribute to the SSB and fishery 1-2 years later. There are no indications of major changes to SSB due to incoming recruitment (ages 3-4) in the next 1-2 years.

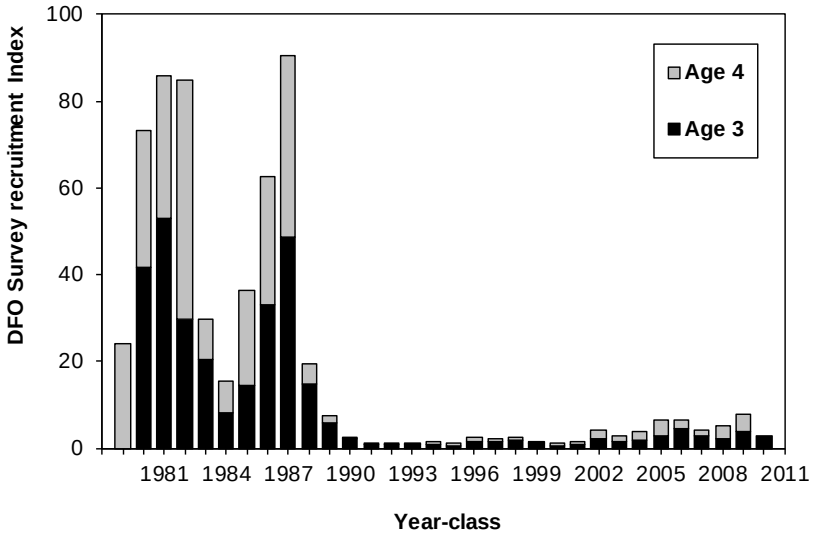

Figure 13. Cod recruitment index (catch rates of each year-class at age 3 and age 4) from autumn research vessel surveys of NAFO Divs. 2J3KL.

Prospects for the next 5 years based on current status and trends

Under productivity conditions observed during 2010-2012 (fishing mortality, natural mortality, and recruitment) the average SSB has been projected to remain stable, well below the LRP.

No projections are available using 2013 survey results, but preliminary indications suggest improved survival and more abundant pre-recruits (ages 1 and 2 (DFO, 2014b)). If these conditions persist, then SSB could improve in 4-5 years (2018-2019), but is expected to remain below the LRP. To reach the LRP by 2019, the stock would have to increase by 50% every year over 2015-2018.

Major Uncertainties and Potential Consequences on Resource Prospects

In recent (2011-2013) surveys, several cohorts have shown increasing numbers at older ages which is not biologically possible. This indicates that one or more of the 2011-2013 surveys may be influenced by a year effect. Consequently, stock trends and total mortality (Z) estimates in the most recent three years and short-term prospects are uncertain.

The 2013 autumn DFO survey found for the first time increased numbers of pre-recruits (ages 1-2) spawned during 2011 and 2012. Until the strength of these year classes is confirmed, their influence on the SSB by 2018-2019 remains uncertain.

Long-term projections conducted during 2009 indicated a broad range of potential outcomes depending on stock productivity scenarios (DFO, 2011). It is highly uncertain which productivity scenario will prevail in 2014-2019.

Changes in the annual level of removals will alter stock prospects and time to recovery.

Prospects for the next five years could be more optimistic if the most recent (2013) survey results reflect current conditions. In this case mortality rates are lower and the more abundant pre-recruits (ages 1 and 2) survive well and recruit to the SSB in 2018-2019. Stock growth could also be enhanced if the improvements in prey (capelin) abundance observed in 2013-2014 persist. However, in this situation the stock is not expected to reach the LRP by 2019.

Prospects for the next five years could be more pessimistic if the 2013 survey result was an overinflated estimate for both biomass and recruitment (year effect). In this case the stock continues to experience relatively high total mortality and does not grow but declines.

Conclusions

Snow Crab

- The overall exploitable biomass has changed little since the mid-2000's. However, both the trap and trawl surveys indicate that Div. 3LNO has accounted for an increased percentage in recent years, from about 40% in 2008 to 75% in 2013.
- Overall, recruitment is expected to decline in the short term (2-3 years).
- A recent warm oceanographic regime suggests weak recruitment in the long term.
- The exploitable biomass has recently declined (and is expected to remain low) in Divisions 2J and 3K, and a decline is expected in Divisions 3LNO in the near future.
- The nature and magnitude of the expected decline in Div. 3LNO, and Div. 2J3KLNO overall, within the next 5 years, are unknown.

Northern Shrimp

- Shrimp fishable biomass in NAFO Divs. 2HJ3KL has declined to its lowest level in the time-series.
- The severity of the decline increases from north (SFA 5: Div. 2HJ) to south (SFA 7: Div. 3L). Corresponding with this pattern, the resource is currently estimated to be in the healthy zone in SFA 5 (Div. 2HJ), in the cautious zone in SFA 6 (Div. 2J3K), and in the critical zone in SFA 7 (Div. 3L).
- Annual shrimp surplus-production rate appears to be reduced since the mid-2000s, particularly in Div. 3L.
- Reduced shrimp production rates were associated with the recent warming trend, early timing of the phytoplankton bloom, increasing biomass of predatory fishes, and fishing.
- The fishable biomass is expected to remain low or decline further over the next 5 years, based on the delayed response of shrimp production to recent and anticipated future unfavourable conditions.

Northern Cod

- Based upon the autumn DFO surveys the three year average SSB increased from 12% of the limit reference point (LRP) in 2010-2012 to 18% in 2011-13. The stock has shown some improvement after 2005 but has remained below the LRP (in the critical zone) since the early 1990s.
- There are no indications of major changes to SSB due to incoming recruitment (ages 3-4) in the next 1-2 years.
- Under productivity conditions observed during 2010-2012 (fishing mortality, natural mortality, and recruitment) the average SSB has been projected to remain stable, well below the LRP.
- No projections are available using 2013 survey results, but preliminary indications suggest improved survival and more abundant pre-recruits (ages 1 and 2). If these conditions

persist, then SSB could improve in 4-5 years (2018-2019), but would likely remain below the LRP.

- If the 2013 survey result was an overinflated estimate for both biomass and recruitment (year effect) the stock will continue to experience relatively high total mortality and will decline rather than experience growth.

Contributors

Name	Affiliation
Brattey, John	DFO Science NL
Coffin, Dave	DFO FAM NL
Corbett, Frank	DFO P&E NL
Dawe, Earl	DFO Science NL
Glavine, Paul	DFO P&E NL
Healey, Brian	DFO Science NL
Koen-Alonso, Mariano	DFO Science NL
Maillet, Gary	DFO Science NL
Meade, James	DFO Science NL (CSAS)
Mowbray, Fran	DFO Science NL
Mullowney, Darrell	DFO Science NL
Orr, Dave	DFO Science NL
Pepin, Pierre	DFO Science NL
Power, Don (Chair)	DFO Science NL
Richards, Dale	DFO Science NL (CSAS)
Rumbolt, Annette	DFO FAM NL
Skanes, Katherine	DFO Science NL
Stansbury, Don	DFO Science NL

Approved by

B. R. McCallum
Regional Director Science
NL Region
Fisheries and Oceans Canada
Date: October 2, 2014

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PO Box 5667
St. John's, NL A1C 5X1

Telephone: (709) 772-3332
Fax: (709) 772-6100
E-Mail: DFONLCentreforScienceAdvice@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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