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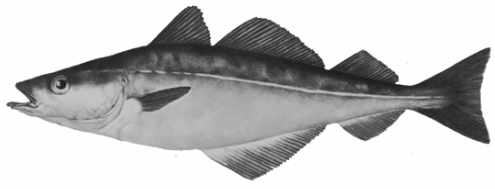
Science Advisory Report 2011/054

WESTERN COMPONENT (4Xopqrs5) POLLOCK MANAGEMENT STRATEGY EVALUATION



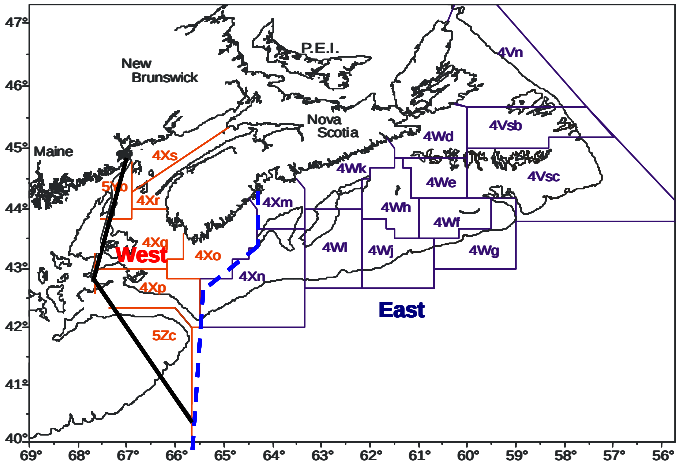


Figure 1: Canadian Pollock management unit showing the Western (4Xopqrs5) and Eastern Component (4VW+4Xmn) areas. Dashed line separates Western and Eastern Components, solid line is the Canada/USA international boundary.

Context:

In the Western Atlantic, Pollock are found from southwestern Greenland to Cape Hatteras, North Carolina. Important Canadian fisheries for Pollock occur on the Scotian Shelf, eastern Georges Bank, and the Bay of Fundy using primarily otter trawl and gillnets, but also handlines and longlines. In the Maritimes Region, two management areas are in place for Pollock within the NAFO Division 4VWX5 management unit: 4VW and 4X5 (Canadian waters only).

A detailed evaluation of Pollock stock structure in 2003 indicated that Pollock in 4VWX5 are represented by two population components: a slower-growing Eastern Component including Divisions 4V and 4W, as well as Unit Areas 4Xm and 4Xn, and a faster-growing Western Component including 4Xopqrs and Canadian portions of Area 5; Figure 1). An analytical assessment has been conducted for the Western Component, while the Eastern Component has been monitored solely with survey indices. The last analytical assessment providing management advice on Western Component Pollock was completed in 2009.

Recently there has been consideration by Fisheries Management and Industry to manage Pollock in the Western Component using a risk management approach. In July 2010, Fisheries Management initiated a Management Strategy Evaluation (MSE) approach with Science and Industry, where Management Objectives and Harvest Control Rules (HCRs) were specified up front.

This report summarizes advice from simulations conducted using Candidate Management Procedures (CMPs) to evaluate management strategies for Western Component Pollock, Harvest Control Rules and protocols for Exceptional Circumstances, and identifies future research which is expected to provide the greatest improvements to management advice.

SUMMARY

- In July 2010, Fisheries Management initiated a Management Strategy Evaluation (MSE) process with Science and Industry for Western Component Pollock.

- Management Strategy Evaluation is a technique to explicitly consider the uncertainty in stock assessment assumptions and models, and to compare the likely consequences to Management Objectives (biological, economic, etc.) when a predetermined Management Procedure (MP) incorporating a Harvest Control Rule (HCR) is applied. Management Strategy Evaluation changes the focus from the traditional "best assessment" to identifying a "best procedure", where "best" implies the procedure that most closely meets the desired Management Objectives.

- The medium-term Management Objectives for Western Component Pollock Management Strategy Evaluation were selected for resource sustainability and catch, and constraints were selected for annual catch variability.

- The 17 Operating Models (OMs) selected in this evaluation span the full range of plausible values for uncertainties. A subset of six Operating Models was chosen as the balanced Reference Set (RS). It is primarily against this Reference Set that the performance of Candidate Management Procedures (CMPs) was evaluated.

- A Pollock Management Procedure (and its constituent Harvest Control Rule) was selected that meets the defined Management Objectives under a core set of plausible scenarios that cover the most important uncertainties concerning the fishery. The choice was driven by the degree of desired conservatism, which traded off the level of catch in the medium-term against the extent of resource recovery.

- A three-year running geometric mean of the summer Research Vessel (RV) Survey Biomass Index provides the measure used in the Harvest Control Rule to establish future catch limits for Western Component Pollock. An annual review will determine if the RV Survey Biomass Index has moved outside projected ranges.

- Exceptional Circumstances provisions are defined and are intended to cover situations outside the range for which the Management Procedure was simulation tested.

