Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences
Maritimes Region
Canadian Science Advisory Secretariat
Science Advisory Report 2012/035

REFERENCE POINTS CONSISTENT WITH THE PRECAUTIONARY APPROACH FOR A VARIETY OF STOCKS IN THE MARITIMES REGION

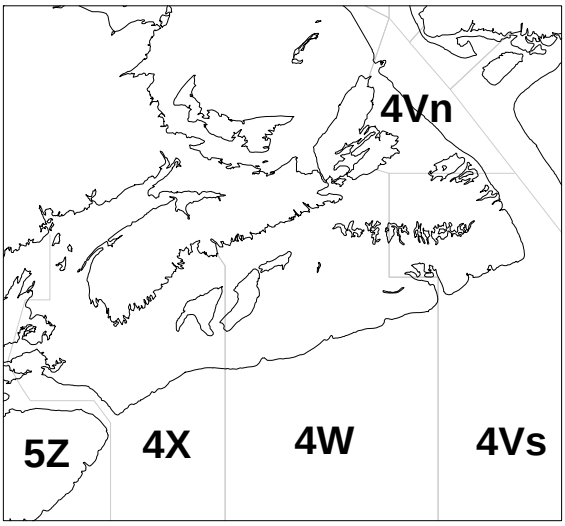

Figure 1. Maritimes Region (NAFO Divisions indicated).

Context

Canada, as signatory to the United Nations Agreement on Straddling and Highly Migratory Fish Stocks (UNFA), has committed to using the Precautionary Approach (PA) in managing stocks targeted by a fishery. In 2009, DFO completed a policy document entitled "A fishery decision-making framework incorporating the Precautionary Approach," which explains in detail how the precautionary approach will be put into practice. To be compliant with the PA, fishery management plans should include harvest strategies that incorporate a Limit Reference Point that delimits the boundary between a critical and cautious zone, and an Upper Stock Reference that delimits the boundary between a cautious and healthy zone on the stock status axis. They should also include a Removal Reference that defines the maximum amount of fishing pressure for each zone.

Fisheries Management and Science in the Maritimes Region determined that PA reference points would be presented for the following Maritimes Region stocks at a regional science advisory meeting: 3NOPs4VWX+5 Atlantic halibut; 4X5Y, 5Zjm,and 4VsW Atlantic cod; 5Zjm and4X5Y haddock, 4VWX snow crab, 4VWX American plaice, western and eastern component pollock, Unit 3 redfish, Southwest Nova Scotia and Bay of Fundy Atlantic herring, Banquereau and Grand Bank Arctic surf clam, Scotian Shelf shrimp, as well as cusk, inshore and offshore scallop, inshore and offshore lobster, Atlantic salmon, American eel, and sea cucumber in the Maritimes Region. Some of these reference points were presented for information only (where they had been peer reviewed previously) and some were presented for peer review. The intent of this meeting was to help develop a common and comprehensive approach, provide science input for discussions on adopting reference points in Integrated Fisheries Management Plans, and demonstrate progress on the regional implementation of DFO's PA framework.

This Science Advisory Report is a product of the Regional Science Advisory meeting of 6-9 February 2012 to review precautionary approach reference points for a variety of stocks in the Maritimes Region. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

SUMMARY

General

- The scientific basis for Limit Reference Points (LRPs), Upper Stock References (USRs), and Removal References (RRs) was proposed or presented for a variety of fish and invertebrate stocks in the Maritimes Region. It is expected that these reference points (particularly the USRs and RRs) will be reviewed with the fishing industry and other advisory committee members prior to their adoption and implementation, with a particular focus on incorporating socio-economic considerations where appropriate to do so.
- The approaches proposed for the selection of reference points for modelled, empirically assessed, and data deficient stocks in the Maritimes Region used different methods depending on the information available for each stock, and were reviewed with respect to consistency with DFO's precautionary approach (PA) framework.
- It was assumed that surveys and other data sources used to establish reference points would continue to be available, in some form, to enable monitoring of stock status relative to these points.

Modelled

3NOPs4VWX+5 Atlantic Halibut

- PA reference points for 3NOPs4VWX+5 Atlantic halibut, based on a modified Sissenwine-Shepard production model using the full time series, were presented for information only.
- Forty percent of spawning stock biomass at maximum sustainable yield (SSB_{MSY}) was presented as the LRP (1,960 t), and 80% of SSB_{MSY} was presented as the USR (3,920 t).
- Fishing mortality at MSY (F_{MSY}=0.36) was presented as a limit RR.
- A target RR of 0.2 has been proposed based on an examination of the data (natural mortality and a rate at which there is scope for growth) and discussions with industry.

4Y5Y Atlantic Cod

- An LRP and limit RR for 4X5Y Atlantic cod were presented for information only. A USR was proposed.
- The LRP (24,000 t) was based on a Beverton-Holt stock-recruitment model using the full time series. The limit RR (0.2) was calculated as $F_{0.1}$ in the 1990s. The USR (48,000 t) is double the LRP.

5Zjm Atlantic Cod

- An LRP for 5Zjm Atlantic cod was presented for information only.
- The LRP (21,000 t) was based on a Beverton-Holt stock-recruitment model using the full time series.

4VsW Atlantic Cod

- An LRP for 4VsW Atlantic cod was presented for information only. A USR was proposed.
- The LRP (50,000 t) was based on 40% of SSB_{MSY} during the productive period before 1990.
- The USR (100,000 t) was based on 80% of SSB_{MSY} during the productive period before 1990.

5Zjm Haddock

- Biomass at MSY (B_{MSY}) and an LRP for 5Zjm haddock were presented for review.
- B_{MSY} (78,000 t) was calculated using a Sissenwine-Shepherd production model for the full time series. The LRP (10,340 t) was based on $B_{recover}$.

4X5Y Haddock

- PA reference points for 4X5Y haddock, based on a Sissenwine-Shepard production model using the full time series, were presented for information only.
- Forty percent of SSB_{MSY} was presented as the LRP (20,800 t), and 80% of SSB_{MSY} was presented as the USR (41,600 t).

4VWX Snow Crab

- PA reference points for 4VWX snow crab, based on a modified biomass dynamics model using the full time series, were presented for review.
- The LRP was proposed as 25% of the carrying capacity of fishable biomass, and the USR was proposed as 50% of the carrying capacity.
- F_{MSY} was proposed as a limit RR. A target RR of 10-30% of the fishable biomass was proposed based upon an examination of the biology of the species, past stock behavior, and discussions with industry.
- The actual values associated with the biomass reference points would be expected to vary over time due to the relative brevity of the current time series.

4VWX American Plaice

- PA reference points for 4VWX American plaice, using a stage-based population model for the full time series to estimate MSY, were presented for review.
- An LRP (12,952 t) of 40% of female-only SSB_{MSY} and a USR (25,905 t) of 80% female-only SSB_{MSY} were proposed.
- F_{MSY} (0.16) was proposed as a limit RR.

Western Component (4Xopqrs5) Pollock

- A Management Strategy Evaluation (MSE) approach has been applied to manage western component (4Xopqrs5) pollock. The MSE approach and Harvest Control Rule (HCR) were presented for information only. How this might be translated into PA reference points was the subject of some discussion.
- The LRP could be defined as the Survey Index Ratio (J_y)=0.2, i.e., when the 3-year geometric mean survey biomass index falls to 20% of the geometric mean survey biomass index for 1984-1994. However, J_y=1.0, i.e., when the 3-year geometric mean survey biomass index reaches the same value as the geometric mean survey biomass index for 1984-1994, was not considered to reflect the definition of a USR. The Survey Index Ratio curve is not used directly to set catch limits, so it was not considered to be reflective of an RR.

Empirical

Eastern Component (4VWXmn) Pollock

- An LRP and USR for eastern component (4VWXmn) pollock were presented for review, based on a proxy for B_{MSY} using data from DFO's summer Research Vessel (RV) survey time series (1970-2011).
- The proposed LRP (40% B_{MSY} proxy) was calculated to be 20,100 t, and the proposed USR (80% B_{MSY} proxy) was calculated to be 40,100 t.

Unit 3 Redfish

- Biological reference points for Unit 3 redfish were presented for information only, based on a proxy for B_{MSY} from DFO's summer RV survey mean (1970-2011). An RR was presented for review.
- Forty percent of the B_{MSY} proxy was presented as the LRP (29,000 t), and 80% of the B_{MSY} proxy was presented as the USR (58,000 t).
- A target RR (0.068) was proposed based on the maximum relative fishing mortality rate (F) that would not result in a reduction in population biomass.

Cusk in the Maritimes Region

- An LRP and USR for cusk in the Maritimes Region were presented for review.
- The proposed LRP (13.3 kg/1000 hooks) and USR (26.6 kg/1000 hooks) were calculated as 40% and 80% of the MSY proxy (commercial longline catch per unit effort from period of high catches, 1986-1992).
- The 3-year geometric mean of the catch per unit effort (2009-2011) from the halibut industry longline survey was 18.2 kg/1000 hooks, which suggests that the stock is in the cautious zone.

Southwest Nova Scotia (SWNS) / Bay of Fundy (BoF) Herring

- An LRP for SWNS/BoF herring was presented for review.
- With the evidence of the decline in spawning grounds, targeting of juveniles in the fishery, declines in catches, as well as the science advice indicating the need for rebuilding, it was proposed that the average of the 2005 to 2010 acoustic survey values be identified as the LRP for SWNS/BoF herring (German Bank and Scots Bay).
- The stability at the 2005-2010 level was support for this as the LRP, and it provided data from which to select a point below which the risk of serious harm would be unacceptable. Other considerations that lead to the selection of this point related to the objective of avoiding negative impacts to the ecosystem and long-term loss of fishing opportunities.

Banquereau and Grand Bank Arctic Surfclam

- PA reference points for Banquereau and Grand Bank Arctic surfclam were presented for review.
- A target RR of F = 0.33M (0.0264) had been recommended previously for Banquereau Arctic surfclam, with a similar approach recommended for Grand Bank Arctic surfclam.
- Using fishable biomass per recruit and estimated average recruitment, the B_{MSY} proxy for Banquereau Arctic surfclam was proposed as 1,015,059 t. Using the default 80% and 40%

of the B_{MSY} proxy, the USR for Banquereau was proposed as 812,047 t and the LRP as 406,024 t.
- Using fishable biomass per recruit and estimated average recruitment, the B_{MSY} proxy for Grand Bank Arctic surfclam was proposed as 703,065 t. Using the default 80% and 40% of the B_{MSY} proxy, the USR was proposed as 562,452 t and the LRP as 281,226 t.
- Currently both stocks are in the healthy zone, above their target biomasses.

