**Proceedings of the
Transboundary Resources Assessment Committee (TRAC)
Mackerel Benchmark Assessment**

**Report of Meetings held
22 - 23 October 2009[1]
1- 4 March 2010[2]**

[1]by Videoconference

**[2]Stephen H. Clark Conference Room
Woods Hole Laboratory
Northeast Fisheries Science Center
Woods Hole, Massachusetts, United States**

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FOREWARD

The purpose of these proceedings is to archive the activities and discussions of the meeting, including research recommendations, uncertainties, and to provide a place to formally archive official minority opinions. As such, interpretations and opinions presented in this report may be factually incorrect or misleading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement had been reached.

AVANT-PROPOS

Le présent compte rendu fait état des activités et des discussions qui ont eu lieu à la réunion, notamment en ce qui concerne les recommandations de recherche et les incertitudes; il sert aussi à consigner en bonne et due forme les opinions minoritaires officielles. Les interprétations et opinions qui y sont présentées peuvent être incorrectes sur le plan des faits ou trompeuses, mais elles sont intégrées au document pour que celui-ci reflète le plus fidèlement possible ce qui s'est dit à la réunion. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s'il est clairement indiqué qu'elle l'est effectivement. En outre, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire.

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ABSTRACT

The Transboundary Resources Assessment Committee (TRAC) met during 22-23 October 2009 by videoconference (Biological Institute of Oceanography, Dartmouth, Nova Scotia, Maurice Lamontagne Institute, Mont Joli, Quebec, and Woods Hole Laboratory, Woods Hole, Massachusetts) to review the stock structure, data inputs and survey indices for Atlantic mackerel (*Scomber scombrus* L.), as well as to discuss a number of related scientific issues related to the assessment of this species. TRAC met again 1-4 March 2010, in Woods Hole, Massachusetts, USA, to review possible assessment models and to complete a joint mackerel assessment.

RÉSUMÉ

Le Comité d'évaluation des ressources transfrontalières (CERT) s'est réuni les 22 et 23 octobre 2009 par vidéoconférence (IOB, IML et Woods Hole) pour réviser la structure du stock, les données d'entrée et les indices de relevé pour le maquereau bleu (*Scomber scombrus* L.), et aussi pour discuter d'un nombre de problématiques scientifiques reliées à l'évaluation de cette espèce. Le CERT s'est réuni à nouveau du 1 au 4 mars 2010, à Woods Hole, Massachusetts, Etats-Unis, pour réviser de potentiels modèles d'évaluation et compléter l'évaluation conjointe du maquereau.

A. DATA MEETING

A. INTRODUCTION

The Transboundary Resources Assessment Committee (TRAC) co-chairs, T. Worcester and L. O'Brien, welcomed participants (Appendix 1) to the videoconferenced TRAC benchmark data review for Atlantic mackerel. As this was the first TRAC meeting related to mackerel, T. Worcester described a bit of the history of TRAC assessments. TRAC was established in 1998 to undertake joint US / Canada assessments of resources in the Georges Bank transboundary region. Eastern Georges Bank cod and haddock and Georges Bank yellowtail flounder were the first species to be assessed by TRAC, followed by herring. A TRAC benchmark for spiny dogfish was initiated in March 2009. The TRAC received its Terms of Reference from the Canada / US Steering Committee.

Participants were reminded that the TRAC review process is two tiered, with assessment updates typically undertaken between more intensive benchmark reviews.

The Terms of Reference and Agenda for the meeting are provided in Appendices 2 and 3, respectively. During the meeting, each working paper was presented by one of the authors and then followed by a plenary discussion of that paper. Rapporteurs documented these presentations and discussions for the Proceedings.

The TRAC review of Atlantic mackerel data inputs commenced on 22 October 2009 and was completed on 23 October 2009. Participants in this teleconference meeting from the Bedford Institute of Oceanography (BIO), the Maurice Lamontagne Institute (MLI), and the Woods Hole Laboratory are listed in Appendix 1. The Terms of Reference are in Appendix 2, and the agenda is in Appendix 3.

A. STOCK STRUCTURE

TRAC Presentation: Temporal and Spatial Distribution of the Stock

Working Paper: Shepherd, G., J. Deroba, S. Sutherland, M. Jones, J. Blaylock, E. Holmes, and J. Nieland. USA Data Summary -- Appendix I. TRAC Working Paper 2009/20A.

Presenters: G. Shepherd and M. Castonguay
Rapporteur: J. Blaylock

Presentation Highlights

The presentation started with a brief summary of the known distribution and movement of Atlantic mackerel in US waters based on survey and fishery information. USA Vessel Trip Report (VTR) data indicate that most of the US mackerel fishery occurs along the edge of the continental shelf in the Mid-Atlantic, primarily during the months of January to May. Starting in January, the fishery moves towards the south from the Long Island region to the southern Mid-Atlantic area, before shifting toward the north again in April. There is also some activity in December, when commercial fishing occurs in the inshore Gulf of Maine and southern Georges Bank area. Data from the US Northeast Fisheries Science Center's (NEFSC) winter and spring research bottom trawl surveys show similar pattern of mackerel distribution.

This was followed by a narrative description of the timing of movement, distribution and spawning activity in Canadian waters. Mackerel are present in the southwestern region of Nova Scotia in early May, and then move up to Cape Breton in late May-early June. The bulk of the population spawns around mid-June, with spawning complete by mid-July. After that, the larger fish leave and go north. When the large 1999 year class occurred mackerel coincidentally expanded their distribution outside the Gulf of St. Lawrence, to the east of Newfoundland. By October, most of the fish move back into the Southern Gulf of St. Lawrence before leaving for their overwintering migration south. It is not clear how far south they go but mixing with the US contingent during the winter is believed to occur.

Discussion

In general, there was considered to be a fairly good understanding of the overall timing and movements of Atlantic mackerel.

There is no evident split in mackerel distribution based on the US data.

It was indicated that US fishermen let each other know where the mackerel are, which could explain the clustering of industry activity evident in some plots (i.e., March 2006).

There was also some discussion of mackerel distribution in the deeper US waters beyond the boundaries of the NMFS surveys and US fishery.

Several points specific to the northern contingent were discussed. For example, there is no evidence of a resident mackerel population in Canadian waters, and the most northern area of mackerel distribution is southern Labrador. There are uncertainties related to the movement of mackerel around the east coast of Newfoundland (either travelling north from the Gulf of St. Lawrence through the Strait of Belle Isle or to the east).

Changes in the distribution of spawning fish (i.e., presence in western Newfoundland) appeared to have occurred with the large 1999 year class, as well as with changes in oceanographic conditions in the southern Gulf of St. Lawrence (cooler). Commercial landings suggest that environmental factors (i.e., temperature) can influence mackerel distribution.

At this time mackerel are thought to spawn primarily in the southern Gulf of St. Lawrence. However, other relatively minor spawning areas might exist. This also depends on the year class size, as range expansion, shift in spawning distribution and/or additional spawning areas could occur with a large year class. There will be new information about spawning area as soon as data from a Scotian Shelf and southern Newfoundland survey conducted in May-June 2009 are available.

Presentation of temporal and spatial distribution patterns led to discussion of stock structure. There was consensus on the need to address the issue of mixing in the winter fishery and agreement that this was sufficient rationale to conduct a joint assessment. Mixing of the southern and northern contingents of mackerel happens in December when the northern contingent moves south. There currently is no reliable method to distinguish individuals of each contingent, but there are plans to research this in the future.