- Unless an Exceptional Circumstance is triggered, the application of the Management Procedure will provide the catch limit for Western Component Pollock. The expected operating timeframe for this Management Strategy Evaluation is 5 years, after which there will be a thorough review.

BACKGROUND

Biology

Pollock (*Pollachius virens*) is a gadid fish species found on both sides of the North Atlantic, ranging from southwestern Greenland to North Carolina in the west, and from around Iceland and the Barents Sea to the Bay of Biscay in the east.

The life history of Pollock in the Northwest Atlantic involves an offshore spawning and larval phase, recruitment to the coastal environment for a period of one to two years, followed by an offshore migration. On the Scotian Shelf and in the Gulf of Maine, Pollock are found at depths ranging from 35 to 550 m with bottom temperatures varying from 5 to 8^{o} C. Unlike other cod-like fishes, Pollock show strong schooling behaviour and spend less time on the bottom and more time moving freely through the water column than their bottom-living relatives. Tagging studies have shown that Pollock are capable of travelling long distances.

Several spawning areas have been identified on the Scotian Shelf, as well as a major spawning area in the western Gulf of Maine. Spawning occurs from November through February. Sexual maturation is essentially complete by age 6, although more than 50% of fish are mature by ages 3 to 4 (45-50 cm), depending on geographic area. Pollock begin to reach commercial size at age 3, and are considered fully recruited to the commercial fishery by age 7. They are relatively long lived, attaining a maximum age of 23 years and may reach lengths of 116 cm and weights of 17 kg.

Juvenile Pollock feed on crustaceans, especially small euphausiids and amphipods, although small fishes, especially Herring and Sand Lance, are also consumed. Food of adult Pollock includes euphausiids, squid and fish such as Herring, Sand Lance, and Silver Hake. Predators include Atlantic Cod, White Hake, and Monkfish, as well as Grey and Harbour seals.

The Fishery

For the 2010-2011 fishing year, landings in the 4VWX5 fishery from April 1st through March 31st were 4,926 t against a **Total Allowable Catch** (TAC) of 5,900 t. Peak landings in 1987 were 46,000 t; landings since 1999 have been less than 10,000 t (Table 1, Figure 2).

Table 1: Landings and TACs (000s t) for Pollock in 4VWX5.[1]

Year	1970-1979 avg.	1980-1989 avg.	1990-1999 avg.	2000-2005 avg	2006	2007[2]	2008	2009	2010[3]
TAC		46.9	24.2	9.4	4.5	5.0	5.8	5.9	5.9
TOTAL	21.9	38.6	19.5	7.2	4.3	5.5	5.5	5.0	4.9
EAST	7.8	21.2	7.7	0.6	0.5	1.1	1.5	1.1	1.1
WEST	14.1	17.4	11.8	6.6	3.8	4.4	3.9	3.9	3.8

[1]Commencing in 2000, fishing year, landings and TAC refer to the period April 1st of the current year to March 31st of the following year.
[2]For the 2007/2008 FY, the TAC was for 4X5 only, but there were additional landings from a test fishery in 4W.
[3]Landings for 2010 are from April 1, 2010 to March 31, 2011.

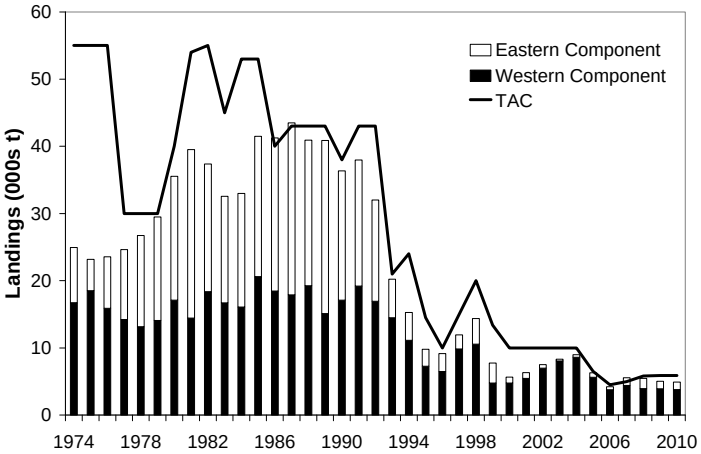


Figure 2: Landings[1] and TACs for Pollock in 4VWX+5, for the Eastern and Western components.

The Pollock fishery has shown appreciable changes in both area fished and in dominant gear type. Landings from the Eastern Component, primarily from the Tonnage Class (TC) 4+ sector (>100' otter trawl vessels), have declined substantially. Since 1993, much of the Eastern Component has been closed to Cod and Haddock directed fishing, which further reduced Pollock landings from that area, with most catches coming from 4Xn. Despite this reduction in fishing effort, there is little indication of a significant increase in biomass. Since 1993, mobile gear catches (TC 1-4+) have accounted for about 70% of landings and fixed gear about 30%.

The mobile gear sector has participated in a test fishery in 4VW beginning in 2007, which has resulted in an increase in catch of about 400 t/year for 2007-2010 (Table 1).