Inshore and Offshore Scallop in the Maritimes Region

- The offshore scallop industry developed an LRP, USR, and a target RR for the scallop fishery on Georges Bank to meet requirements for Marine Stewardship Council certification; these were presented for information only. The biological reference points were established as 30% (LRP = 3,000 t) and 80% (USR = 8,000 t) of the mean biomass from the stock assessment population model from 1981-2009 as a proxy for B_{MSY} (10,000 t). The target exploitation rate (0.25) corresponds to the mean exploitation rate since 1999, a period over which population biomass had remained above average. A similar approach was proposed for scallops on Brown's Bank.
- For the inshore scallop fishery, the currently used target RR of 0.15 was proposed for areas where population models are used. For these areas, LRPs based on the lowest biomass that the stocks have recovered from were proposed. For areas where models are not used, the possibility of using commercial catch rate and/or survey catch rates as biomass proxies, and effort as an exploitation proxy, will be investigated.
- For Scallop Fishing Area 29, current research has been directed towards defining reference points based on a habitat suitability model, which has been shown to match the distribution of the fishery.

Scotian Shelf (4VWX) Shrimp

- PA reference points for Scotian Shelf shrimp were presented for review.
- An LRP and USR of 30% (5,459 t) and 80% (14,558 t) of the average SSB maintained during the modern fishery (2000-2010) were proposed.
- Secondary indicators, which were also proposed for review, have been used to inform management responses (i.e., the total allowable catch).
- A target RR of 20% of the SSB (female exploitation) was proposed.
- These reference points had been set for a productive period and may have to be revisited if natural mortality were to increase significantly.

Inshore Lobster (Lobster Fishing Areas [LFAs] 27-36, 38)

- LRPs and USRs for inshore (LFAs 27-36, 38) lobster were presented for review. An approach to establishing a limit RR was also proposed.
- For inshore lobster, PA reference points were provided on an LFA basis, with a B_{MSY} proxy estimated as the median of the landings over a productive period. For the USR and LRP, the values of 80% and 40% of the B_{MSY} proxy were proposed. Where there were observations of lower landings from 1985-2009 from which the fishery recovered, the lowest point of a 3-year running average was proposed as the LRP.
- Secondary indicators for lobster may change the perception of stock status and inform management responses to changes in stock condition. LFAs are not biological units, and connectivity among them should be recognized at the level of secondary indicators.

- Under current conditions, lobsters appear to be resilient to high exploitation. If an RR were to be adopted, it was proposed that it be at the high end (e.g., 90th percentile) of estimates from 1999-2010.

Offshore Lobster (LFA 41)

- PA reference points are being developed as part of the Marine Stewardship Council conditions for the offshore (LFA 41) lobster fishery. Progress to date was presented for information and comment.
- It was proposed that the mean number per tow from DFO's summer (4X) and winter (5Z) RV trawl surveys be assessed as a biomass proxy (B_{MSY}) for the 4X and 5Z portions of the offshore lobster stock.
- Exploitation rates cannot be estimated directly but are inferred to be low based on stability in size structure since the start of the fishery in 1972. Without a direct estimate of exploitation rates, it was proposed that the median size be used as a proxy or index of the exploitation rate.
- Secondary indicators were proposed to assess the stock health, in combination with the primary indicators, and aid in determining the management responses to changes in stock condition.

Atlantic Salmon in the Maritimes Region

- LRPs for Atlantic salmon in the Maritimes Region (Areas 19, 20, 21 and 23) were presented for review.
- The empirical work defining 2.4 eggs/m^2 of fluvial rearing habitat as the Atlantic salmon conservation requirement, its adoption by the Canadian Atlantic Fisheries Scientific Advisory Committee, and recent population dynamics research supporting the Beverton-Holt relationship indicate that, in the Maritimes Region, the conservation requirement is consistent with an LRP in the PA framework.
- Individual river values based on 2.4 eggs/m^2 of fluvial rearing habitat had been estimated using methods that were consistent with the framework advice on dealing with changes in productivity. It was proposed that these estimated values be used as individual river LRPs for the Maritimes Region.
- It was proposed that additional research on refinement of reference points and HCR for fishery removals in this region is not warranted given the current stock status and level of fish removals. Rather, it was proposed that research guiding recovery action plans to appropriately limit mortality from all sources, or to increase productivity would be required.

American Eel in the Maritimes Region

- An LRP and RR for American eel in the Maritimes Region were presented for information only.
- Spawner per Recruit (SPR) modelling was used to define mortality reference points, with the mortality rate that results in 30% of SPR ($F_{30\%SPR}$) proposed as the limit RR, and the mortality rate that results in 50% of SPR ($F_{50\%SPR}$) proposed as the target RR.

Data Deficient

Sea Cucumber in the Maritimes Region

- Two approaches to the setting of reference points for sea cucumber in the Maritimes Region were proposed: one based on split weight and one based on spatial habitat information.

INTRODUCTION

The Department's "*A fishery decision-making framework incorporating the Precautionary Approach"* (PA Policy) provides guidance on implementing a harvest strategy. In resource management, the precautionary approach (PA) in general is about being cautious when scientific information is uncertain, unreliable or inadequate and not using the absence of adequate scientific information as a reason to postpone or fail to take action to avoid serious harm to the resource (DFO 2009). The Privy Council Office Guidance (2003) on implementing a PA instructs that "precautionary measures should generally be implemented on a provisional basis; that is, they should be subject to review in light of new scientific information or other relevant considerations, such as society's level of protection against risk". Accordingly, the data that are currently available will be used for calculating reference points, with the expectation that assessment frameworks and their components will be reviewed periodically and, where appropriate, refined over time.

In general, as long a time series as possible should be used in establishing reference points for a stock. Many stocks will show substantial variation in productivity over a long time series, and this variation should be taken into account when setting the reference points. As a general rule, the only circumstances when reference points should be estimated using only information from a period of low productivity is when there is no expectation that the conditions consistent with higher productivity will ever recur naturally or be achievable through management (DFO 2009). In addition, while the preferred approach is to have reference points and harvest rules based on the best information available on stock biology and fishery characteristics, "default" reference points of 40% B_{MSY} (LRP) and 80% B_{MSY} (USR) are suggested in the PA Policy when there is insufficient information on which to base choices of stock-specific precautionary reference points.

A regional science advisory process was held at the Bedford Institute of Oceanography from 6-9 February 2012 to review PA references for a variety of fisheries resources in the Maritimes Region. The principal purpose of the meeting was to peer review the science input that will form the basis for fishery-specific reference points for a number of the Region's stocks. A secondary purpose was to provide advice on application of the PA Policy, with the expectation that such advice would contribute to the consistency of the Policy's application within the Region.

The components of PA frameworks presented at this meeting were divided into two categories: those that were presented for information, and those that were proposed for peer review. Those components that were presented for information were those where scientific peer review had already taken place. The rationale for including them reflected the secondary purpose of this meeting, which, as stated above, was to provide advice on consistent application of the PA Policy. Those proposed for peer review were those where peer review had not already taken place, or where further review was being sought.

The stocks for which assessment framework components were being presented for peer review were selected because it was believed that significant progress in developing a PA framework could be made in the short term by virtue of there being sufficient data available on the stock and/or removals, there being resources available to work on the framework, and the stock falling wholly or largely within the jurisdiction of the Maritimes Region. The exclusion of stocks from this process was not intended to suggest that the PA Policy did not apply to them or that progress on developing and implementing PA frameworks for them was not expected. Indeed, it was anticipated that the guidance on and experience with application of the PA Policy that would result from this process would help advance the implementation of the PA Policy for all stocks to which it applies.

Recommendations from this advisory meeting will be used to provide science input to Fisheries Advisory Committees where Fisheries Management and the fishing industry will discuss and refine reference points prior to their implementation (DFO 2012).

Definitions

For the purposes of this report, the following definitions are provided:

Limit Reference Point (LRP): As defined in DFO (2006), the LRP is considered here to be the stock level below which productivity is sufficiently impaired to cause serious harm to the resource but above the level where the risk of extinction becomes a concern.

Upper Stock Reference (USR): As defined in DFO (2006), the USR is the stock level threshold below which the removal rate is reduced.

Limit Removal Reference (limit RR): Is defined here as the maximum acceptable removal rate (the Removal Reference in the DFO PA Framework) for conditions under which the reference was set. As explained in DFO (2009), the removal reference is typically expressed in terms of fishing mortality (F) or harvest rate. It could be described in ways other than this, but it must always be described in terms of fishery-related pressure that affects the overall stock.

Target Removal Reference (target RR): Is defined here as some removal rate or a range of removal rates below the limit RR that the fishery targets for economic or ecological reasons.

ASSESSMENT

General

The approaches proposed for the selection of reference points for modelled, empirically assessed, and data deficient stocks in the Maritimes Region use different methods depending on the information available for each stock, and were reviewed with respect to consistency with DFO's PA framework.

In general, modelled stocks made use of the full time series available when setting reference points, while empirically-derived reference points were often based on a productive time period. However, reference points that were set during a current productive period (e.g., shrimp, snow crab, lobster) may need to be revisited if conditions become unfavourable. Appendix A summarizes the approach and reference points for each stock considered.

For many stocks, the use of secondary indicators was considered to be helpful, and in some cases necessary, for context in establishing stock status, in determining appropriate management responses, or, with further work, to help refine harvest control rules.

It was recommended that the assumed characteristics (e.g., gear selectivities) of the fisheries for each stock be clearly defined when establishing removal references.

The biological reference points were set in a single-species context; however, important linkages between species were recognized. In some cases, target removal references were set with consideration of these interactions. Further work would be required to explore the implications of species interactions, and the impacts of changing environmental conditions, on reference point selection.

Modelled

3NOPs4VWX+5 Atlantic Halibut

PA reference points for 3NOPs4VWX+5 Atlantic halibut (*Hippoglossus hippoglossus*) were presented for information only, as they had been reviewed previously during the halibut framework (DFO 2011a) and most recent assessment (Trzcinski and Mohn 2012).

A modified Sissenwine-Shepherd production model was run to estimate maximum sustainable yield (MSY) and related parameters using the full time series available. A Ricker stock-recruitment relationship was assumed. Forty percent of spawning stock biomass at MSY (SSB_{MSY}) was presented as the LRP (1,960 t) and 80% of SSB_{MSY} was presented as the USR (3,920 t). The biomass metric used was spawning stock biomass (SSB), as opposed to total or fishable biomass.