While there is evidence that NAFO Subarea 2-6 mackerel can be considered one stock unit with two spawning contingents, scientists felt that additional research and investigation was required to discuss this issue with a higher level of confidence. In the past, the US has considered mackerel as a unit stock (recognizing that this includes most of the southern contingent with

some of the northern contingent present in the mixing), while Canada has focused on mackerel in NAFO Units 2-4. It was recommended that stock-related information should be reviewed in the future and that the assessment structure be modified as necessary based on the available scientific evidence.

A. OTOLITH EXCHANGE

TRAC Presentation: Otolith Exchange

Working Paper: Grégoire F., N. Shepherd, and S.J. Sutherland. Inter-laboratory Ageing Exchange of Atlantic Mackerel (*Scomber scombrus*) Otoliths for the 2009 Transboundary Resources Assessment Committee Assessment. TRAC Working Paper 2009/15.

Presenter: J. Burnett
Rapporteur: J. Blaylock

Presentation Highlights

Samples of 100 mackerel otoliths each were exchanged between ageing labs at the US Northeast Fisheries Science Center (NEFSC) and the Canadian Maurice Lamontagne Institute (MLI). US samples came from the winter otter trawl fishery in the Mid-Atlantic Bight, and Canadian samples were from the spring gillnet fishery in the Baie des Chaleurs (Gulf of St. Lawrence). Age readers in both labs performed blind reads of the exchanged samples. Results show a high level of agreement between readers, with low coefficients of variation (CVs) and no bias between NEFSC and MLI age determinations. After the exchange, the NEFSC lab had to assign a new reader to age mackerel. Results of re-ageing tests showed high levels of inter- and intra-reader precision indicating that the change in reader should not affect the current assessment, or future age data for mackerel. In conclusion, ageing between the two labs is consistent. Similar otolith exchanges should continue in the future.

Discussion

The suggestion was made to continue this type of exchange every other year. Other suggestions included development of a reference collection and additional verification/validation of ages, where possible. The exchange shows that both labs agree, however both could be wrong. This is a difficult matter to address because of the lack of known-aged fish. However, the presence of strong year classes in the population (e.g., the 1999 year class) can serve as indirect validation.

Discussion of the otolith exchange led to discussion of the seeming lack of old fish in the population. It was noted that mackerel can live to age 20, but in recent years they are typically only occurring in the surveys (and fishery) at about half that age. US data show a steady decrease in maximum aged fish from the mid-teens in the 1980s to about eleven years old currently and a similar pattern is evident in Canada. Several hypotheses were proposed, including possible changes in natural mortality rates; sampling issues (i.e., older fish present in offshore areas beyond the survey and current fishery), and the suggestion that older fish would be detected less frequently in the surveys during periods of high population abundance.

Sampling mackerel farther offshore could be an option to consider to attempt to get otoliths from older fish.

A. FISHERIES

TRAC Presentation: Canadian Fishery

Working Paper: Grégoire, F. Update of the Commercial Landings for 2007-2008. TRAC Working Paper 2009/17.

Presenter: M. Castonguay
Rapporteur: J. Blaylock

Presentation Highlights

Landings were presented since 1960, including landings by area, gear type, and province (since 1995). Historical landings from the 1800s were also provided. Landings increased in recent years to a high of 54,279 mt in 2005, but have subsequently declined to 28,245 mt in 2008. This rise in landings, primarily from Newfoundland waters, is coincident with the strong 1999 year class, which has dominated in the last number of years and is now declining. A look at landings by gear indicates that the increase in catch was largely due to the small purse seine fishery (<65'), as well as the start of a new tuck-ring seine fishery in 2004. The reasons for the large catches were a combination of the presence of a strong 1999 year class, as well as strong fishing effort in Newfoundland. Most landings come from the west (e.g. NAFO Division 4R) and east (3KL) coasts of Newfoundland during the fall. In the 1990s, few catches of mackerel were landed on the east coast of Newfoundland. Efforts are underway to get a better handle on discards, especially from the fall hook and line fishery of the southern Gulf of St. Lawrence, which are known to be an issue since there is a minimum legal size (250 mm). Means to account for catches in the personal bait fishery are also being investigated. Preliminary estimates for one area were quite large, but it is unclear whether this is representative of all areas. Estimates of recreational catches are also not likely to be available for a couple of years. It was acknowledged that there are some data gaps in estimates of removals. Length frequencies by gear type (from 1976) were presented, as well as the catch at age since 1968. Catch at age data show that the 1999 year class is tapering off much earlier (around age 6-7) than the 1982 year class, which was still strong at age 8-10.

Discussion

No information was available regarding discards. The main concern would be in the bait fishery, where underreporting is a serious problem and discards could be as large as recorded landings.

No information was available regarding the recreational fishery but indices are currently being developed.

Mackerel were typically not caught on the east coast of Newfoundland until 2001, when catch started to increase. No management regulations are thought to have influenced this, although quotas on other fisheries (herring and crabs) could have an effect on landings.

It was noted that there was a discrepancy between the landings data presented here and data in TRAC Working Paper 2009/20 that should be resolved. The explanation is that an update of the data was done just before the videoconference. Landings data will be updated again for the March meeting.

Additional questions related to whether the data suggested there had been changes in growth rates over time or whether there might be some issues with gear selectivity that would have to

be addressed in the March modelling meeting. There is a request from the group to calculate and revise the slopes (arrows) shown on the length frequency plots by gear (p.6). This would be helpful to see the different patterns of gear selectivity that are reflected in these slopes.

TRAC Presentation: US Fishery

Working Paper: Shepherd, G., J. Deroba, S. Sutherland, M. Jones, J. Blaylock, E. Holmes, and J. Nieland. USA Data Summary. TRAC Working Paper 2009/20.

Presenter: G. Shepherd
Rapporteur: J. Blaylock

Presentation Highlights

US mackerel landings have increased since the 1960s and reached recent peaks in 2004 and 2006 (56,640 mt in 2006) before dropping by about half in 2007-2008 (21,749 mt). It was noted that US landings are not dockside monitored; however, both trip and dealer reports are submitted to NMFS. Landings were described in terms of market categories (small, medium, large) since 1994. Distribution of catches was presented graphically by month. Recreational landings represent a relatively small proportion of total catch and they have decreased over time since the mid 1980s (reliable since 1981 with a relatively organized fishery). Discards are small relative to landings. The US mackerel fishery is very seasonal and is dominated by the mid-water and otter trawls. Based on NMFS records, market category determination by length can vary but length frequency data show that fewer large fish have been landed in recent years. The personal bait fishery is not considered to be an issue.

Discussion

Historical catch records (see TRAC Working Paper 2009/17) suggest that present landings are relatively close to those in the early 1800s. However, the US historical landings included fleets fishing in Canadian waters, so they are more comparable to combined US and Canadian catches today. In the 1960-70s, international fleets were a big driver of landings.

One possible explanation for the low numbers observed in the last two years could be a change in weather patterns. The absence of significant storms left mackerel more spread out making it more difficult for fishermen to find schools of fish. It was noted that some work had been done on this previously, which could be summarized.