Since 2000, total fishery removals have averaged 6,200 t/year, with the Western Component of the management unit contributing 86% of total landings on average during this period. Smaller mobile gear vessels (TC 1-3) have accounted for most of the Western Component landings, followed by gillnet (Figure 3). The percentage of total landings taken by gillnet has declined since 2000 whereas the small mobile share has increased. The contribution of larger trawlers to total landings (TC 4+) has been steadily declining since the mid-1990s, increasing slightly in 2006 and again in 2010. In recent years, this offshore sector has used smaller <65' vessels (TC 1-3) to catch their allocation. The contribution by the longline/handline sector has also declined since the mid-1990s, but there has been a modest increase over the past five years.

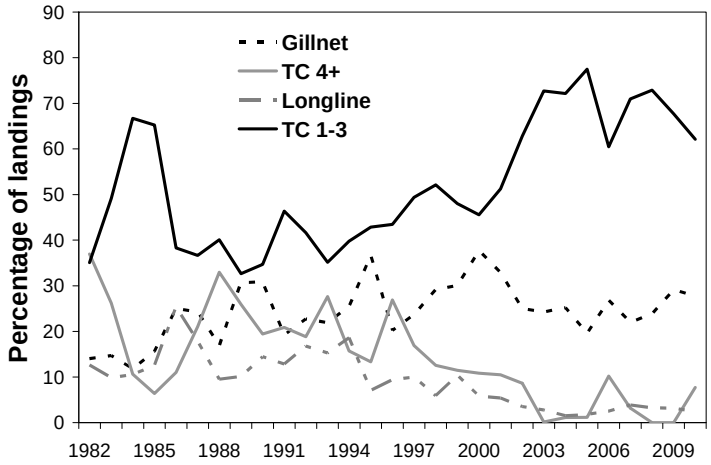


Figure 3: Percentage of Pollock landings by gear type for the Western Component, 1982-2010.

Landings from the Western Component now come mostly from Unit Areas 4Xpq and have declined substantially from all other areas, *i.e.*, Bay of Fundy, Georges Bank (5Zc), and 4Xo (Figure 4).

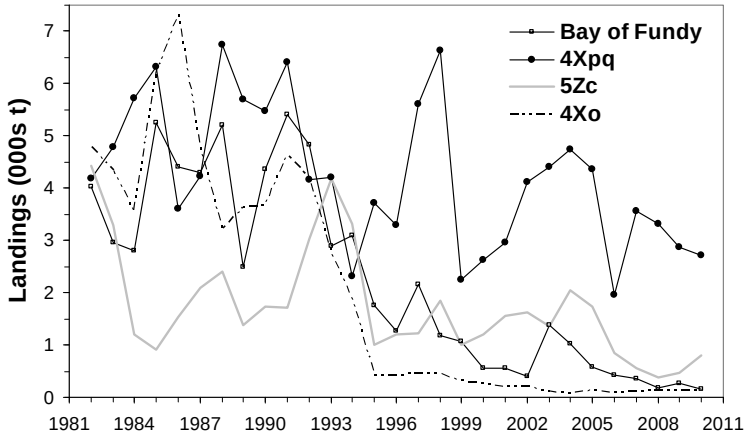


Figure 4: Pollock landings by area for the Western Component, 1982-2010.

Management Strategy Evaluation

There are multiple objectives in fisheries: sustainable utilization, maximum economic value, stable catch limits to allow for investment planning, *etc*. **Management Strategy Evaluation** (MSE) makes the objectives explicit, and then assesses the consequences of a range of management options for each objective.

Management Strategy Evaluation is a technique to explicitly consider the uncertainty in stock assessment assumptions and models, and to compare the likely consequences to **Management Objectives** (biological, economic, etc.) when a predetermined **Management Procedure** (MP) incorporating **Harvest Control Rules** (HCRs) is applied. The performance of these rules against the objectives is systematically evaluated using simulation to ensure that they are likely to provide reasonably robust performance given the plausible range of scientific and operational uncertainties considered to apply to the resource.

As such, Management Strategy Evaluation is distinguished from a more standard stock assessment and management decision process in three ways:

- rather than attempting to develop a "best assessment" model with assumptions made about key uncertainties (such as future recruitment levels, natural mortality, etc.) to represent the fish stock in question, a series of **Operating Models** (OMs) are developed that cover the full plausible range of these uncertainties;
- management objectives are explicit and quantified, and performance of the approach is evaluated against these objectives; and
- a Management Procedure is applied, in which an agreed Harvest Control Rule dictates future management responses (such as catch limit adjustment) that is to occur based on the results obtained from ongoing monitoring (*e.g.*, annual surveys) of the resource. This establishes a formula for catch limit adjustment, which is evaluated for meeting objectives.