Fishing mortality at MSY (F_{MSY} = 0.36) was presented as a limit RR (as the fully recovered F). A target RR of 0.2 has been proposed based on an examination of the data (natural mortality and a rate at which there is scope for growth) and discussions with industry.

No secondary indicators were considered at this time. Monitoring of the LRP and USR would be based on the annual halibut longline survey and DFO's annual summer Research Vessel (RV) survey. The RR could be monitored through monitoring of the catches that produce F in the projections or through monitoring of F produced from tagging studies.

A large degree of uncertainty in the USR and LRP are due to the stock-recruitment model chosen. The Ricker model fit the data better, but if the Beverton-Holt model is true then our understanding of the productivity of the stock changes dramatically, producing an LRP that is twice as high.

Further discussions with industry are required to determine an accepted harvest control rule (HCR) for incorporation into the management plan.

4X5Y Atlantic Cod

An LRP and limit RR for 4X5Y Atlantic cod (*Gadus morhua*) were presented for information only, as the LRP had been reviewed previously at a zonal advisory meeting in 2010 (Clark et al. 2011) and the limit RR has been adopted by the Scotia-Fundy Groundfish Advisory Committee. A USR was proposed.

The previously proposed LRP was based on a Beverton-Holt stock-recruitment model and was calculated to be 24,000 t using the full time series available (1980-2007). The accepted limit RR (0.2) was calculated as $F_{0.1}$ in the 1990s.

The USR proposed here (48,000 t) is double the LRP. Reaching the USR is expected to be difficult without a reduction in natural mortality.

No secondary indicators were considered at this time. Monitoring of the LRP and USR (Age 3+ biomass) would be based on trends in DFO's annual summer RV survey and periodic assessments.

5Zjm Atlantic Cod

5Zjm Atlantic cod is a transboundary stock that is co-managed with the USA. An LRP for 5Zjm Atlantic cod was presented for information only, as it had been reviewed previously at a zonal advisory meeting in 2010 (Clark et al. 2011).

The previously proposed LRP was based on a Beverton-Holt stock-recruitment model and was calculated to be 21,000 t using the full time series available (1978-2009).

No secondary indicators were considered at this time. Monitoring of the LRP (3+ biomass) would be based on trends in the annual Georges Bank RV surveys and annual assessments.

4VsW Atlantic Cod

An LRP for 4VsW cod was presented for information only, as it had been reviewed previously at a recovery potential assessment in 2011 (DFO 2011b).

The LRP (50,000 t) was based on 40% of SSB_{MSY} during the productive period before 1990. Estimated SSB has been below the LRP since 1992 with the exception of the 2009 estimate of 64,000 t, 25% above the LRP.

The proposed USR (100,000 t) was based on 80% of SSB_{MSY} during the productive period before 1990 (1958-2009).

No RR has been proposed at this time, as fully recruited F and F_{MSY} depend on fishing patterns. There is no directed fishery at this time.

No secondary indicators were considered at this time. Monitoring of the LRP and USR would be based on trends in DFO's annual summer RV survey.

5Zjm Haddock

5Zjm haddock (*Melanogrammus aeglefinus*) is a transboundary stock that is co-managed with the USA. B_{MSY} and an LRP for 5Zjm haddock were presented for review (Wang and Van Eeckhaute 2012). Advice on an RR or USR has not been requested at this time.

Based on the conclusion that 5Zjm haddock has not experienced productivity regime changes during 1931 to 2011, the long-term time series for weights at age and recruit/SSB and population weighted Partial Recruitment (PR) from 1995 to 2010 (due to gear changes) were used for the reference point calculations. SSB_{MSY} was calculated using a Sissenwine-Shepherd production model to be 78,000 t with a 95% confidence interval of 60,000 t to 91,000 t. The LRP

was based on $B_{recover}$ and was determined to be 10,340 t with a 95% confidence interval of 10,250 t to 10,430 t.

No secondary indicators were considered at this time. Monitoring of the LRP would be based on trends in the annual Georges Bank RV surveys and annual assessments.

4X5Y Haddock

PA reference points for 4X5Y haddock were presented for information only, as they were reviewed previously at the most recent assessment (DFO 2012).

Using a Sissenwine-Shepard production model for the full time series (1970-2010), MSY was estimated to be 14,700 t and SSB_{msy} was estimated to be 52,000 t. Forty percent of SSB_{MSY} was presented as the LRP (20,800 t), and 80% of SSB_{MSY} was presented as the USR (41,600 t).

Monitoring of the LRP and USR would be based on trends in DFO's annual summer RV survey with periodic assessments.

An RR will be reviewed at the next framework assessment.

4VWX Snow Crab

PA reference points for 4VWX snow crab (*Chionoecetes opilio*) were presented for review (Choi et al. 2012).

A modified biomass dynamics model (1999-present) was used to determine reference points relevant to 4VWX snow crab. The LRP was proposed as 25% of the carrying capacity of fishable biomass, and the USR was proposed as 50% of the carrying capacity. The fishable biomass is that of mature male crab > 95 mm carapace width (CW).

F_{MSY} was proposed as a limit RR. A target RR of 10-30% of the fishable biomass was proposed based upon an examination of the biology of the species, past stock behavior, and discussions with industry. The actual values associated with the biomass reference points would be expected to vary over time due to the relative brevity of the current time series.

Using these reference points, an HCR is proposed (Figure 2).

A number of secondary indicators are reviewed during the annual stock assessment. These are used to modulate the harvest control rule, as they reduce the uncertainties associated with using solely the primary stock status indicator.

Monitoring of the LRP, USR and RRs would be based on the fishery, annual snow crab survey, and assessments.

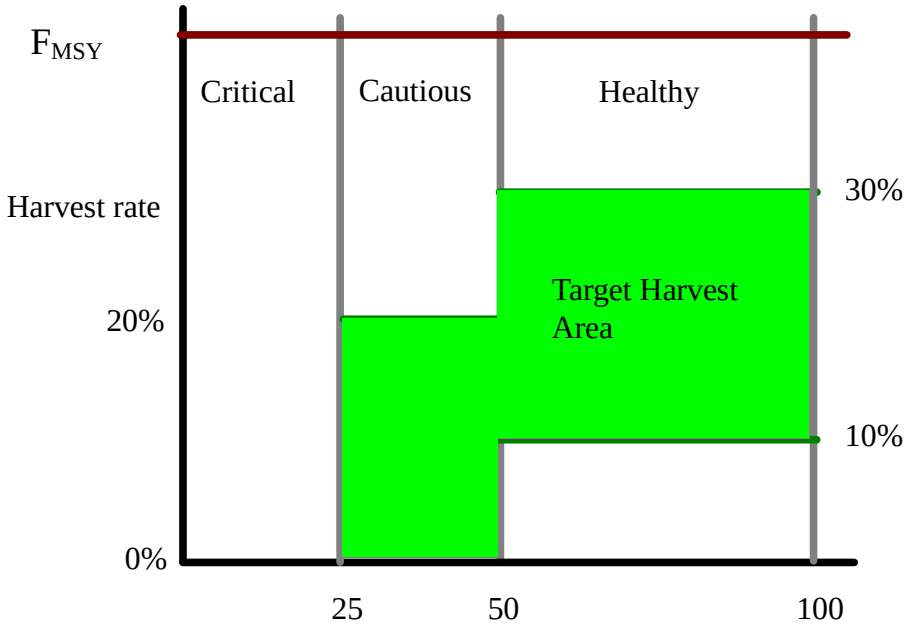

Figure 2. Proposed Harvest Control Rule for 4VWX snow crab.

4VWX American Plaice

PA reference points for 4VWX American plaice (*Hippoglossoides platessoides*) were presented for review (Fowler 2012).

A stage-based population model (using the full time series: 1970-2009) was run to estimate MSY and related parameters for 4VWX American plaice, with female-only SSN_{MSY} suggested as the basis for reference points. This is converted to SSB_{MSY} for management purposes.

An LRP (12,952 t) of 40% of female-only SSB_{MSY} and a USR (25,905 t) of 80% female-only SSB_{MSY} were proposed. Female length at 50% maturity (L_{50}) was proposed as a secondary indicator with which to monitor for changes in productivity.

F_{MSY} (0.16) was proposed as a limit RR (as the fully recovered F).

Using these reference points, an HCR is proposed (Figure 3).

An approach to monitoring of these reference points needs further development.

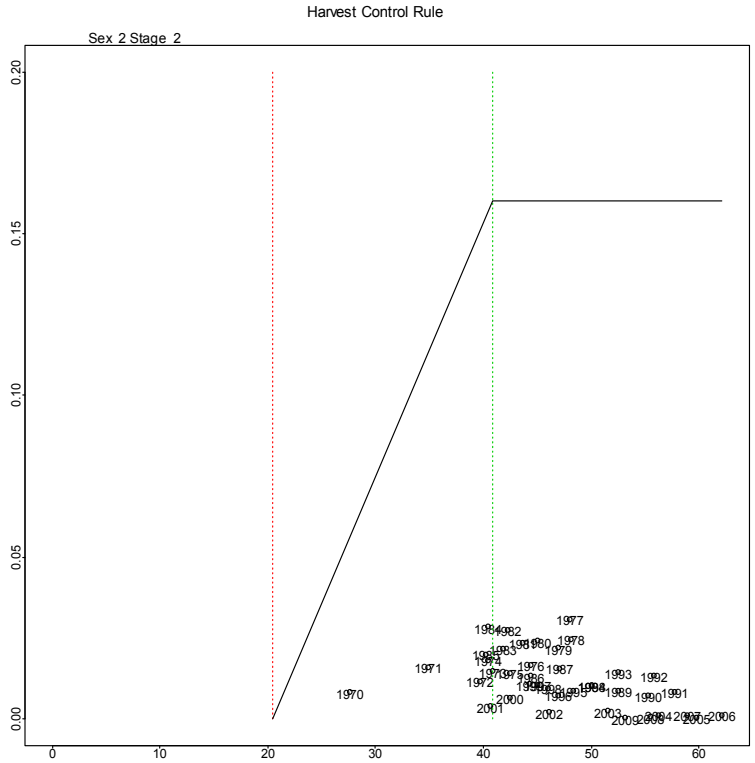

Figure 3. The proposed Harvest Control Rule for American plaice, with fishing mortality as the vertical axis and SSN as the horizontal axis. The vertical lines represent the LRP and USR bounding the Cautious Zone. The precautionary F line is a diagonal slider in the Cautious Zone, attaining a plateau at F_{MSY} for SSN values above SSN_{MSY}.