There were a few ideas to improve data and analysis. A suggestion was made to examine the data disaggregated by area and possibly exchange data to enhance calibration between the US and Canada. In addition, one could add a spatial component to the length-weight data to make it possible to look at areas other than the Mid-Atlantic Bight.

Some clarification questions were addressed:

• Recreational fishery landings include data on private/personal vessels and party/charter boats. The bait fishery is included in the commercial data.

• US landings come from Vessel Trip Report (VTR) and dealer reports; there is currently no dockside monitoring.

- Sampling is the same between NMFS and the fishing industry, but there are some differences in market category classification.

A comparison between fresh and previously frozen fish shows that the freezing process results in an increase in the length-weight relationship relative to fresh mackerel. This could be a result of shrinkage in length, while the weight is not significantly affected. An alternative explanation is that no shrinkage occurs but remains of ice on the fish increase the weight at length. Simple experiments could be conducted to identify the cause. The suggestion was made to combine survey and industry samples, as well as to continue to investigate the need for a conversion factor for frozen samples.

There is a need to make sure that Canada and US are both using the same total landings – tables should be checked.

A. ECOSYTEM CONSIDERATIONS

TRAC Presentation: Pelagic Fish Outburst or Suprabenthic Habitat Occupation

Working Paper: McQuinn, I.H. Pelagic Fish Outburst or Suprabenthic Habitat Occupation: Legacy of the Atlantic Canada Cod Collapse in Eastern Canada. TRAC Working Paper 2009/19.

Presenter: I. McQuinn
Rapporteur: J. Blaylock

Presentation Highlights

Bottom trawl indices (BTI) from research surveys in eastern Canada show an increase in abundance of pelagic species beginning in the early 1990s. This formed the basis for the development of a top-down 'trophic cascade' hypothesis on the Eastern Scotian Shelf (ESS) by Frank et al. (2005). According to research BTIs, while groundfish, zooplankton, and nutrient abundances have decreased since the mid 1980s, small pelagic, shrimp, and phytoplankton abundances have increased. This major shift in biomass is underlined with a mass-balance ecosystem model analysis, which highlights the increasing presence of capelin, sand lance, herring, and shrimp in the 1990s. During the same period in eastern Canadian ecosystems, cod populations declined in biomass and distributional extent. In parallel, data from herring acoustic surveys show a change in preference for the suprabenthic habitat starting between 1989 and 1991, resulting in an increase in catchability to bottom trawls for this species coinciding with the decrease in cod biomass. A similar pattern is evident between capelin and cod whereby if cod are present, capelin move up in the water column. Therefore, the increasing trend in bottom trawl indices for pelagics in Western Newfoundland is not caused by a population increase, but is rather a reflection of available biomass on the sea floor where catchability to the bottom trawl has increased by orders of magnitude over time. This pattern is also observed on both the Eastern and Western Scotian Shelf.

Discussion

It was suggested that the sensitivity of the analysis to 1989 data should be investigated. Comments were also made about what was known about the relevance of this hypothesis to mackerel, as most of the examples and data were for herring, and whether mackerel and herring were expected to behave similarity. The presenter noted that in the face of the evidence for changing catchability to bottom trawls for herring, capelin, and sand lance it would be risky to

assume that mackerel catches would not be affected in a similar manner. The limitations of bottom trawl surveys for pelagic fish assessment were recognized, but some felt that the RV survey indices could provide some useful information (e.g., tracking of cohorts) in the absence of other datasets. Some felt these indices do provide trends in relative biomass indices over the time series. No consensus was reached on this matter.

TRAC Presentation: Consumption Estimates of Mackerel

Working Paper: Link, J. Forage TOR. TRAC Working Paper 2009/21.

Presenter: J. Link
Rapporteur: G. Pastershank

Presentation Highlights

An evacuation rate model has been used in the US to estimate the predatory removals of mackerel by fish species sampled in the NMFS RV survey since 1973 and documented in a large food habits database. This estimate did not take into account consumption by other predator species, such as marine birds, mammals, or large highly migratory species like tuna. Neither did it include an estimate of consumption in Canadian waters. It did include predation in US waters by fish species such as: spiny dogfish, winter skate, silver hake, cod, pollock, white hake, red hake, summer flounder, bluefish, striped bass, and goosefish. Preliminary results indicate a peak in mackerel consumption by these species in the early 1980s, a subsequent decline, then a smaller increase in the late 1990s and 2000, and then a decline again. Possible reasons for peaks included increases in abundance of predators, prey switching, and availability of mackerel to these predators. Preliminary estimates of total consumption (considered to be a conservative estimate) were in the same order of magnitude as landings, in some years were higher than landings, and trends were consistent with landings trends in the mid-part of the time series. Further work includes: age allocation of consumption, consideration of spatial overlap between predators and mackerel (especially during northern migration), consideration of Canadian consumption (investigation of Canadian stomach contents database), and incorporation into assessment models (e.g., as a separate fleet), and accounting for variance (triple variance method, maximum CV, or Bayesian approach).

Discussion

A question was asked about whether marine mammals consume higher aged mackerel. It was noted that fish are primarily eating age 0 to 2 mackerel. Marine mammals have a larger window of age classes that it feeds on. There was a paper published on this – two mammals were feeding on the older age 3 mackerel.

Whether or not predators feeding on mackerel were doing so opportunistically or in a directed manner was discussed. Preference can be estimated; however, predators will generally eat what they can capture given gape-wide and swimming considerations.

For natural mortality (M), fish can die from either predation or disease and the relative amounts for the two parameters are not known. In terms of scaling, currently the stock assessments use 0.2 for M (M1 which represents disease, senescence and other sources of mortality and M2 which represents predation). This number gives a rough estimate of the total M. However, we know M is both time and age variant. This needs to be considered. As predation is one part of M, and M is assumed to be constant, it was suggested that the models should be tested under a number of different assumptions. Models can be scaled and tuned to address this.

In 1973, the food habits database accounted for some species, and, later in the time series (1977), additional species were considered. It was unclear how these data gaps were addressed. It was clarified that, in the first few years, there were three less predators. In 1977, when data were collected for the other predators, they were added to the time series.

Although this is one of the largest stomach contents databases, it still has some limitations, especially for large, highly migratory species, which were not included in the original sampling protocol. For example, swordfish and tuna are thought to eat a lot of mackerel in Canadian waters. There are three ways that highly migratory species could be taken into account. First, each season could be overlapped with the spatial distribution of the migratory species, as has been done. Alternatively, consumption of migratory species could be calculated as a whole and then pro-rated. Finally, regional breakdowns could be applied for the migratory species. However, there are other studies that show finfish are the predominate predators. In terms of whether or not the results of the consumption analysis would change if other predators were added, it was felt that the shape of the graph would likely be retained. These other species can be added, and they can be included with some assumptions.

It was asked whether mackerel are bottom feeders. If mackerel change their behavior and shift their food preference, they are not obligatory bottom feeders. Predators can adapt with movement of prey, especially for visual predators such as goosefish that can swim near the bottom and attack. Is it possible to use mackerel stomach contents to illustrate potential changes in their behavior (i.e., benthic versus pelagic)? This would likely be difficult to tease apart. It is not known why a mackerel would choose one prey item over another – there are too many confounding factors, plus mackerel are primarily pelagic feeders.

Collaboration with the oceanographic team helped to characterize the seasonal average temperatures with survey data. There was the choice of using either sea surface temperature or bottom temperature, but since most of the predatory fish are demersal, the bottom temperatures were used.