There is considerable flexibility in setting Management Objectives. In order to reduce the complexity, probably a limit of three or four objectives is most appropriate – if more are specified, the task of balancing competing objectives becomes difficult. Ordinarily, the objectives are set in relation to issues of sustainability (such as desired biomass levels, but stock structure could also be included), catch (a desired annual level of catch), and inter-annual stability of catch (*e.g.*, a maximum increase or decrease in catch from one year to the next). Making choices about these objectives inevitably requires trade-offs, and the Management Strategy Evaluation approach provides a disciplined approach to their consideration.

Operating Models are selected to span the major sources of uncertainty about the resource. A subset of Operating Models are then identified to be included in the **Reference Set** (RS), which constitutes a balanced core group of Operating Models considered to be the most plausible and to cover the most important uncertainties. Included in the Reference Set will be Operating Models that are relatively pessimistic and relatively optimistic – performance is evaluated against the Reference Set to ensure objectives are met. The Reference Set should span the full reasonable breadth of uncertainty, and as a set represents a balanced view from relatively optimistic to relatively pessimistic.

Development and evaluation of a Management Procedure therefore:

- considers alternative stock assessment approaches for identifying both desirable and undesirable outcomes;

- evaluates alternative forms of decision rules that specify how controls will change (*i.e.*, corrective actions) in response to estimates of stock status relative to operational targets as provided by resource monitoring data; and
- demonstrates, via computer simulation, how effectively alternative management procedures meet fishery management objectives.

Thus, Management Strategy Evaluation changes the focus from the traditional "best assessment" to identifying a "best procedure" from a set of candidates that is robust to uncertainties about the real world. Here, "best" implies the procedure that most closely meets the desired Management Objectives over a wide range of plausible scenarios about the resource and fishery processes.

ANALYSES

Stock Trends

Indices from the summer **DFO research vessel (RV) survey** for 1984-2010, which incorporates a stratified random sampling design, have been used in the traditional stock assessment of the Western Component Pollock and provide the main source of monitoring data used to update the Management Strategy Evaluation model catch limit calculations.

The summer RV **Survey Biomass Index**, while variable, showed a general declining trend in the 1980s, followed by a period of low biomass from the mid-1990s to early 2000s and then a trend of increasing biomass from 2003 to 2009 (Figure 5). This is followed by a very sharp decline in 2010 which appears inconsistent with the trend of increasing biomass since 2003, and may be a negative year-effect. Strong year-effects are apparent in the time series (*i.e.*, 1988, 1990, 1996 and 2006) and probably primarily reflect the semi-pelagic schooling behaviour of Pollock and changes in availability arising from differing distributions of Pollock in the water column at the times of the surveys.

Although the RV Survey Biomass Index is highly variable from one year to the next, it is the information on long-term trends from this series that are important. In the Management Strategy Evaluation context, the summer RV survey 3-year running geometric mean biomass index (Figure 5) will provide the monitoring data used to update the Management Procedure calculations for future catch limits for Western Component Pollock. (The geometric mean was chosen in preference to the arithmetic mean because it dampens the impact of occasional very high results on the average, so providing slightly enhanced stability of year-to-year management advice developed on this basis.)

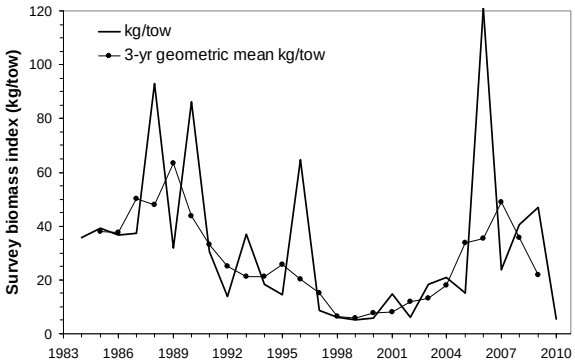


Figure 5: DFO summer Survey Biomass Index (kg/tow) for Pollock.

The RV survey age-specific indices show low abundance of older (ages 6+) fish from 1995 to 2005. However, strong year effects make it difficult to track the strength of individual year classes (yc) (Figure 6). While recent RV surveys have caught more fish at ages 6 and 7, recruitment at Age 3 appears to have been weak for the past three years.

RV survey mean weights-at-age (equivalent to mid-year population weights-at-age) declined after the mid-1980s, although the pattern has been somewhat variable over the past decade (Figure 7), indicating a reduction in this aspect of productivity. If productivity is lower now compared to the past, it may not be possible to achieve population biomass levels comparable to the 1980s, even if catches are kept at low levels.

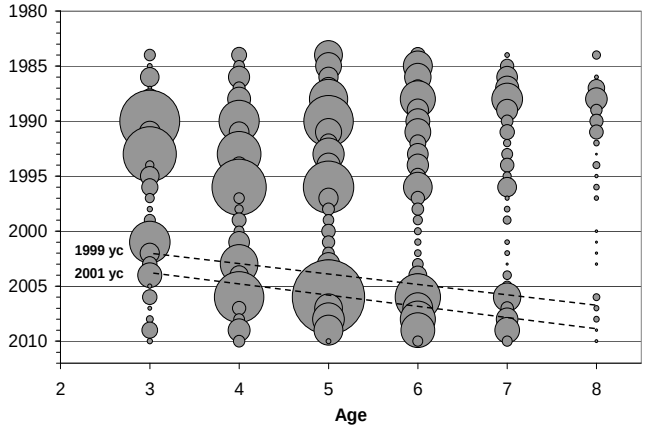


Figure 6: RV survey indices at age for the Western Component. The index value is proportional to bubble area.