Western Component (4Xopqrs5) Pollock

A Management Strategy Evaluation (MSE) approach has been applied to manage western component (4Xopqrs5) pollock (*Pollachius virens*) (DFO 2011c). A management procedure model was developed to optimize pre-defined management objectives and is coupled with an HCR to either increase/decrease the future catch limits based on results from ongoing monitoring from DFO's annual summer RV survey. The medium term management objectives include:

1. *Sustainability:* maintain exploitable (B^{4-8}) biomass in 2021 at a level 1.5 times B^{4-8} in 2000 (7,400 t from Virtual Population Analysis x 1.5 = 11,100 t).

2. *Catch:* must be greater than 4,000 t/year over next 5 years, starting in 2012.

3. *Restrictions on annual catch changes and maximum catch:* maximum inter-annual catch increase of 20% or 500 t, whichever is greater; maximum inter-annual catch decrease of 20% (which could be greater depending on survey results).

The MSE uses results from a core group of operating models that span the most important sources of uncertainty about the resource, then projects what population abundance would be over the next 10 years given a certain level of harvest and some assumptions about future recruitment. There are exceptional circumstance provisions in place to cover situations that fall outside the range for which the management procedure model was simulation tested (i.e., extreme survey results) and would allow for some form of intervention.

The MSE approach and HCR (Figure 4) were presented for information only. How this might be translated into PA reference points, as described by DFO (2006), was the subject of some discussion at this meeting. The LRP could be defined as the Survey Index Ratio (J_y)=0.2, i.e., when the 3-year geometric mean survey biomass index falls to 20% of the geometric mean survey biomass index for 1984-1994, which triggers an exceptional circumstance. However, while it was proposed that the USR could be defined as J_y=1.0, i.e., when the 3-year geometric mean survey biomass index reaches the same value as the geometric mean survey biomass index for 1984-1994, this was not considered to reflect the definition of a USR. The Survey Index Ratio curve is not used directly to set catch limits, so it was not considered to be reflective of an RR.

A secondary indicator could be the changes in age structure from the fishery and survey (either expanded or contracted) that could trigger an exceptional circumstance.

The summer RV survey biomass index will be the primary source monitoring data used to update the management procedure calculations for future catch limits for the western component pollock. The expected operating timeframe for the MSE is 5 years, after which there will be a thorough review which may result in revisions to the management procedure model.

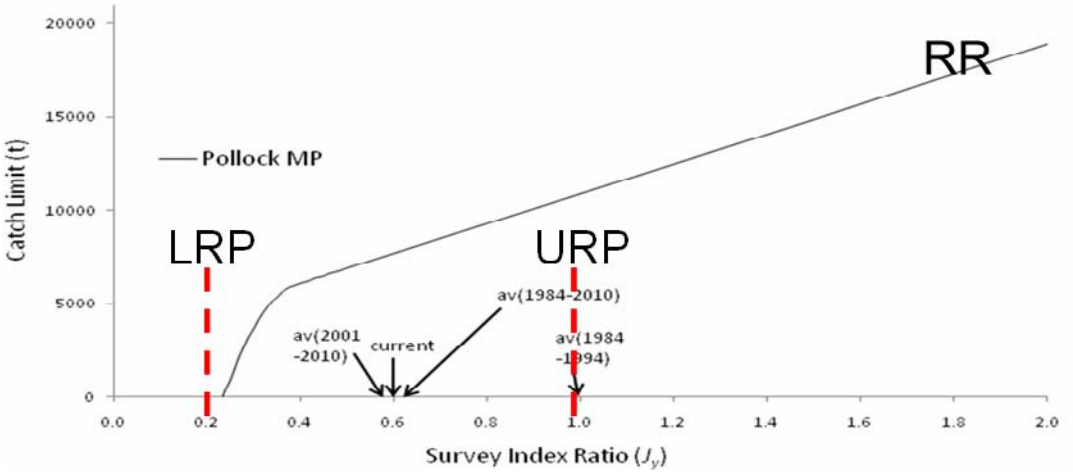

Figure 4. Catch limit from the western component pollock management procedure (MP) model versus survey index ratio (J_y).

Empirical

Eastern Component (4VWXmn) Pollock

An LRP and USR for eastern component (4VWXmn) pollock were presented for review (Stone 2012).

Biological reference points were calculated based on a proxy for B_{MSY} using data from DFO's summer RV survey time series (1970-2011). For the purpose of calculating reference points, it was assumed that productivity of this resource has not changed appreciably over the past four decades. A 10-year period from 1984-1993 was arbitrarily chosen to reflect a sustained period of high productivity. The bias adjusted geometric mean total biomass from 1984-1993 from the summer RV survey (used as a proxy for B_{MSY}) was 50,200 t with a 95% Confidence Interval (CI) ranging from 36,700 t to 72,600 t. No secondary indicators were proposed at this time.

The proposed LRP (40% B_{MSY} proxy) was calculated to be 20,100 t (95% CI: 14,674 to 29,043 t), and the proposed USR (80% B_{MSY} proxy) was calculated to be 40,100 t (95% CI: 29,347 to 58,086 t).

Total survey biomass has only been above the LRP five times since 1994, four of which have occurred since 2006, suggesting that the status of this resource is improving.

Future research should focus on the development of an HCR for eastern component pollock based on results from ongoing monitoring (i.e., annual summer RV survey) as well as reducing the variability in the summer survey series (i.e., by increasing the number of sets).

Unit 3 Redfish

Biological reference points for Unit 3 redfish (*Sebastes fasciatus)* were presented for information only, as they had been reviewed previously at a Recovery Potential Assessment (DFO 2011d). An RR was presented for review.

A proxy for B_{MSY} from DFO's summer RV survey mean (1970-2010) mature biomass (>22cm) was previously calculated to be 73,000 t. Forty percent of the B_{MSY} proxy was presented as the LRP (29,000 t), and 80% of the B_{MSY} proxy was presented as the USR (58,000 t). No secondary indicators were proposed at this time.

A target RR (0.068) was proposed based on the maximum relative F that would not result in a reduction in population biomass.

Using these reference points, an HCR was proposed (Figure 5).

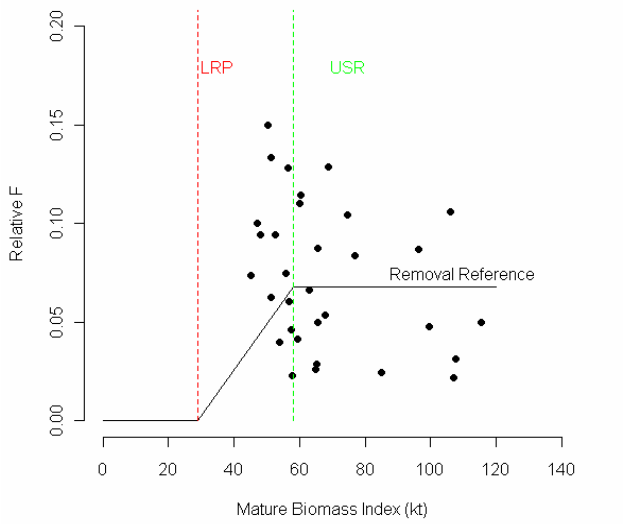

Figure 5. Graphical representation of the precautionary approach reference points for Unit 3 Redfish. Values for Limit Reference Point (LRP), Upper Stock Reference (USR), and Removal Reference are 29,000 t, 58,000 t, and 0.068, respectively.

Cusk in the Maritimes Region

An LRP and USR for cusk (*Brosme brosme*) in the Maritimes Region were presented for review (Harris et al. 2012).

Proposed biological reference points for cusk were based on the average commercial longline catch per unit effort from 1986-1992 (considered a productive period), scaled to the halibut longline survey catch per unit effort, as a proxy for MSY. The proposed LRP is 40% of the MSY proxy (13.32 kg/1000 hooks), and the proposed USR for cusk is 80% of the MSY proxy (26.6 kg/1000 hooks).

The recent trend in the halibut survey would be used to determine the status of the cusk biomass in relation to the reference points.

The mean catch per unit effort (CPUE) from the halibut industry longline survey has been at or above the proposed LRP for the last 3 years, although a high level of uncertainty is indicated by the wide confidence interval. The 3-year geometric mean of the CPUE (2009-2011) was 18.2 kg/1000 hooks, which suggests that the stock is in the cautious zone.

Southwest Nova Scotia/Bay of Fundy Herring

An LRP for Southwest Nova Scotia/Bay of Fundy herring (*Clupea harengus)* was presented for review (Clark et al. 2012).

With the evidence of the decline in spawning grounds, targeting of juveniles in the fishery, declines in catches, as well as the science advice indicating the need for rebuilding, it was proposed that the average of the 2005 to 2010 acoustic survey values (Figure 6) be identified as the LRP for Southwest Nova Scotia/Bay of Fundy herring (German Bank and Scots Bay). The stability at the 2005-2010 level was support for this as the LRP, and it provided data from which to select a point below which the risk of serious harm would be unacceptable.

Other considerations that led to the selection of this point relate to the objective of avoiding negative impacts to the ecosystem and long-term loss of fishing opportunities. Ecosystem considerations include herring's role as a forage fish.

It is proposed that a 3-year running average be used to determine the state of the Southwest Nova Scotia/Bay of Fundy herring (German Bank and Scots Bay) in relation to the LRP because of the variability in the annual acoustic point estimates. Given the life history characteristics of herring, the 3-year running average is more appropriate for detecting the trend and would smooth out the inter-annual variability.