The consumption estimates provided here were for the US waters as a whole and were not disaggregated regionally. Also the estimates presented are considered to be conservative as they do not include Canadian data. To be considered more fully in the assessment, information on the mackerel feeding in Canadian waters during the summer would be valuable to include (e.g., Gulf of St. Lawrence and northern areas where summer feeding occurs). The analysis would be enhanced by incorporating Canadian data; however, Canadian studies have not measured the same data over the same temporal extent. There is some data on the Scotian Shelf. Also, useful information may come from numerous ecosystem studies that have been published.

There are three ways to address the uncertainties in the consumption modeling. First, a statistical triple variance can be used. This accounts for the variance in abundance of stomach contents and their associated CVs. Second, the maximum CV should be used (e.g., 60%). And third, a Bayesian approach or semi-Bayesian approach can be conducted. However, as seen for herring, this can be labor intensive.

In the Bay of Fundy, there is an abundance of seals. It is not clear if they are having an impact on the mackerel stock, but seals can prey on mackerel. It was suggested that pinnipeds should also be included in the estimates of consumption. Another question came up on how to incorporate this type of information into stock assessments. It was agreed that it will be important to incorporate ecosystem considerations into stock assessments.

Multi-species virtual modeling analysis exists (MSVPA). There are numerous multi-species models; however, some members were of the opinion that the MSVPA was outdated, which is why the US has developed MSVPA-X, to accommodate other considerations. However, MSVPA can produce outputs that can be used for a reality check and fine tuning and could also provide context (e.g., source of estimates for scaling to determine the magnitude of an issue). Exploration of this model would need to be prioritized as it would be time consuming to conduct.

A. RESEARCH SURVEYS

TRAC Presentation: Canadian Surveys – Update of SSB

Working Papers: 1) Grégoire, F. Update of SSB for 2008, 4T Survey. TRAC Working Paper 2009/18.
2) Grégoire, F., W. Barry, J.-J. Barry, J. Barry, C. Lévesque, J.-L. Beaulieu, and M.-H. Gendron. Calculation of the Atlantic Mackerel (*Scomber scombrus* L.) Spawning Biomasses from the Ichthyoplankton Surveys Conducted on the West Coast of Newfoundland in July 2007 and 2008. TRAC Working Paper 2009/16.

Presenter: M. Castonguay
Rapporteur: G. Pastershank

Presentation Highlights

Spawning stock biomass (SSB) of the northern contingent is based on calculations of total egg production from the southern Gulf of St. Lawrence (4T) egg survey, where eggs are collected during the mackerel spawning season. For the time series (e.g., 4T), the survey started in 1983 with gaps for a couple of years (e.g., in 1995 the program was switched to every second year and then returned annual surveys in 2000). Details of the survey and the method used to estimate SSB were presented. There was a very large SSB calculated for the strong 1982 year. The SSB has been weaker since 2000. The SSB value for the 1999 strong year class was weak. Not detecting the strong 1999 year class has lead to hypothesis that the mackerel changed their spawning behavior at this time. This was also the rational for an Atlantic-wide survey – to try and determine where spawning was/is occurring (e.g., offshore or new locations). The latest mackerel assessment indicated that they were at their lowest in the time series. It is possible that ocean temperatures and timing of mackerel reproduction may be changing (behavioral change).

Brief mention was also made of the ichthyoplankton surveys conducted on the west coast of Newfoundland since 2004. While a similar analytical approach has been used to calculate spawning biomass from these surveys, the results have not been used in the Canadian SSB index.

Figures showing the mackerel trends in the Georges Bank and Scotian Shelf RV surveys were shown later in the day, but the lack of confidence in these results was expressed given the high number of zero catches accompanied by the occasional very large tow of mackerel, as well as the potential change in mackerel catchability in these surveys (as described in the 'Pelagic Fish Outburst or Suprabenthic Habitat Occupation" presentation above).

Discussion

There was some concern that the existing egg survey was not adequately capturing all significant spawning activity in Canada, particularly when large year classes spawn. It was hoped that the most recent Atlantic-wide egg survey would provide a better indication of the extent of spawning activity in Canadian waters; however, it was noted that the survey may have been too late to adequately capture the full extent of the once strong (but now diminished) 1999 year class. Preliminary results indicate that not many mackerel eggs were found in the survey. It may have been better to conduct the survey in the early 2000s when there was a strong 1999 cohort but funds were not available at that time.

There was a NEFSC study that collected data for 100 stations in cooperation with industry that may have some useful information.

There are no dedicated surveys for adult mackerel biomass in Canada. In Canadian waters, mackerel are not caught regularly in bottom trawls or as by-catch. It was felt that the egg survey is the "state of art". Biological data are also collected to calculate the gonadosomatic index (GSI).

The NEFSC autumn survey, which includes the Georges Bank area may provide some information. It is unlikely that there will be any additional information for the southern and northern Gulf of St. Lawrence. A concern was raised that not all data is available at this workshop, and the next one is for modeling. It was felt that any additional data from Canadian waters would be insignificant. M. Castonguay will look to see what other types of data inputs may be available to bring to the meeting in March.

There seemed to be a discrepancy between the landings and SSB data. The gill nets (e.g., area 4T) are catching spawners; however, the egg production data indicates no eggs or SSB. It is possible that there is a shift in spawning area (e.g., moving offshore) and fish then come back, or that they are fished-out. The southern Gulf of St. Lawrence is the main spawning area; however, there may be others. More information will be available when the Atlantic-wide study is completed.

Mackerel can spawn elsewhere. For example, in 1967, the mackerel did not spawn when there was a strong year class in the Gulf. This may have been due to changes in oceanographic conditions, subsequently causing a shift in the seasonal timing. Colder conditions would result in mackerel arriving later than the typical time of May-June. The US is not seeing shifts in spawning distribution; however, this could be due to the wider area that is surveyed. Perhaps the bigger picture is being captured.

It was suggested that a broad-scale egg/larval survey should be conducted every three years. This is in-line with the Europeans are doing for the northeast Atlantic mackerel.

TRAC Presentation: US Surveys

Working Paper: Shepherd, G., J. Deroba, S. Sutherland, M. Jones, J. Blaylock, E. Holmes, and J. Nieland. USA Data Summary. TRAC Working Paper 2009/20.

Presenter: J. Deroba
Rapporteur: G. Pastershank

Presentation Highlights

The Northeast Fisheries Science Center (NEFSC) has conducted research bottom trawl surveys during the spring, winter, and fall, and these surveys were considered for inclusion as indices of abundance for assessing Atlantic mackerel. The surveys have been conducted for a varying range of years depending on the season. Mackerel catches in the spring and winter surveys occurred from Cape Hatteras to Georges Bank, but were consistently highest in the Mid-Atlantic region. Mackerel were caught less frequently in the fall survey than in other seasons because an unknown proportion of the stock was distributed inshore or in Canadian waters and were unavailable to the survey. Consequently, the fall survey was not used during the last assessment. The location of mackerel catches during the spring and winter survey were also generally similar to the location of commercial catches. For each season, an annual index of abundance was estimated using an arithmetic mean, geometric mean (i.e., ln retransformed), and delta approach. The trends in the indices of abundance among years for each season were generally the same regardless of the method of estimation. For the spring survey, the index of abundance increased since the 1970s and varied without trend for the last 10 years. For the winter survey, the index of abundance varied without trend during the entire time series with the exception of a large increase in 2005, which was caused by two unusually high catches in that year. The fall survey was more highly variable than the other seasons with no obvious trend. The proportion of zero mackerel catches for each season averaged 69% or more among years. Positive survey catches showed no relationship with bottom temperature for any year or survey season. Length frequency plots in each year for the spring and winter surveys generally showed multiple year classes and some large year classes could be tracked through time. The same results were evident for age frequency plots.