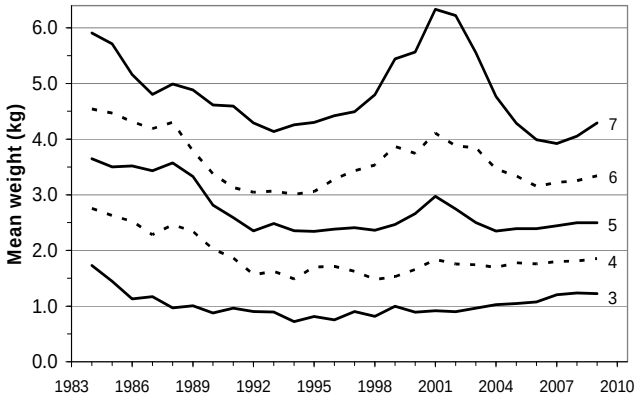


Figure 7: RV survey weights-at-age (3-year geometric mean) for Pollock in the Western Component.

Management Objectives

Medium-term Management Objectives for this Management Strategy Evaluation are:

- *Sustainability:* The median of the ratio of the projected exploitable biomass ($B_{4\text{-}8}$) in 2021 to that in 2000 must be at least 1.5; the lower 25 percentile for this ratio must be at least 1 (the 2000 biomass is used as it is the lowest value in the time series; it is also more precisely estimated than values for more recent years);
- *Catch*: Projections of median catch resulting from the Harvest Control Rule must be greater than 4000 t for each of the next 5 years starting in 2012; and
- *Restrictions on annual catch changes and maximum catch*: The maximum annual catch is restricted to an increase of 20% or 500 t, whichever is greater; the maximum inter-annual catch limit is restricted to a decrease of 20% provided the geometric mean of the last three RV survey estimates remains at least 20% of the geometric mean over the 1984-1994 period (if this value drops below the 20% level, greater decreases are permissible); the maximum annual catch is restricted to 20,000 t.

It is against these objectives that the performance of the Management Procedure is evaluated using the Reference Set. The selected objectives are a management choice about the best balance among the sustainability, annual catch and catch change objectives.

Operating Models

The major sources of uncertainty in the Pollock assessment model and the projections arising from it include:

- variability of RV surveys and hence in the relationship between the Survey Biomass Index and the underlying population abundance;
- changes in natural mortality (M);
- partial recruitment on older ages;
- high variability in recruitment (note that the last 2 years are poorly estimated); and
- stock-recruitment relationship.

The 17 Operating Models selected (Table 2) span the full range of plausible values for these uncertainties, although partial recruitment scenarios for older age fish were not explored fully. A subset of six Operating Models was chosen as the balanced Reference Set (Table 2). It is primarily against this Reference Set that the performance of **Candidate Management Procedures** (CMPs) was evaluated. All Operating Models employ the existing Virtual Population Analyses (VPA) based assessments.

*Table 2: Set of Operating Models (OMs) and Reference Set (RS; in **bold**) agreed to for the Management Strategy Evaluation application to 4Xopqrs5 Pollock (M=natural mortality).*

Uncertainty	Operating Model characteristics*	Stock-recruitment relationship
Reference Case	**1. RAD 1 (Rademeyer and Butterworth 2011): no bias correction, M = 0.2, including 2010 RV survey estimate**	**Based on last 10 reliable years (1999-2008)**
RV Survey Variability & Relationship between RV Survey Index and Population Abundance	**2. Stone (Stone 2011): with bias correction, M = 0.2, including 2010 RV survey estimate**	**Based on last 10 reliable years (1999-2008)**
	3. Stone (Stone 2011): with bias correction, M = 0.2, excluding 2010 RV survey estimate	**Based on last 10 reliable years (1999-2008)**
	4. As OM1 but using square root function for RV survey abundance	Based on last 10 reliable years (1999-2008)
	5. As OM1 but using power (square) function for RV survey abundance	Based on last 10 reliable years (1999-2008)
	6. As OM1 but using mixture distribution for future RV survey abundance	Based on last 10 reliable years (1999-2008)
Changes in Natural Mortality	7. As OM1 but using M=0.2 for ages 6 or less, age 7-13 M=0.675 - no change in future	Based on last 10 reliable years (1999-2008)
	8. As OM1 but using M=0.2 for ages 4 or less, M=0.579 for ages 5 and 6 and M=0.617 for ages 7 and above - no change in future	**Based on last 10 reliable years (1999-2008)**
	9. M as in OM7 but back to 0.2 after 5 years	Based on last 10 reliable years (1999-2008)
	10. M as in OM8 but back to 0.2 after 5 years	Based on last 10 reliable years (1999-2008)
Partial Recruitment on Older Ages	12. As OM1 but using dome–shaped RV survey partial recruitment on older ages	Based on last 10 reliable years (1999-2008)
High Variability in Recruitment & Stock-Recruitment Relationship	13. As OM1	Based on last 5 reliable years (2004-2008)
	14. As OM1	**Beverton-Holt, fit up to a maximum value corresponding to the average values for spawning stock biomass**
	15. As OM8	Based on last 5 reliable years (2004-2008)
	16. As OM1 but using M=0.2 for ages 6 or less, age 7-13 M=0.76 - no change in future	Based on last 5 reliable years (2004-2008)
	17. As OM1	**Based on all reliable years (1984-2008)**
	18. As OM1	Based on 1984-1994 period