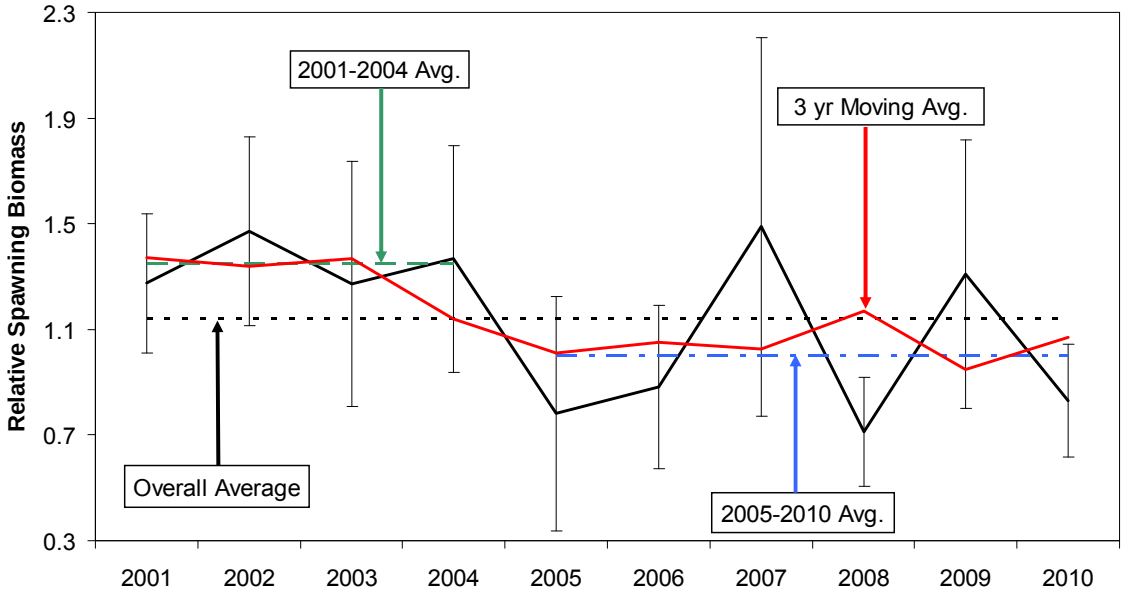

Figure 6. Relative spawning stock biomass index (with 95% standard errors) and the calculated three year moving average for the SW Nova Scotia/Bay of Fundy spawning component (German Bank and Scots Bay), scaled to the period 2005 to 2010.

Grand Bank and Banquereau Arctic Surfclam

Reference points for Grand Bank and Banquereau Arctic surfclam (*Mactromeris polynyma*) had been proposed previously (Roddick et al. 2007; Roddick et al. 2011) but were presented for further review.

A target RR of F = 0.33M (0.0264) had been recommended previously for Banquereau Arctic surfclam, with a similar approach recommended for Grand Bank Arctic surfclam. For the Grand Bank, the dredge efficiency was assumed to be 1, which results in an underestimate of current biomass. This bias will affect the average recruitment estimate at the same time, so the relative position of the current and target biomass estimates, and thus the determination of stock health, should be correct.

Using fishable biomass per recruit and estimated average recruitment, the B_{MSY} proxy was proposed as 1,015,059 t for Banquereau and 703,065 t for Grand Bank Arctic surfclam. Since these stocks have never been depleted, a stock-recruit function cannot be estimated and the historic lows cannot be used to estimate reference levels. Using the default 80% and 40% of the B_{MSY} proxy, the USR and LRP for Banquereau Arctic surfclam were proposed as 812,047 t and 406,024 t. For Grand Bank Arctic surfclam, the USR and LRP were proposed as 562,452 t and 281,226 t, respectively.

Currently both stocks are in the healthy zone, above their target biomasses and are being fished at a rate that is below the target removal rate.

This fishery is relatively new and has not had a high exploitation rate to date. The species is long-lived and there are a large number of year classes in the catch. Because of this, it is not known how the stock or ecosystem would react to the stock being fished down to low levels.

Inshore and Offshore Scallop

The fisheries for sea scallops (*Placopecten magellanicus*) in the Maritimes Region are managed geographically as offshore fisheries (Georges, Browns, German, Sable, Western and Middle banks) and inshore fisheries (Bay of Fundy and approaches, Scallop Fishing Area [SFA] 29 West). Population models are used to set total allowable catch (TAC) advice for a number of scallop fisheries, but the lack of stock/recruitment relationships and evidence for B_{MSY} in the surplus production estimates makes it difficult to use these models to estimate biomass-based reference points. As a result, empirical reference points have been developed.

Georges Bank 'A' Scallop

The offshore scallop industry developed an LRP, USR, and target RR for the scallop fishery on Georges Bank to meet requirements for Marine Stewardship Council (MSC) certification (Smith and Hubley 2012); these were presented for information only.

The biological reference points were established as 30% (LRP = 3,000 t) and 80% (USR = 8,000 t) of the mean biomass from the stock assessment population (delay-difference) model from 1981-2009 as a proxy for B_{MSY} (10,000 t). Note that 10,000 t approximately delineates the periods of high and low average levels of biomass in this fishery.

The industry proposal also defined the mean exploitation of 0.25 as a target RR. The target exploitation rate corresponds to the mean exploitation rate since 1999, a period over which population biomass has remained above average. This rate was also very close to the exploitation rate that was calculated to result in no change in scallop biomass (0.27) from 1981-2007. This definition of an RR, along with the biomass reference points mentioned above, can be used to construct an HCR (Figure 7).

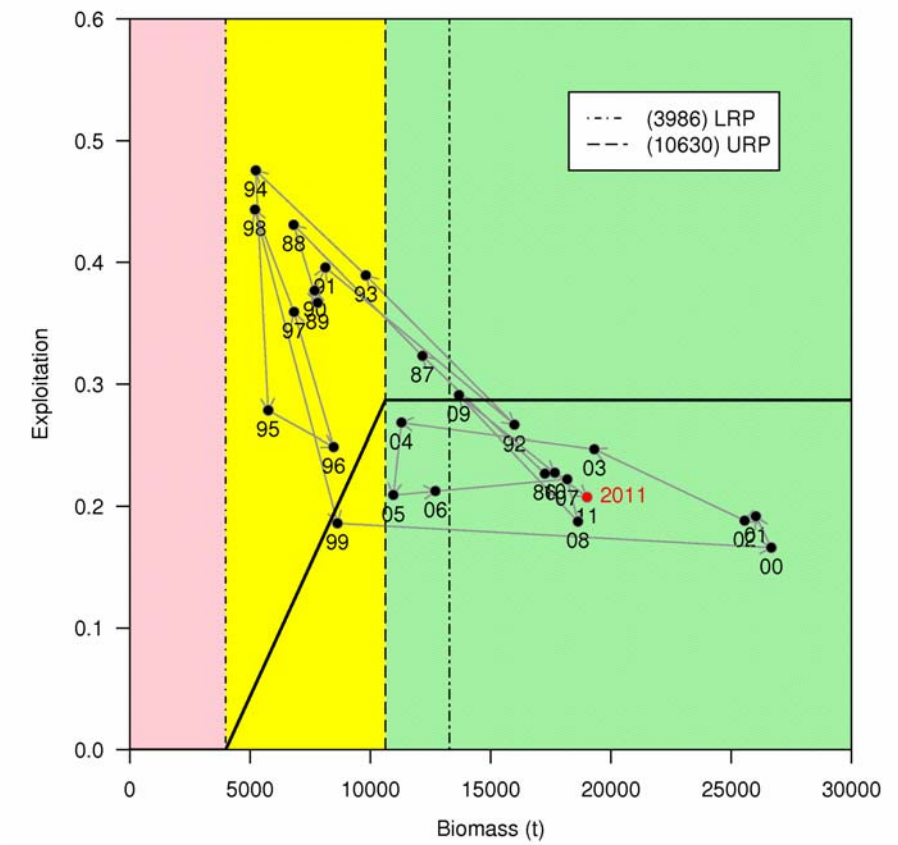

Figure 7. Reference points and harvest control rules for scallop on Georges Bank based on the Marine Stewardship Council (MSC) accepted proposal from the offshore scallop industry. Note: the range of years displayed here differs from the range used for MSC certification.

Browns Bank Scallop

Reference points for Brown's Bank scallop were proposed for review (Smith and Hubley 2012).

Using the approach for Georges Bank 'A' described above, a PA framework for Browns Bank North could be as follows: an LRP and USR defined as 30% (2,184 t) and 80% (5,824 t) of the mean biomass from the stock assessment population (delay-difference) model from 1991-2010 as a proxy for B_{MSY} (7,281 t). The proposed LRP is similar to the lowest biomass from which a secure recovery has been demonstrated (2,730 t in 1991).

A target RR could be the exploitation rate that represents no change in biomass (0.1).

These reference points could be used to construct a candidate HCR (Figure 8).

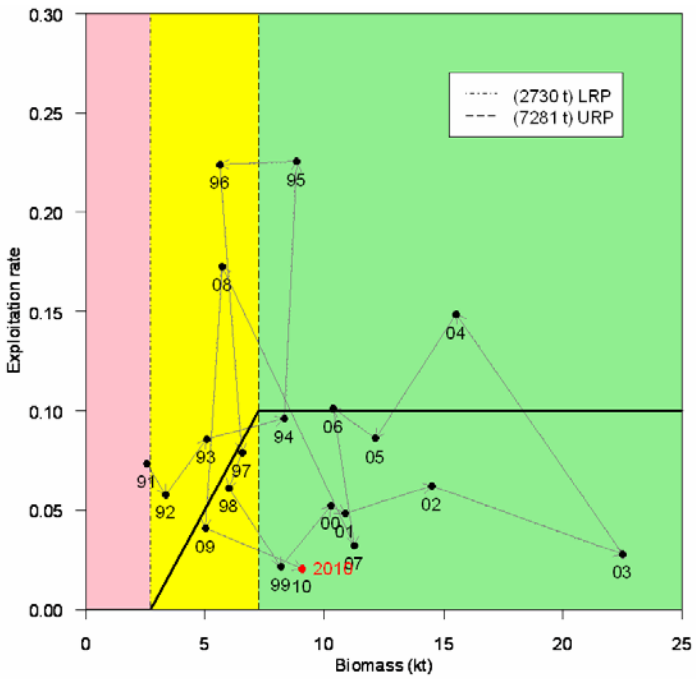

Figure 8. Proposed reference points and harvest control rules for scallop on Brown's Bank based on the MSC accepted rules for Georges Bank scallop.

Inshore Scallop

Discussions have been initiated with representatives of the inshore scallop industry on setting reference points and developing HCRs. Currently, HCRs are in place for areas where population models are used to keep exploitation close to a target of 0.15. This target level was determined according to empirical estimates of the exploitation rate that resulted in no change in biomass from year to year. For those areas where population models are used, LRPs based on the lowest biomass that the stocks have recovered from have been proposed (Smith and Hubley 2012). Setting of the USR will require discussion on setting the biomass level high enough that there would be time for management action with minimal economic disruption. The USR will also have to reflect the productivity of the stocks.

For those inshore and offshore areas where models are not used, the possibility of using commercial catch rates and/or survey catch rates as biomass proxies, and effort as an exploitation proxy, will be investigated.