Discussion

It was suggested that the arithmetic mean may not be the most appropriate choice given the high proportion of zeros with occasional very large tows. The geometric means showed a lower magnitude of abundance than the other two mean abundance indices.

Changes in research survey vessels or gear over time had not been accounted for to date.

Additional discussion included tracking of large year classes in the 1980s and 1990s in the RV indices (RV surveys suggested the 1999 year class was much larger than the 1982 year class) and the limited catches of mackerel after approximately age 4 (scaling issues to be checked).

The 1999 year class appeared to be gone by 2004. It was unclear whether this was an indicator that the surveys don't capture the big fish or that abundance was too low. This same result is also observed with industry data - the strong 1999 age class was not found in 2005. It was asked whether the bottom trawl survey ever caught larger/older fish. Back in the 1980s, the RV surveys captured the older fish that they are not capturing now, so the lack of old fish may not be due to the method of sampling. Fish over 3 or 4 years of age are not being caught. Currently the maximum age observed is about 8 or 9 yrs. About 15 yrs ago, it was common to catch 11

and 12 year old fish and occasionally 16 year old fish. It was suggested that it may be better to plot the results on a log scale in order to see that there are older fish. It is a question of relative abundance of the age classes, and if the catch curve is capturing the different cohorts.

It was asked why there was no abundance peaks for the strong 1982 year class in the RV survey data -- whether it was a question of scale. The data indicated that there are more fish now than in 1980s. This was felt to be consistent with the current understanding of the stock. Abundance is higher now than in 1970s (mackerel were collapsed in 1970s) and the mackerel stocks have recovered significantly.

It was suggested that the catch curves be investigated by cohort, and additional diagnostics be conducted.

It was suggested that there may be a behavioral shift happening for mackerel (from pelagic to benthic), which could mean more mackerel would be caught in bottom trawls.

It was noted that mackerel is one of the top 10 species caught in the US bottom trawl survey. For the North Sea herring, use of an RV survey index is the second top index that they use, and their data are well analyzed. It was noted, however, that there are limitations to using bottom trawl data for small pelagic fish.

TRAC Presentation: US Larval Surveys

Working Paper: Shepherd, G., J. Deroba, S. Sutherland, M. Jones, J. Blaylock, E. Holmes, and J. Nieland. USA Data Summary. TRAC Working Paper 2009/20.

Presenter: D. Richardson
Rapporteur: D. Robert

Presentation Highlights

A presentation was made on the US larval surveys (MARMAP: 1977-1988, ECOMON 1999-present) and the approaches taken to date to estimate seasonality of spawning, larval mortality and an annual abundance index. Preliminary results indicate a decline of over an order-of-magnitude in larval abundance from 2001 to 2007. Proposed explanations included 1) a shift in spawning season 2) a change in spawning location for the southern contingent, 3) a decline in SSB of the southern contingent, or 4) a combination of these. A sensitivity analysis was presented to evaluate the magnitude of a spawning season shift that would be required to account for the decline. A shift of at least 3-4 weeks is required to account for the decline; if the spawning season shifted more it is expected that larvae would have been caught in higher numbers during cruises in the spring or late summer. Additional work that could be used to resolve the reasons for the decline include: extra plankton tows added to existing cruises or extending the survey through a US/Canada effort. It was noted that eggs used to be identified during the MARMAP years (1977-1988), but they are not currently. Molecular ID techniques (using Bar Code of Life protocols) were used on a test basis in May/June of 2009 to investigate cost effectiveness for egg identifications. No mackerel eggs were identified during this survey.

Discussion

Discussion focused on 1) the feasibility of applying the data as a recruitment index versus an abundance index, 2) potential reasons for the decline in larval abundance on the U.S. shelf

since 2001 and 3) the need for a joint Canada/US egg/larvae survey and 4) more general questions about the time series.

The feasibility of applying the data as a recruitment index versus an abundance index — The larval index had a few multi-year peaks. The first peak in the larval index doesn't correspond with the strong 1982 year class, but occurs in 1980 and 1981. The 1982 strong year class seen in the bottom trawl survey is not detected in the larval index. Survey data was not available in 1999. The second peak occurred from 2000-2002.

Potential reasons for the decline in larval abundance on the U.S. shelf since 2001 — One hypothesis for the decline was that the spawning seasonality shifted substantially (3-4 weeks), and thus larvae are no longer collected on the late-May/early-June ECOMON cruise. Whether spawning season could have shifted in such a dramatic way remains unknown. Sea surface temperatures during the May/June larval surveys for the three most recent low years (2005, 2006, 2007) were low, high and average respectively. If spawning season shifted, would it have shifted earlier or later? There is no evidence suggesting that a shift in either direction is more likely than the other, and a one-month spawning shift would be a very large shift. A question was asked about whether gonad weights are monitored (from commercial samples, etc) for evaluating the timing of spawning. Currently no such data is available.

It was suggested that spawners and egg distribution might have shifted offshore explaining the absence of larvae in recent years. This was considered unlikely, as the surveys extend to the edge of the continental shelf, and larvae are generally only found on the inner half of the continental shelf

The need for a joint Canada/US egg/larvae survey — An offer was made by Canada (IML) to help process egg samples. The use of the gonadosomatic index (GSI) or aging of larvae could be used to pinpoint timing of spawning. It was suggested that an egg production analysis of the US samples could be compared to Canadian results, even if only for one year for contextual purposes. A question was raised about whether plans for collaboration between Canada and the US for an egg survey in 2009 had been made? There was a sampling effort by the U.S. but samples remain to be examined. Examining these samples would help resolve the hypothesis of a spatial shift in spawning. It was noted that complete coverage (Canada & US) during an egg survey is very promising for better understanding SSB and spatial patterns of spawning.

General Notes/Comments

- Differences in larval numbers between good and bad years are huge (5000 vs. 22). These differences remain unexplained.

- The data for 2003 and 2008 were not usable due to ship time cutbacks.

- The larval index suggests similar magnitudes between 1982 and 1999, but this is very different from what the BTI shows (as well as the Canadian index).

- A question was raised about why molecular techniques are used for mackerel egg ID when visual identification is straight-forward. The NEFSC no longer has the personnel trained to morphologically identify eggs, and it is unlikely that an individual will be hired in the near future. Molecular techniques are also getting cheaper, becoming more competitive with the costs of contracting individuals to do morphological identifications. Finally, the NEFSC surveys target multiple species. Molecular identification techniques enable the full suite of

species in the samples to be identified. Many of these species cannot be identified morphologically.

A. SAMPLING ADEQUACY

TRAC Presentation: US Sampling Adequacy

Presenter: G. Shepherd (US)
Rapporteur: D. Robert

Presentation Highlights

In general, US sampling is considered to be adequate since 2005. In the 1990s, most of the samples were obtained from otter trawl, the primary gear. The number of length samples has increased significantly in recent years. Industry sampling has not yet been included in the results, but they will be. Recreational sampling is opportunistic but adequate. Expansion into catch at age was done by market categories, not gear types.