* Note that #11 was eliminated from consideration.

Management Procedure and its Constituent Harvest Control Rules

The Harvest Control Rule is a consistent procedure used to set the catch limit following the receipt of the biomass estimate from the update of the Survey Biomass Index for the Western Component. As such, the Management Procedure is based on the direct use of an annual biomass index from the results of the summer RV survey. The Harvest Control Rule provides a pre-defined means of changing the catch limit in response to the available observations from the RV survey which is being used to monitor changes in the condition of the stock.

Seven Candidate Management Procedures were evaluated; the choice between them was driven by the degree of desired conservatism, which traded off the level of catch in the medium-term against the extent of resource recovery. Although 20-year projections were used for the illustrative runs, the focus in the Management Strategy Evaluation, consistent with the Management Objectives, is on the first 10 years. This is a fundamental difference from the traditional Pollock VPA assessment for which only one or two year projections are conducted.

The Candidate Management Procedures included the following rules: If the RV Survey Biomass Index three-year running geometric mean (GM) dropped below 20% of the 1984-94 GM, the provision limiting catch reductions from one year to the next to 20% was modified to allow reductions to 40%; if the GM dropped further to less than 10% of the 1984-94 GM, even greater reductions (including closure) become possible.

A robust Management Procedure produces outcomes that meet predefined Management Objectives under a core set of plausible scenarios that cover the most important uncertainties concerning the fishery. Each Candidate Management Procedure was evaluated against the Reference Set to produce performance statistics, such that a comparison of results against the Management Objectives was possible. Following a review of performance (Table 3), the final Pollock Management Procedure was selected as it represented the best performance against each of the Management Objectives (see bold in Table 3). Table 3 also shows the 'no catch' scenario which provides a useful baseline illustrating the upper boundary of resource recovery expectations.

*Table 3: Projection results (median, with upper and lower 25 percentiles in parentheses) for a series of performance statistics for no catch and the Pollock Management Procedure under the Reference Set. Figures in **bold** relate to satisfying the Management Objectives (B=biomass, C=catch).*

Performance statistics	No catch		Pollock Management Procedure*	
$B^{4\text{-}8}_{2021}/B^{4\text{-}8}_{2000}$	3.52	(2.45; 4.53)	**1.67**	**(1.01;** 2.54)
$B^{sp}_{2021}/B^{sp}_{2000}$	8.70	(5.93; 10.65)	2.16	(1.26; 3.93)
$B^{4\text{-}8}_{2021}/B^{4\text{-}8}_{2010}$	2.12	(1.64; 3.10)	1.10	(0.61; 1.84)
$B^{4\text{-}8}_{2021}/\text{av}(B^{4\text{-}8}_{1982\text{-}2010})$	1.26	(0.97; 1.58)	0.63	(0.38; 0.94)
C_{2011}	6000	(6000; 6000)	6000	(6000; 6000)
C_{2012}	0	(0; 0)	**5373**	(4800; 6289)
C_{2013}	0	(0; 0)	**4786**	(3840; 6280)
C_{2014}	0	(0; 0)	**4608**	(3046; 6912)
C_{2015}	0	(0; 0)	**4441**	(2351; 7086)
C_{2016}	0	(0; 0)	**4381**	(2037; 7249)
$C_{2011\text{-}2020}$	600	(600; 600)	4677	(3249; 6609)

* Referred to as CMPint+ in the Research Document.

The Harvest Control Rule associated with this Management Procedure will be used as the annual catch limit-setting mechanism following the completion of the RV survey. If a RV survey

does not occur in one year, the average of the last two data points will be applied; two consecutive RV surveys missed constitutes an Exceptional Circumstance (see below).

The **Survey Index Ratio** (J_y) is the geometric mean of the RV Survey Biomass Indices over the last three years as a proportion of the geometric mean of the index value for 1984 to 1994 (this reference period was chosen as it represented the period of highest productivity during the available time series). The curve in Figure 8 shows the relationship between the catch limit output by the Pollock Management Procedure and the Survey Index Ratio. (Note that the output from this relationship may subsequently be modified to conform with restrictions on the extent to which the total catch allocation may change from one year to the next.)