The scallop fishery in SFA 29 West began in 2001, and the population biomass has been fished down from very high levels. As a result, the time series of catch rates and biomass estimates from the surveys contain little information on the range of potential scallop productivities or the lowest biomass level for stock recovery that could be used to set the LRP. Current research has been directed towards defining reference points for the SFA 29 West area based on a habitat suitability model, which has been shown to match the distribution of the fishery. Research indicates changes in scallop density due to the fishery (i.e., highest densities occur initially in the higher suitability areas and fishing tends to level out the densities over all areas), and has also demonstrated that scallops in different habitats exhibit different intrinsic growth rates. Current work is concentrating on using a combination of productivity, density, and area to identify LRP and USR reference points that could be used for scallops in this area, and eventually the other areas being managed.

Scotian Shelf Shrimp

PA reference points for Scotian Shelf shrimp (*Pandalus borealis*) had been proposed previously (Hardie et al. 2011) but were presented for further review.

For Scotian Shelf shrimp, an LRP of 30% of the average SSB (5,459 t) maintained during the modern fishery (2000-2010) was proposed. This was approximately equal to the average SSB during the low-productivity (pre-1990) period, characterized by low shrimp abundance, high groundfish abundance and relatively warm temperatures. The justification for this metric as the LRP is twofold. First, the Scotian Shelf shrimp population previously increased from low level during the transition from low- to high-productivity, so the working assumption was that shrimp could once again recover from this level given appropriate environmental conditions and fishing pressure. Secondly, given the important role of shrimp in the Scotian Shelf ecosystem, particularly as prey for groundfish, this LRP was set to avoid a decrease in shrimp abundance below the level at which it was previously able to fulfill its ecosystem roles under a situation of high groundfish abundance (i.e., to avoid a scenario in which low shrimp abundance could act as a limiting factor in groundfish recovery).

A USR of 80% of the average SSB (14,558 t) maintained during the modern fishery (2000-2010) was proposed. This USR has been selected as it maintains a sufficient gap between the LRP and USR to account for uncertainty in the stock and RR values, and to provide sufficient time for real biological changes in the population to be expressed, detected and acted upon.

Secondary indicators, which were also proposed for review, have been used to inform management responses (i.e., the total allowable catch).

A target RR of 20% of the SSB (female exploitation) was proposed. Given that shrimp survive for approximately 3-4 years after their recruitment to the fishery, it can be approximated that on the order of 25-33% of the fishable biomass would be subject to natural mortality in any given year. Although some have suggested that exploitation scenarios in which fishing mortality equals natural mortality results in optimal yield, this approach has been shown to overestimate potential yields in many stocks. As a result, the maximum RR of 20% for shrimp is on the conservative side of the simplistic approximate range of natural mortality (25-33%). In addition, 20% has not been exceeded during the modern fishery, a period during which CPUE and biomass have remained high.

These reference points had been set for a productive period and may have to be revisited if natural mortality were to increase significantly.

Inshore Lobster (Lobster Fishing Areas 27-36, 38)

LRPs and USRs for inshore (Lobster Fishing Areas [LFA] 27-36 and 38) lobster (*Homarus americanus*) were presented for review (Tremblay et al. 2012). An approach to establishing a limit RR was also proposed.

For inshore lobster, PA reference points were provided on an LFA basis. It is recognized that LFAs are not biological units, and connectivity among them should be recognized at the level of secondary indicators. Research on the appropriate biological units is underway. A B_{MSY} proxy was estimated as the median of the biomass proxy (landings) over a productive period. The median is proposed rather than the mean, as the frequency distribution of landings is skewed and the median gives less weight to the high landings seen in some areas in recent years. The

25-year period from 1985-2009 is proposed. This represents a productive period but also includes years when landings were substantially lower than at present.

For the USR and LRP, the values of 80% and 40% of the B_{MSY} proxy were proposed as suggested in the PA Policy. Where there were observations of lower landings from 1985-2009 from which the fishery recovered, the lowest point of a 3-year running average was proposed as the LRP. These values are set out for each LFA in Table 1. To reduce the uncertainty of using landings from a single year, a 3-year running mean of landings (mean of 3 most recent years) would be used to decide whether the biomass proxy was below the USR. For each LFA, the LRP is substantially above the lowest landings recorded from 1947-2009. The USRs are substantially lower than recent landings and target reference points based on alternative measures of stock productivity or on economics should be considered.

Table 1. Upper Stock References (USR) and Limit Reference Points (LRP) by LFA (based on landings). The recommended LRP is highlighted in bold. The LRP in last column is the lowest point of 3-year running average for 1985-2009. The last column is the lowest recorded landings from 1947-2009, together with the year in brackets.

LFA	B_{MSY} proxy (Median 1985-2009)	USR (80%)	LRP (40%)	LRP (lowest 1985-2009	Lowest 1947-2009 (Year)
27	2,036	1,629	**814**	1,390	540 (1969)
28-29	150	120	60	**57**	20 (1978)
30	99	79	**40**	65	13 (1980)
31	313	250	**125**	175	41 (1980)
32	303	242	**121**	229	49 (1979)
33	2,297	1,838	**919**	1696	213 (1978)
34	11,071	8,857	**4,428**	6,834	2,215 (1959)
35	731	585	292	**240**	71 (1980)
36	666	533	266	**247**	65 (1977)
38	648	518	259	329	130 (1976)

Given uncertainties and caveats in the use of landings as a biomass proxy, and uncertainties in the stability of the current lobster production region, the proposed reference points should be used only with additional consideration of secondary indicators.

Available secondary indicators vary from LFA to LFA. Five groups of secondary indicators were proposed for consideration:

- abundance/biomass (commercial sizes);
- production (recruitment, reproduction);
- demography (size structure, sex ratio);
- fishing pressure (effort, exploitation); and
- environment (factors potentially affecting catchability, e.g., temperature and storms, and physical or biological factors affecting recruitment, growth, and survival).

Secondary indicators of commercial biomass, together with fishing effort and key indicators of lobster catchability, could be used to verify that changes in landings reflect abundance changes. For example, reduced fishing effort or conditions that reduce lobster catchability might explain a decline in landings unrelated to abundance. By averaging the biomass proxy (landings) over 3 years, it is less likely that annual differences in catchability would affect the reliability of the biomass proxy, but these factors need consideration.

Secondary indicators may change the perception of stock status and inform management responses to changes in stock condition. Some of the secondary indicators could become "primary indicators" in the near future (next 5 years) with associated reference points.

Under current conditions, lobsters appear to be resilient to high exploitation. If an RR were to be adopted, it was proposed that it be at the high end (e.g., 90th percentile) of estimates from 1999-2010. If the production regime changes to one that is less favourable to lobster populations, the current levels of exploitation would likely need to be reduced.

Suggested next steps:

- Further explore data on lobsters captured in trawl surveys (ITQ, summer trawl, scallop surveys). Develop abundance indicators(s) and reference points as appropriate.
- For all LFAs, develop an alternative to landings as the sole commercial biomass proxy, and, where the alternative is not fishery-independent, develop protocols to conduct fishery-independent surveys for application if the biomass proxy approaches the cautious zone.
- Explore the University of Maine model for application to one or more of Maritimes Regions LFAs.
- Further develop secondary indicators, including:
  - improve models of CPUE of commercial sizes, sublegal sizes and spawners;
  - evaluate how indicators for adjacent interacting management units can be incorporated into decision making;
  - develop (or use existing) indicators that would signal a change in the production regime either due to environmental factors or predator abundance; and
  - evaluate the rate of mating success and interaction with sex ratio, and assess effect on population egg production.

Offshore Lobster (LFA 41)

PA reference points are being developed as part of the MSC conditions for the offshore (LFA 41) lobster fishery. Progress to date was presented for information and comment.

It was proposed that the mean number per tow from DFO's summer (4X) and winter (5Z) RV trawl surveys be assessed as a biomass proxy (B_{MSY}) for the 4X and 5Z portions of the offshore lobster stock. Various reference time periods and indicator boundary levels were discussed and further analysis is underway.

Exploitation rates cannot be estimated directly but are inferred to be low based on stability in size structure since the start of the fishery in 1972. Without a direct estimate of exploitation rates, it was proposed that the median size be used as a proxy or index of the exploitation rate.

Secondary indicators were proposed to assess the stock health, in combination with the primary indicators, and aid in determining the management response to changes in stock condition.

Secondary indicators include:

- Additional estimates of biomass and indicators of spatial distribution from the Individual Transferable Quota (ITQ) trawl survey (4X), DFO summer RV surveys in 4W, and the USA National Marine Fisheries Service (NMFS) RV surveys (5YZ).
- Indicators of lobster demographics including size, sex ratios, mating success, and reproductive potential from at sea samples of commercial catch, DFO, and NMFS RV surveys, and the ITQ survey.
- Indicators of environmental and ecosystem conditions such as bottom water temperature, major oceanographic events, predation levels and disease.

- An assessment of the indicators and status of adjacent lobster areas (USA Georges Bank and Gulf of Maine, LFA 33-38), to account for potential interactions between areas.
- Commercial CPUE will be tracked for large changes, but for a variety of reasons is not a useful indicator of year-to-year changes in abundance.

Uncertainties exist in the completeness in the early part of the RV survey time series (i.e., whether all lobsters were recorded), the state of the offshore lobster stock prior to the start of fishing activity in 1972, relationships with adjacent lobster fisheries and the effect of the RV survey design, set allocation, and gear selectivity on the survey results.

The largest uncertainty revolves around the concept of production regime change and what factors influence lobster abundance. Throughout most of its range, current lobster production is much higher than the 1970s and early 1980s. Release from predation by larger fish species and changes in physical environmental conditions have been postulated as potential factors contributing to the change. Major temperature shifts in the deep-waters of the Gulf of Maine have occurred in the past, as illustrate by the cold water during the 1960s followed by a return to warmer conditions during the early 1970s.

Next steps include:
- Further exploration of data from the various trawl surveys to develop primary and secondary indicators for biomass, distribution, size structure and sex ratios;
- Determination of appropriate reference periods and boundary levels for an indicator based on number per tow in the trawl surveys as a proxy for biomass;
- Evaluation and development of secondary indicators of biomass, distribution, demographics, environment and ecosystem;
- Development of a “Traffic Light” approach of multiple indicators for evaluating the overall health of the stock; and
- Exploration of the potential use of the University of Maine lobster model.