Discussion

A question of clarification was asked as to the age of fish targeted by the commercial fishery. It was clarified that, in the graphs, age 0 should be read as age 1.

Landings values in 2006 (4 times higher) were asked to be verified.

TRAC Presentation: Canadian Sampling Adequacy

Presenter: M. Castonguay
Rapporteur: D. Robert

Presentation Highlights

As mentioned previously, there are gaps in the landings data for the bait fishery, recreational fishery, and discards. In particular, bait fisheries could add substantially (50 to 100%) to total fishing mortality. A pilot bait fishery program started in 2007, and preliminary results show that landings could be underestimated by 80-100%.

As an indication of the sampling adequacy of the commercial fishery, approximately 13,000 length frequency samples were collected from port sampling in 2007. There are some gaps in port sampling in eastern Newfoundland. There was considered to be adequate samples per gear type relative to the metric tons landed.

Discussion

Commercial landings per area and gear should be well summarized for the modeling meeting. It was suggested that the number of samples per metric ton by gear type and area be provided as a reference table.

A. DATA BENCHMARK CONSENSUS

Atlantic mackerel is considered a single stock unit, with seasonal migratory movements between Canadian and US waters. The stock includes both a northern and southern spawning

contingent. The northern contingent spawns primarily in the Gulf of St. Lawrence during May-August, with peak spawning occurring in June and July, whereas the southern contingent spawns in the mid-Atlantic and Gulf of Maine during April-June. The two contingents mix during the winter fishery. This species responds to oceanographic conditions and, as such, additional studies are needed to determine the overall spatial distribution, including the spatial extent of the commercial fishery, and the extent of mixing of the spawning contingents.

Ageing of otoliths is consistent between the laboratories with a high level of agreement between readers (low CVs and no bias). The recommendation was to continue to exchange otoliths every other year.

For Canadian catch, there is sufficient sampling of the commercial landings, however; there is incomplete information on commercial discards, the bait fishery removals, and recreational catches.

For the US catch, sampling of the commercial catch is adequate since 2005 and will be supplemented with industry length frequency samples. Sufficient information is available on recreational catches and discards, but these were not dockside monitored. Historical and distant water fleet landings are relatively reliable. The recommendation was to exchange Canadian/US length frequency samples.

Fishery independent data for mackerel in Canadian waters is derived as SSB using total egg production based on the 4T egg survey. The Newfoundland ichthyoplankton surveys and the Georges Bank and Scotian Shelf RV groundfish surveys are not used in analyses. The DFO groundfish surveys have very few tows with large numbers of mackerel. A broad scale egg survey was conducted in 2009; however, the results are still preliminary.

Fishery independent data for mackerel in US waters is derived as abundance and biomass indices from the spring, winter, and autumn RV groundfish surveys; however, the autumn data is not used in analyses. Data from larval surveys (MARMAP 1977-1988, ECOMON 1990-present) are available.

As an additional index for use in modelling, a catch per unit effort index will be derived using both US and Canadian fishery data. Use of abundance indices from the DFO groundfish surveys will also be explored.

Estimates of consumption of mackerel by predatory fish, as sampled in NMFS RV groundfish surveys in U.S. waters, will be available for modeling. These estimates do not, however, include consumption by marine birds or mammals, or highly migratory species (e.g., tuna).

A number of different modelling approaches / models will be explored for the model meeting, including e.g. forward projecting models, ASAP, SSA, CLAMS, ADAPT . European approaches to modeling (SVPA, XSA, ICA) will also be explored.

Data was exchanged, and the need for additional uniformity in the presentation of data was recommended. It was recognized that there is a need to resolve disagreement on the nature and perception of data quality.

A. RESEARCH RECOMMENDATIONS

- Exchange otoliths every other year to monitor agreement between NEFSC and DFO age readers. Initiate development of a reference collection.

- Investigate the need for a conversion factor for the length-weight relationship for frozen mackerel samples.

B. MODEL BENCHMARK AND ASSESSMENT MEETING

B. INTRODUCTION

The Transboundary Resources Assessment Committee (TRAC) co-chairs, L. O'Brien and T. Worcester welcomed participants (Appendix 4) to the 2010 TRAC benchmark model review and assessment of Atlantic mackerel. The meeting commenced on 1 March 2010 and was completed on 4 March 2010.

The Terms of Reference and Agenda for the meeting are provided in Appendices 2 and 5, respectively. During the meeting, presentations of research topics and working papers were followed by a plenary discussion on that topic. Rapporteurs documented these presentations and discussions for the Proceedings.

B. DATA MEETING CONSENSUS REVIEW

TRAC Presentation: Review of Benchmark Data Consensus

Presenter: T. Worcester

Presentation Highlights

See Section *A. Data Benchmark Consensus*

B. DATA UPDATE

TRAC Presentation: Review of Updates/Modifications to Data

Presenter: G. Shepherd
Rapporteur: J. Nieland

Presentation Highlights

The Age Structured Assessment Program (ASAP) software was used at the 2005 Atlantic mackerel assessment (SAW42 2006). Since that time, updates have been made to ASAP. Differences in the results from SAW42 and results using the new software were minimal. The use of a constant likelihood, an option not available in the previous version of ASAP, influenced the terminal estimates of fishing mortality; however, the magnitude difference in F between model runs was minimal. Catch estimates have been updated since the data meeting in October 2009, and ASAP was rerun. Foreign landings in Canada from 1968 to 1977, previously not included, were added, and the Canadian 1985-1989 catch at age data were updated to include all available length and age data from that period. The largest decrease occurred in 1970 with a reduced catch estimate of 17,086 mt, while the largest gain was 522 mt in 1982. In addition, US landings at age for 2006 to 2008 were re-calculated with the inclusion of length data collected by commercial industry funded sampling.

Discussion

Mackerel abundance and SSB increased in the model with the revised catch estimates. The changes in catch had a cumulative effect on abundance and SSB (i.e., differences in estimated abundance and SSB between the model using the original data and the model using the revised data increased over time.) The effect of the revised data on the retrospective patterns was not evaluated.

B. STOCK STRUCTURE

TRAC Presentation: Review of Tagging, Stock Structure and Sette's Research

Presenters: M. Castonguay and F. Grégoire
Rapporteur: J. Nieland

Presentation Highlights

Sette's work was reviewed with respect to stock structure of mackerel in the NW Atlantic, and, in particular, with respect to winter mixing of the two contingents. Sette identified two spawning groups or contingents in the NW Atlantic that each had their own spawning areas separated by 100s of km. Sette also determined that the two contingents overwinter in deep water, primarily between Cape Hatteras and Cape Cod, but also as far north as Nova Scotia. In spring, the appearance of the two contingents in inshore waters at different times and in different areas led Sette to argue that the contingents overwinter in largely distinct areas with an overlapping zone off Long Island. Sette argued that the southern contingent occurs off Long Island and southwestward while the northern contingent is found off Long Island and northeastward. However the evidence for or against contingent mixing during winter should be regarded as fairly weak and may have changed since Sette's (1950) time. If Canada and the US wish to pursue joint assessments in the future, the relative contribution the two contingents in the US winter fishery and in the area covered by the spring survey should be estimated, possibly through a joint tagging program.