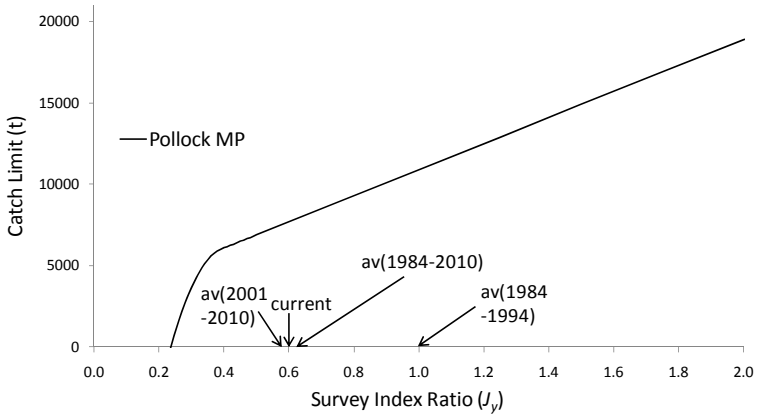


Figure 8: Relationship between the catch limit output by the Pollock Management Procedure and the RV Survey Index Ratio. The arrows indicate values of this ratio at other times or averaged over the periods indicated.

Figure 9 shows the median catch and exploitable (ages 4 to 8) biomass relative to 2000 level for no catch and the Pollock Management Procedure applied to the Reference Set. The values of the Pollock Management Procedure median curve for total catch over 2012 to 2016 show that the catch-related Management Objective of values above 4000 t are met for that period. Similarly the Pollock Management Procedure curves in the right plot show that in 2021 the two sustainability related management objectives are met.

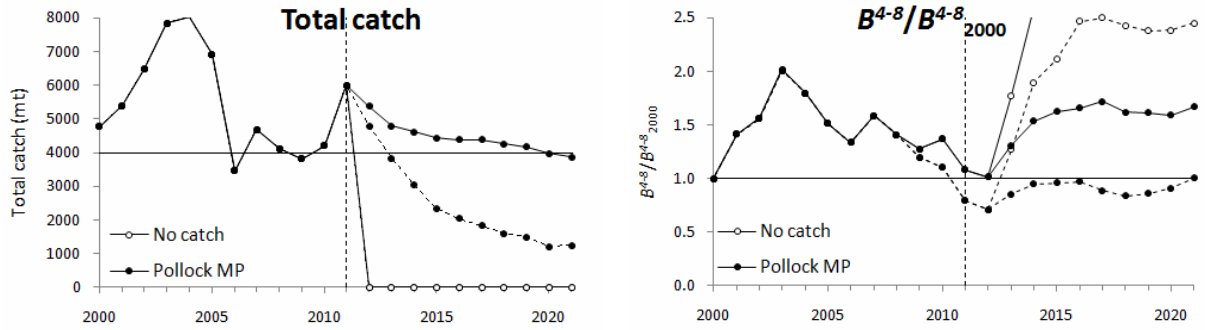


Figure 9: Median (full lines) and lower 25 percentiles (dashed lines) for total catch and exploitable (ages 4 to 8) biomass (relative to 2000 level) for no catch and the Pollock Management Procedure each applied to the Reference Set.

The Pollock Management Procedure results (Figure 10) show projected distributions of the Survey Biomass Index for each future year, with a 90% probability interval within which the RV survey result is projected to lie. Provided the result falls inside such an interval, there is no

evidence that the actual situation is outside the range of circumstances considered in the testing, and for which the Management Procedure is considered to be adequately responsive. However if a result falls outside this interval, that would be grounds for deciding that Exceptional Circumstances apply (see below).

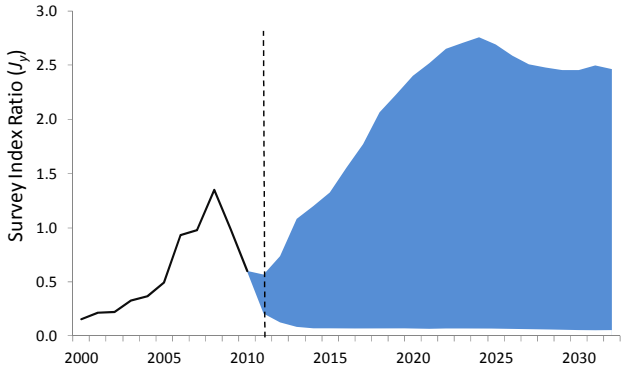


Figure 10: Projected distributions of results of the Survey Index Ratio (J_y) from RV surveys for each future year, with a 90% probability interval within which the RV survey result is projected to lie (based on 5000 replicates for each Operating Model in the Reference Set).

Exceptional Circumstances Protocol

The Management Procedure, once adopted, should be applied in autopilot style, *i.e.*, given the new monitoring data required for an updated catch limit calculation (the latest RV Survey Biomass Index in the case of Pollock), the Management Procedure formula to compute the catch limit should be applied automatically, and the result put into place by decision-makers.