Atlantic Salmon in the Maritimes Region (Areas 19, 20, 21 and 23)

LRPs for Atlantic salmon (*Salmo salar*) in the Maritimes Region (Areas 19, 20, 21 and 23) were presented for review (Gibson and Claytor 2012).

The empirical work defining 2.4 eggs/m^2 of fluvial rearing habitat as the Atlantic salmon conservation requirement, its adoption by the Canadian Atlantic Fisheries Scientific Advisory Committee, and recent population dynamics research supporting the Beverton-Holt relationship indicate that, in the Maritimes Region, the conservation requirement is consistent with an LRP in the PA framework.

Individual river values based on 2.4 eggs/m^2 of fluvial rearing habitat had been estimated by O’Connell et al. (1997) using methods that were consistent with the framework advice on dealing with changes in productivity. These values are supported by the current population dynamics work on the LaHave River (above Morgans Falls). It was proposed that these estimated values (O’Connell et al. 1997) be used as individual river LRPs for the Maritimes Region. It was proposed that monitoring of reference points be conducted through an index river survey in each Designatable Unit.

It was proposed that additional research on refinement of reference points and HCRs for fishery removals in this region is not warranted given the current stock status and level of fish removals identified in recent Recovery Potential Assessments and summaries of stock status. Rather, it

was proposed that research guiding recovery action plans to appropriately limit mortality from all sources, or to increase productivity would be required.

American Eel in the Maritimes Region

An LRP and RR for American eel (*Anguilla rostrata*) in the Maritimes Region were presented for information only, as they had been proposed previously by the International Council for the Exploration of the Sea (ICES 2001).

ICES (2001) described Spawner per Recruit (SPR) modelling to define mortality reference points for the American eel and proposed the mortality rate that results in 30% of SPR ($F_{30\%SPR}$) as the limit RR and the mortality rate that results in 50% of SPR ($F_{50\%SPR}$) as a target RR. SPR analysis makes no assumption about the recruitment obtained from a spawning escapement. It only considers how many spawners are produced from recruited eels and assumes that average life history characteristics are not modified by the relative size of the recruitment, i.e., no density-dependent effects.

Due to the phenotypic plasticity of the American eel and the association of some of these characteristics (sex ratio, growth rates, length at maturity, age at maturity, natural mortality) with geographic region and rearing habitat, SPR analysis should be done at the geographic scale that corresponds to a set of homogeneous life history characteristics, termed a stock complex. The reference points derived using SPR depend upon the life history characteristics of the stock complex as well as the timing of the anthropogenic stressor in the eel's life cycle. The SPR model analysis can be extended to incorporate complex geographic structuring and multiple anthropogenic stressors.

Maritimes Region Sea Cucumber

Two approaches to the setting of reference points for sea cucumber (*Cucumaria frondosa*) in the Maritimes Region were proposed: one based on split weight and one based on spatial habitat information.

Split Weight Approach

Data and resources for analysis are limited in micro fisheries, such as the sea cucumber fishery. However, it is important that all fisheries, even those small in comparison, report on overall removals and provide information from a representative sample of the species being removed to inform stock status.

Since its commencement with exploratory fishing, the sea cucumber fishery has collected data on length, weight, circumference, wall thickness and meat weight on samples of individual sea cucumbers. These measures were found not to be useful to inform management decisions as they contained a high amount of variance. The split weight (total weight of the animal - less fluid) would be an improved measure. It was proposed that points between initial median split weights and the split weight at minimum legal size could be used to position reference points.

Likewise, the sea cucumber fishery has been collecting data on removals. Initial catch and effort information provides baseline data when the fishery began harvesting on a virgin biomass. Annual effort data can be used to determine the footprint (area swept) of the fishery. As densities of sea cucumber decline, more effort is exerted, increasing the overall area swept. Primary or secondary reference points can be positioned at levels higher than the initial median footprint estimate.

DFO's summer RV survey provides a secondary proxy of abundance/biomass where it spatially intersects the sea cucumber fishery, mainly offshore. The RV survey has been recording captures of this species since the late 1990s. An abundance/biomass indicator, i.e., mean catch/tow, could be developed. A period that represents a productive time could be used to determine a B_{MSY} proxy, with 80% B_{MSY} proxy as a USR and 40% B_{MSY} proxy as an LRP.

Spatial Management Approach

An alternate, spatial approach to management was also proposed. Data-poor fisheries must rely on sparse information to make management decisions, which can be enhanced by support from ecological principles and experience in other fisheries. Protection of high-quality habitat and critical densities in invertebrate fisheries has been recommended elsewhere, as location and density for sessile invertebrates may be more important than absolute population size. In the Maritimes Region, areas with high densities of sea cucumber could be protected as a sustainable source of recruitment to other areas. Spatial "reference points" were proposed to maintain spatial distribution.

Sources of Uncertainty

Numerous sources of uncertainty exist with fisheries assessments, from observation errors (sampling, design, recording, misreporting) to model/process errors (model formalism, parameterization errors, numerical optimization techniques), assumptions of inter-specific interactions, as well as climatic/environmental interactions. Without exception, the error propagation from initial sample to final predictions is incomplete. This improper handling of observation and process errors will result in extremely small confidence intervals and/or biased reference point estimates. Overconfidence in such estimates and their confidence bounds is risk prone and not risk averse.

The determination of reference points typically involves knowledge of stock characteristics, comparison of results from competing models, and judgment. Further, the models describing productivity dynamics often do not convincingly explain the variation in the observations, hence the requirement to consider several competing models. In such a situation, the prevailing uncertainty that is associated with judgment of the model inadequacies and the estimation of uncertainty from any specific model is not particularly useful. Instead, the estimation of uncertainty is fully expressed in the risk management uses of the reference points, once they have been selected. Accordingly, the reference points are taken as prescribed constants based on consideration and judgment of a range of competing techniques.

Although statistical estimation of uncertainty is an important tool, all of the sources of uncertainty cannot be quantified. This should be kept in mind when considering results, and it implies that real-world risks associated with management choices can only be larger than the risks produced by quantitative analyses.

CONCLUSIONS AND ADVICE

The scientific basis for Limit Reference Points, Upper Stock References, and Removal References was proposed for peer review or presented for information for a variety of fish and invertebrate stocks in the Maritimes Region. It is expected that these reference points (particularly the USRs and RRs) will be reviewed with the fishing industry and other advisory committee members prior to their adoption and implementation, with a particular focus on incorporating socio-economic considerations where appropriate to do so.

The approaches proposed for the selection of reference points for modelled, empirically assessed, and data deficient stocks in the Maritimes Region used different methods depending on the information available for each stock, and were reviewed with respect to consistency with DFO's PA framework.

For many stocks, the use of secondary indicators was considered to be helpful, and in some cases necessary, for context in establishing stock status, in determining appropriate management responses, or, with further work, in helping to refine harvest control rules.

Provision of science advice on the RR was found to be more problematic than for the LRP and USR. Some additional guidance on what is meant by "serious harm" in the context of a limit RR, particularly for empirically-based species, may have been useful. It was recommended that the assumed characteristics of the fisheries (e.g., gear selectivities) for each stock be clearly defined when establishing the RR.

It was assumed that surveys and other data sources used to establish reference points would continue to be available, in some form, to enable monitoring of stock status relative to these points.

The biological reference points were set in a single-species context; however, important linkages between species were recognized. In some cases, target RRs were set with consideration of these interactions. In other cases, further work would be required to explore the implications of species interactions, and the impacts of changing environmental conditions, on reference point selection.

While not explored in detail during the meeting, it was suggested that a number of the methods proposed here could be adopted and used to set reference points for other fish and invertebrate species in the Maritimes Region. For example, an RV survey index could be used to develop a B_{MSY} proxy if the RV survey is thought to be reflective of population trend.

Comparing tolerance for risk across frameworks was difficult, given the variations in data, methodologies and biological characteristics. Understanding and improving consistency in this respect is likely to require further review as frameworks are refined and as the Region gains experience in applying the Policy.

SOURCES OF INFORMATION

This Science Advisory Report is from a Regional Science Advisory meeting of 6-9 February 2012; review of the Precautionary Approach Reference Points for a Variety of Fisheries Resources in the Maritimes Region. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

Clark, D. 1997. Assessment of cod in Division 4X in 1997. DFO Can. Stock Assess. Sec. Res. Doc. 97/110.

Clark, D.C., K.J. Clark, and I.V. Andrushchenko. 2011. Precautionary Approach Limit Reference Points for Atlantic Cod (*Gadus morhua*) in NAFO Divisions 4X5Yb and 5Zjm. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/085.

Clark, D.S., K.J. Clark, R. Claytor, S. Leslie, G.D. Melvin, J.M. Porter, M.J. Power, H.H. Stone, and C. Waters. 2012. Limit Reference Point for Southwest Nova Scotia / Bay of Fundy Spawning Component of Atlantic Herring, *Clupea harengus* (German Bank and Scots Bay). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/025.

Choi, J.S., B.M. Zisserson, and B.J. Cameron. 2012. Assessment of Scotian Shelf Snow Crab in 2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/024.

DFO. 2006. A Harvest Strategy Compliant with the Precautionary Approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/023.

DFO. 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach. *http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-eng.htm* (Accessed June 6, 2012).

DFO. 2011a. Assessment of Atlantic Halibut on the Scotian Shelf and Southern Grand Banks (NAFO Divisions 3NOPs4VWX5Zc). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/001.

DFO. 2011b. Recovery Potential Assessment for the Laurentian South Designatable Unit of Atlantic Cod (*Gadus morhua*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/028.

DFO. 2011c. Western Component (4Xopqrs5) Pollock Management Strategy Evaluation. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/054.

DFO. 2011d. Recovery Potential Assessment of Redfish (*Sebastes fasciatus* and *S. mentella*) in the Northwest Atlantic. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/044.

DFO. 2011. Assessment of Lobster in Lobster Fishing Area 41 (4X + 5Zc) DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/033.

DFO. 2012. Assessment of the Status of 4X5Y Haddock in 2011. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/023.

Fowler, G.M. 2012. Investigating reference points for American plaice on the Scotian Shelf (4VWX). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/030.

Gibson, A.J.F., and R.R. Claytor. 2012. What is 2.4? Placing Atlantic Salmon Conservation Requirements in the Context of the Precautionary Approach to Fisheries Management in the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/043.

Hardie, D., M. Covey, M. King, and B. Zisserson. 2011. Scotian Shelf Shrimp 2010-2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/102.

Harris, L.E., G. Somers, and D.S. Clark. 2012. Reference Points for Cusk (*Brosme brosme*) in NAFO Divisions 4VWX5Z Under the Precautionary Approach Framework. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/026.