Discussion

The relative contributions of the northern and southern mackerel contingents to the US winter fishery and the NEFSC spring bottom trawl survey is not well known. The data from Sette's work was collected during 1925 – 1930, and the distributions could have changed since that time. Participants at the October 2009 TRAC data meeting concluded that more fish from the two contingents overlapped in Sette's time than now. Recent observations show the distribution of mackerel in the northeastern Atlantic is changing. The cause of this change is unclear.

Current data to examine the distributions of the two contingents is sparse because foreign fleets no longer fish in Canadian waters. Data from the foreign fleets that were fishing in US waters might be analyzed.

A joint tagging program could help provide the necessary data. Canada has already started tagging mackerel but has not caught many fish (only 500 were tagged off Nova Scotia in 2009). The number of tagged mackerel needed to obtain a good estimate has not been calculated yet, but the returns should be high considering the high fishing mortalities estimated from the current assessment.

The Canadian egg survey is used to estimate SSB of the fish that spawn in the southern Gulf of St. Lawrence (the traditional spawning ground for mackerel in Canadian waters). This survey was expanded in 2009 to the Scotian Shelf and southern Newfoundland. Few eggs were found, and this would confirm that the reduction of SSB estimated for the southern Gulf of St. Lawrence was caused by a real reduction of stock abundance and not by a major change in the fish distribution (i.e., mackerel are present but spawning elsewhere).

A capelin and herring larval survey has also been conducted on the west coast of Newfoundland since 2004. Surprisingly, mackerel eggs and larvae were found at almost every sampling station during this survey. The abundance of mackerel eggs has even increased since 2004. The west coast was not sampled prior to this time (at least the area located between Bonne Bay and Port au Port Bay), so it is not possible to say that this is a new spawning ground for mackerel. Small mackerel (young of the year) were also caught on the east coast of Newfoundland, and this represents a strong indication that mackerel spawn in the area. The fishery on the east coast caught large, old fish in the late 1980s, likely from the 1982 year class. That was also the case during the mid-2000s (1999 year class). Recently, the fishery catches mostly small and young fish (age 3).

An important reduction in SSB has been estimated since the mid-1990s using the egg survey. What is causing this reduction? The 1999 year class was likely fished too hard (it disappeared quickly from the catches), but are fishery landings alone responsible for the decrease in SSB? Alternatively, the stock in the northwest Atlantic could have shifted to the northeast. If this is the case, would the northern contingent still be able to travel to Long Island to overwinter and mix with the southern contingent? We need more information about mackerel movement to answer this question, and a tagging program could help. Colder water temperatures have also coincided with the reduction in SSB.

TRAC Presentation: Shelf/Slope Waters

Presenter: G. Shepherd
Rapporteur: J. Nieland

Presentation Highlights

Atlantic mackerel are generally distributed in winter across shelf waters south of the Scotian Shelf. Spring migration results in a re-location to more northern waters and into the Gulf of St. Lawrence. Changing water temperature coincides with the return fall migration. Distribution is controlled in part by thermal conditions with a preference temperature greater than 5°C. Examples of annual changes in the extent of the preferred thermal regime were examined for the Mid-Atlantic and Georges Bank. For example, cold water on Georges Bank in the spring of 1968 appears to have restricted mackerel to edge of the shelf further south where water temperature was appropriate. In contrast, the spring of 2001 was warmer on Georges Bank and mackerel were abundant across the Bank and further to the east than other years. The annual variation in distribution coinciding with changes in shelf water temperature may have implications in interpretation of the survey results and commercial catches. During the years that the NEFSC survey included the Scotian Shelf there were either no mackerel encountered or small numbers per tow.

Discussion

The SSB in the Gulf of St. Lawrence is much smaller than previously observed. Is this because mackerel have shifted to the northeast or because there are fewer mackerel? The egg survey

was expanded to the Scotian Shelf and southern Newfoundland in 2009, but few eggs were found. This would imply that there are fewer mackerel. In recent years, water temperatures in the Gulf of St. Lawrence were too warm for mackerel during the summer and fall. Based on the landings pattern, it seems that the fish shifted to the northeast to reach the west and east coasts of Newfoundland. Fish from the 1982 and 1999 year classes were also found on the eastern coast of Newfoundland. The presence of large year classes could cause a shift in the distribution of mackerel.

B. CATCH PER UNIT EFFORT

TRAC Presentation: US Commercial CPUE

Working Paper: Deroba, J. Developing an Index of Atlantic Mackerel Abundance Using Commercial Catch and Effort Data in the U.S. Waters of the North Atlantic. TRAC Working Paper 2010/03.

Presenter: J. Deroba
Rapporteur: J. Nieland

Presentation Highlights

Commercial mackerel catch per effort (CPUE) data was considered for use as an index of abundance. Using commercial CPUE data as an index of abundance, however, must be done cautiously because commercial CPUE can change due to factors other than abundance. To account for some of the variation in commercial mackerel CPUE data not attributable to abundance, the data were standardized to better evaluate its usefulness as a potential indicator of changes in abundance.

Analyses were conducted using data from paired trawls, bottom fished otter trawls (OTF), and mid-water otter trawls (OTM), which have accounted for over 99% of mackerel catches in recent years. Data from paired trawls, however, were intermittent and available for less than ten years, and so were dropped from consideration as an index of abundance. Effort was defined as days absent from port and catch was defined as pounds of mackerel landed. Only fishing trips that landed at least 25% mackerel were included in the analysis. "Raw" CPUE for each year and gear type was defined as the sum of catch divided by the sum of effort in each year. Raw CPUE was used as a baseline for comparison to evaluate the effect of standardization. As a preliminary evaluation of the consistency of the commercial mackerel CPUE data with a standardized survey that has previously been used in assessments, the trends among years in raw CPUE for mid-water and bottom fished otter trawls were qualitatively compared to the trend among years from the NMFS spring bottom trawl survey. General linear models were used to standardize the CPUE data for each gear type separately, and included fixed effects of year, month, NAFO statistical area, ton class, state where landings occurred, hull number, and all two-way interactions without year. Model selection was done using percentage of deviance explained ($\geq$ 5% required for retention). The standardized indices were calculated as the bias corrected, back-transformed least squares mean for each year. To evaluate the effect of the standardization, the trends among years in raw CPUE were qualitatively compared to the trends among years from the standardized indices.

The trends in raw CPUE among years for the OTF and OTM gear types were generally similar to the trends for the NMFS spring bottom trawl survey, which suggested that the commercial CPUE data were consistent with NMFS survey. The raw CPUE values for the OTF and OTM gear types suggested different temporal trends from the standardized indices over some or all of

the time series. These results suggested that the commercial CPUE data may be useful as an index of abundance. Furthermore, standardization of CPUE data can affect the trend of the indices, and although standardization cannot guarantee an accurate index, such methods should be used whenever possible.