Exceptional Circumstances provisions are intended to cover situations outside the range for which the Management Procedure was simulation tested (correspondingly beyond situations that the autopilot was designed to handle). In such cases the decision-maker has reasons to stop the automatic application of the Management Procedure and perhaps to amend the catch limits set by the Management Procedure or also require the Management Procedure to be revised. This should not be a frequent occurrence – certainly an anticipated average rate of less than once per decade – and accordingly, compelling evidence should be required to invoke such provisions.

When exceptional circumstances are detected, three courses of action are possible depending on the degree and type of the circumstance observed. In descending order, they would be considered as follows:

1. review the information, but maintain the Management Procedure as the management mechanism - additional research/monitoring may be recommended to determine if the signal detected warrants moving to step 2;
2. advance the review period, and potentially revise the Management Procedure, but implement the Management Procedure outputs; and
3. set a catch limit that departs from the Management Procedure, and revise the Management Procedure.

The main reasons for deciding that such circumstances should apply would be either unexpected results (positive or negative) arising from monitoring data; or evidence becoming available that the true situation of the resource/fishery/monitoring differed (better or worse) from that envisaged by the operating models used for the testing.

The sources of data that could be used for this purpose are RV Survey Biomass Index results, and the average age and age structure of the catch and/or RV survey.
Results that will trigger an exceptional circumstance review:

1. if the RV Survey Index Ratio ($J_{y)}$) is <0.2 (Figure 8), or outside the 90% probability interval within which the RV survey result is projected to lie (Figure 10); and
2. if the RV Survey Biomass Index is <6 kg/tow for two consecutive years (Figure 5).

Additional situations that would trigger an Exceptional Circumstance review:

- the RV survey not taking place or being substantially curtailed or changed, for two consecutive years;
- catches, including estimated discards, appreciably exceeding the limit set by the Management Procedure;
- an important change in the fishery and population age structure (compressed or expanded) as reflected in the fishery catch at age and the RV survey age-specific indices of abundance (this could also imply changes in selectivity patterns beyond those assumed);
- an important change in understanding of the biology assumed for the operating models, *e.g.*, ageing found to have been biased, or the estimated age at maturity substantially in error;
- commercial catch is <0.75 Management Procedure-derived catch - are there reasons other than abundance decline?; and
- evidence that there is a substantial biomass increase in the Western Component not captured by the summer RV survey.

Sources of Uncertainty

Pollock, being a semi-pelagic, schooling species, are less well sampled by the summer RV survey (stratified randomly selected bottom trawl sets) when compared to other gadids. This creates high variability in the RV Survey Biomass Index from year-to-year.

There are indications of a fairly recent increase in natural mortality, but little basis to infer for how long this might continue. Recruitment is highly variable and this, in combination with the high variability of RV survey results, makes management difficult as resource declines or increases can occur before this becomes unequivocally clear from the RV Survey Biomass Index trends.

The Management Strategy Evaluation process has, through its various Operating Models, attempted to capture most of this uncertainty so that the Management Procedure can be evaluated to give robust performance even given this lack of perfect knowledge.

OTHER CONSIDERATIONS

Information Support Requirements and Implementation Processes

An annual review will determine if the RV Survey Biomass Index has moved outside projected ranges.

Unless an Exceptional Circumstance is triggered, the application of the Management Procedure will provide the catch limit for Western Component Pollock. The expected operating timeframe

for this Management Strategy Evaluation is 5 years, after which there will be a thorough review. This may result in a revision to the Management Procedure.

Research Recommendations

Research topics that would have the greatest impact to improve the Management Strategy Evaluation are: firstly investigate methods to reduce the variance in the RV survey, and secondly to both improve estimates of natural mortality and determine the causes of the relative absence of older fish in the catch and RV survey. However, clear analyses of the investment required for and the potential benefits to be obtained from such research should be made.

CONCLUSION

The Management Strategy Evaluation applied here for 4Xopqrs5 Pollock (Western Component) is the result of a year-long process that brought together a project team composed of DFO Science, DFO Management, Industry representatives and outside experts. This is an exercise that requires specialized technical capacity and if DFO intends use Management Strategy Evaluation in the future for other fisheries, an internal capacity should be developed.

It was concluded that the Management Strategy Evaluation developed for Western Component 4Xopqrs5 Pollock is sufficiently robust to plausible uncertainties, and if the selected Management Procedure is employed, will result in an acceptable trade-off between the three Management Objectives. The Management Procedure selected should be used to derive management advice and direct management decisions, unless any of the above-noted Exceptional Circumstances are deemed to apply. The expected operating timeframe for this Management Strategy Evaluation is 5 years, after which there will be a thorough review. This may result in a revision to the Management Procedure.

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Maritimes Regional Advisory Process meeting of May 9-10, 2011 on Western Component (4Xopqrs5) Pollock Management Strategy Evaluation. 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.

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