International Council for the Exploration of the Sea (ICES). 2001. Report of the Working Group on Eels St. Andrews, N.B., Canada, 28 August – 1 September 2000. ICES CM 2001/ACFM:03.

O'Connell, M.F., D.G. Reddin, P.G. Amiro, F. Caron, T.L. Marshall, G. Chaput, C.C. Mullins, A. Locke, S.F. O'Neil, and D.K. Cairns. 1997. Estimates of Conservation Spawner Requirements for Atlantic Salmon (*Salmo salar* L.) for Canada. DFO Can. Stock Assess. Sec. Res. Doc. 97/100.

Roddick, D., R. Kilada, and K. Mombourquette. 2007. Assessment of the Arctic Surfclam (*Mactromeris polynyma*) stock on Banquereau, Nova Scotia, 2004. DFO Can. Sci. Adv. Sec. Res. Doc. 2007/035.

Roddick, D., J. Brading, L. Carrigan, T. Davignon-Burton, S. Graham, and C. McEwen. 2011. Assessment of the Arctic Surfclam (*Mactromeris polynyma*) Stock on Grand Bank. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/052.

Smith, S.J., and P.B. Hubley. 2012. Reference Points for Scallop Fisheries in the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/018.

Stone, H.H. 2012. Biomass Reference Points for Eastern Component Pollock (4VW+4Xmn). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/027.

Tremblay, M.J., D.S. Pezzack, and J. Gaudette. 2012. Development of Reference Points for Inshore Lobster in the Maritimes Region (LFAs 27-38). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/028.

Trzcinski, M.K., and R.K. Mohn. 2012. An Evaluation of Reference Points and Risk of the Scotian Shelf and Southern Grand Banks Atlantic Halibut Stock. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/047.

Wang, Y., and L. Van Eeckhaute. 2012. Canadian Biomass Reference Points for Eastern Georges Bank (5Zjm) Haddock. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/029.

Appendix A. Summary of Approaches and Reference Points for Each Maritimes Region Stock Considered.

Cells in blue italics are For Information Only; references are indicated.

Modelled						
Stock	**Model**	**Assumptions**	**LRP**	**USR**	**RR**	**Monitoring**
3NOPs4VWX+ 5 Atlantic Halibut	Sissenwine-Shepherd Production Model using the full time series: 1970-2009 (RV survey), 1998-2009 (halibut longline survey)	Ricker stock-recruitment relationship	*40% SSB_{MSY} 1,960 t (DFO 2011a)*	*80% SSB_{MSY} 3,920 t (DFO 2011a)*	*limit F_{MSY}=0.36 (DFO 2011a)* target F≤0.2	Halibut longline and RV surveys (annual) and assessments
4X5Y Cod	Beverton-Holt Stock Recruitment Model using the full time series (1980-2007)		*BH_{50} 24,000 t (Clark et al. 2011)*	twice the LRP 48,000 t (3+ SSB)	*target $F_{0.1}$ in the 1990s = 0.2 (Clark 1997)*	RV surveys (annual) and assessments
5Zjm Cod	Beverton-Holt Stock Recruitment Model using the full time series (1978-2009)		*BH_{50} 21,000 t (Clark et al. 2011)*			RV surveys and annual assessments (annual)
4VsW Cod	Sissenwine-Shepherd Production Model using the productive period (1958-1990)	Assumes that there have been two productivity regimes	*40% SSB_{MSY} 50,000 t (DFO 2011b)*	80% SSB_{MSY} 100,000 t	*Productive MSY is 48,000 t (DFO 2011b)*	RV surveys (annual)
5Zjm Haddock	Sissenwine-Shepherd Production Model using the full time series (1931-2011)		$SSB_{recover}$ 10,340 t	USR not determined SSB_{MSY}=78,000 t		RV surveys and annual assessments (annual)

Modelled						
Stock	**Model**	**Assumptions**	**LRP**	**USR**	**RR**	**Monitoring**
4X5Y Haddock	Sissenwine-Shepherd Production Model using the full time series (1970-2010)		*40% B_{MSY} 20,800 t (DFO 2012)*	*80% B_{MSY} 41,600 t (DFO 2012)*		RV survey (annual)
4VWX Snow Crab	biomass dynamics model (1999-present), recalculated each year		25% of the carrying capacity of fishable biomass	50% of the carrying capacity of fishable biomass	<u>limit</u> F_{MSY} <u>target</u> 10-30% of fishable biomass	Fishery, snow crab survey, and annual assessments
4VWX American plaice	Stage-based population model (female only spawning stock biomass) using the full times series (1970-2009)	Carrying capacity is assumed 4VWX American plaice is considered a single population	40% female SSB_{MSY} (12,952 t)	80% female SSB_{MSY} (25,905 t)	<u>limit</u> F_{MSY} = 0.16	Needs further development
Western Component (4Xopqrs5) Pollock	Management Strategy Evaluation using management procedure model coupled with an HCR	While the HCR of the MSE does not translate directly to PA RPs, the HCR is consistent with the PA.	*3-year geometric mean = 20% of 1984-1994 average (i.e., Jy = 0.2)* *Functions much like an LRP. (DFO 2011c)*		*N/A* *No maximum* *(to be reviewed in 5 years)*	RV summer survey catch rate (kg/tow) – annual (3-year geometric mean)

Empirical						
Stock	**Approach**	**Assumptions**	**LRP**	**USR**	**RR**	**Monitoring**
Eastern Component (4VWXmn) Pollock	10-year geometric mean total biomass from the RV summer survey during a productive period (1984-1993) as a proxy for B_{MSY}	Productivity of the resource has not changed appreciably over the past 4 decades	40% B_{MSY} proxy (20,100 t)	80% B_{MSY} proxy (40,100 t)	Information on F not available	RV summer survey total biomass
Unit 3 Redfish	RV survey mean mature (>22cm) biomass using the full time series (1970-2010) as a proxy for B_{MSY}		*40% B_{MSY} proxy 29,000 t (DFO 2011x)*	*80% B_{MSY} proxy 58,000 t (DFO 2011x)*	target Relative F that results in no decline in biomass (0.068)	RV survey mature (>22cm) biomass
Cusk in the Maritimes Region	average commercial longline CPUE from a productive period (1986-1992) scaled to the halibut longline survey CPUE as a proxy for MSY		40% MSY proxy (13.3 kg/1000 hooks)	80% MSY proxy (26.6 kg/1000 hooks)		Halibut longline survey catch rate (kg/1000 hooks)
SWNS/BoF Herring	Acoustic herring spawning stock biomass index		2005 to 2010 average acoustic survey value - stable but low			Acoustic herring spawning stock biomass index (3-year running average)
Banquereau Arctic Surfclam	2010 Arctic surfclam survey (fishable biomass) as a B_{MSY} proxy (B_{target}) biomass per recruit times average		40% of B_{target} (406,024 t)	80% of B_{target} (812,047 t)	target F=0.33M (0.0264)	CPUE, fishery footprint, abundance of older ages in catch – to trigger review

Empirical						
Stock	**Approach**	**Assumptions**	**LRP**	**USR**	**RR**	**Monitoring**
	recruitment					
Grand Bank Arctic Surfclam	2006- 2009 Arctic surfclam survey (fishable) biomass as a B_{MSY} proxy (B_{target}) biomass per recruit times average recruitment		40% of B_{target} (281,226 t)	80% of B_{target} (562,452 t)	target F=0.33M (0.0264)	CPUE, fishery footprint, abundance of older ages in catch – to trigger review
Offshore Scallop (GB 'A' SFA 27A)	mean commercial-size biomass (1981 to 2009) from the delay-difference model as B_{MSY} proxy		*30% of B_{MSY} proxy* *3,000 t*	*80% of B_{MSY} proxy* *8,000 t*	*target* *mean exploitation rate (0.25)*	scallop survey
Offshore Scallop (Browns Bank)	mean commercial-size biomass (1991 to 2010) from the delay-difference model as B_{MSY} proxy		30% of *B_{MSY} proxy*	80% of *B_{MSY} proxy*	target exploitation rate resulting in no change in biomass (0.1)	scallop survey
Inshore Scallop (model-based assessment areas: 1A, 1B, 3, 4)			Lowest biomass that stocks recovered from ($B_{recover}$)		target exploitation rate = 0.15	scallop survey
Inshore Scallop (other: 5, 6)	commercial catch rate and/or survey as biomass proxies to be investigated				effort as an exploitation proxy to be investigated	
SFA 29 West	Habitat suitability approach to be developed					
Scotian Shelf Shrimp	average SSB from a productive period (2000-2010)		30% of this average SSB (5,459 t)	80% of this average SSB (14,558 t)	target ≤20% of the SSB (female exploitation)	Annual shrimp survey, commercial data

Empirical						
Stock	**Approach**	**Assumptions**	**LRP**	**USR**	**RR**	**Monitoring**
			(Hardie et al. 2011)	(Hardie et al. 2011)		and port sampling, with assessments
Inshore Lobster (LFAs 27-36, 38)	25-year median landings from a productive period (1985-2009) as a B_{MSY} proxy	Landings are proportional to abundance	40% of B_{MSY} proxy	80% of B_{MSY} proxy	If one is to be implemented, RR should be at the high end (90^{th} percentile) of estimates within the last 10-15 years.	Landings, trap catch rate, trawl survey catch rate
Offshore Lobster (LFA 41)	RV summer and winter survey mean #/tow with three year moving average as B_{MSY} proxy		TBD – expressed as some % of B_{MSY} proxy	TBD – expressed as some % of B_{MSY} proxy	Exploitation rate has not been directly estimated TBD using size (e.g., median) as a proxy for an RR	summer (4X) and winter (5Z) RV surveys
Atlantic salmon in the Maritimes Region	the Atlantic salmon conservation requirement in eggs/m^2		Individual river LRPs using 2.4 eggs/m^2 of fluvial rearing habitat (O'Connell et al. 1997)			An index river survey in each designatable unit
American eel in the Maritimes Region	Spawner per Recruit modelling	No density dependence			<u>limit</u> F that results in 30% of SPR ($F_{30\%SPR}$) <u>target</u> F that results in 50% of SPR ($F_{50\%SPR}$)	

Data Deficient	
Stock	**Approach**
Maritimes Region Sea Cucumber	Reference points could be developed based on split-weight measures (e.g., in relation to split weight at minimum legal size)
	"Spatial" reference points could be developed to maintain spatial distribution

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