Discussion

The group discussed the commercial fisheries, the NEFSC spring bottom trawl survey, and the CPUE analysis in greater detail. The diagnostic plots (i.e., residual and normality plots) for the commercial fisheries did not violate model assumptions. The mid-water otter trawl data before 1994 was too spotty to use. The paired trawl fishery did not have enough years of data to be included in the analysis either. The number of boats operating in the commercial fisheries was on the order of hundreds in any given year, but varied from year to year. Including hull number in the standardization helps account for the changes in technology. The distributions of individual trips and the percent of landings attributed to each fishery in each year would be interesting to see. No depth data from the fisheries was available to examine. Locations by latitude and longitude could be tested as another effect in the model, but this effect might not be that useful because the fisheries tend to follow the seasonal mackerel migration (e.g., the bottom fished otter trawl fishes inshore in the summer, offshore from December to March, and on the shelf edge from March to May). The NEFSC spring bottom trawl survey samples all but the most extreme inshore areas. Each fishery was a separate index in the model (e.g., a different catchability was used for each fishery). The indices were aggregated (not separated by age) because data to disaggregate the CPUE trends by age were unavailable.

B. SURVEY INDICES

TRAC Presentation: NEFSC Survey Indices

Working Paper: Deroba, J. A Consideration of Factors Potentially Affecting the National Marine Fisheries Service Bottom Trawl Survey Indices of Abundance for Mackerel. TRAC Working Paper 2010/04.

Presenter: J. Deroba
Rapporteur: J. Nieland

Presentation Highlights

During the Atlantic mackerel TRAC data review meeting, held October 22-23, 2009, suggestions were made to: 1) explore the use of a delta method for estimating indices of abundance, 2) consider the affects of temperature, time of day, survey timing, and gear characteristics on the catch of NMFS surveys, and 3) evaluate if mackerel have occurred more frequently in demersal habitats in response to low cod abundance.

The delta method was applied to the NMFS spring survey data and involved fitting two statistical sub-models, one for standardizing the probability of obtaining a non-zero catch, and a second for standardizing positive mackerel catches. The sub-model used for the probability of obtaining a non-zero catch was a generalized linear model with a logit link function, and included fixed effect of year, stratum, survey vessel, time of day, temperature, and a year by stratum interaction. The sub-model used for positive mackerel catches was a general linear model with $\log_e$(CPUE) as the dependent variable and the same fixed effects as the sub-model for the probability of a non-zero catch. Model selection for both sub-models was done using AIC. The annual indices were calculated using a combination of results from each sub-model, and

involved multiplying the probability of a non-zero catch for each year from the sub-model for the probability of obtaining a non-zero catch by the bias corrected, back transformed year effect from the sub-model for positive catches. To evaluate the effect of the delta method, the trends among years in these annual indices were qualitatively compared to the geometric means for each year, which are more commonly used as the index.

To evaluate the issues highlighted in suggestion two above, annual indices of abundance were estimated separately for day and night tows, and these trends were qualitatively compared. The proportion of tows that occurred during each time of day for each year was also calculated. The timing of the survey was evaluated by examining the trend among years of the mean Julian date of the spring survey in each year. Lastly, the effect of vessel, net, and door changes on survey catches was evaluated by reviewing relevant literature.

To evaluate whether mackerel have occurred more frequently in demersal habitats in response to low cod abundance, trends in the proportion of tows in each year that caught both cod and mackerel were examined among years, in addition to the trends in the proportion of tows in each year that caught mackerel but not cod.

The trends among years between the delta method and geometric means were generally similar. The delta method, however, was less variable. These results suggested that use of the delta method would not result in significantly different indices of abundance than using the more customary geometric means.

Catches of the spring survey were higher during the daytime than nighttime, but trends were generally similar. Furthermore, the proportion of tows during each time of day was nearly equal and has not trended through time. So, time of day may not have affected indices of abundance. The mean Julian date of the spring survey did not trend among years, and so was likely not affecting indices of abundance. Little data exist on the effect of vessel, net, and door changes on the catches of mackerel. Consequently, conclusions were difficult.

The trends among years in the proportion of tows in each year that caught both cod and mackerel and in the proportion of tows in each year that caught mackerel but not cod did not strongly support or refute the hypothesis that mackerel have occurred more frequently in demersal habitats in response to low cod abundance. So, this topic should remain an active area of research.

Discussion

The delta method and geometric mean estimates of mackerel catches were compared. The 2001 and 2003 spikes in the delta method are important even though the trend between the delta method and the geometric mean are the same. The VPA should be run with the delta method point estimates as well. A deviance table should be made for the delta method. The geometric mean estimates included a bias correction. The original delta method estimates did not include a bias correction, but this correction was included later. Adding the bias correction to the delta method did not change the general conclusions about comparisons of the delta method to the geometric means.

The affects of temperature, time of day, survey timing, and gear characteristics on mackerel catch were considered further. Temperature included only non-zero catches. This method does not address the temperature induced changes on the mackerel distribution, only how temperature may affect survey catch rates. Temperature should be modeled as a range rather than a continuous variable. Modeling temperature as a random effect is another option. For

ease of comparison, the mean catch per tow during the day and night needed to be rescaled to the average over each time series. The scale of the mackerel indices was generally higher during the day than at night. Could the large amounts of mackerel taken by the commercial fishing industry, specifically the foreign fleet, have influenced the NEFSC spring survey day vs. night mackerel catch during this period? The years when there were gear changes on the NEFSC survey vessel might have influenced catchability.

Analyses were performed to determine whether or not changes in mackerel distribution coincided with changes in cod abundance. The size of cod should be accounted for in these analyses. Performing the same analyses with herring instead of mackerel as well as substituting other predators for cod would be interesting.

B. MODEL REVIEW

Initial Model Presentations

Initial model presentations were made by both NEFSC and DFO scientists to demonstrate the range of model results. Discussions about each model presentation were followed by a broader discussion that compared and contrasted the models and led to development of new analyses. Much of these later discussions focused on model diagnostics and how the different pieces of information were trading off against each other in the different model configurations. After much discussion, a consensus model formulation was agreed upon and biological reference points were derived from this run, although the results from other model runs were considered informative relative to the amount of uncertainty in this assessment.

The NEFSC scientists brought forward three modeling approaches: ASAP, ASAP with predation, and VPA, recommending VPA as the initial best approach. The DFO scientists brought forward two additional approaches: SVPA and XSA, neither of which was recommended for consideration as the main management model. Results from a production model analysis were also put forward, but as an exploratory model only.

TRAC Presentation: Brief Overview of Benchmark Models to be Reviewed: ASAP, ADAPT-VPA, SVPA, XSA, Other SCAA

Presenters: J. Deroba and F. Grégoire
Rapporteur: J. Nieland

Presentation Highlights

ASAP

ASAP is a forward projecting, age-structured assessment model that is implemented in the AD Model Builder software. The forward projection requires estimating recruitment in each year and abundance at age in the first year. The model is fit to catch at age and abundance indices data and has the flexibility to allow selectivity and catchability coefficients to vary through time. Different data sources (i.e., parts of the objective function) can also be given different relative weights in the fitting process.

ADAPT-VPA

Adapt-VPA is a backward projecting, age-structured assessment model. The backward projection requires estimating the number of fish in the final year and a decision rule for

calculating the fishing mortality rate on the oldest age group in all years. Abundance at age is then projected backward through years and ages by minimizing the sums of squares difference between abundance and one or more abundance indices (catchability coefficients for each index are also calculated during the model fit) and iteratively solving for the fishing mortality rates in each age and year that would have produced the observed catch at age.

SVPA

The Separable VPA assumes that fishing mortality can be separated into an age component common for all years and a year component common to ages within the year. The age component is usually called the exploitation pattern and the year component the fully exploited fishing mortality.

According to this model, fishing mortality F (i, j) acting at year i on age j is given by:

$$F (i, j) = F (i) \times S (j)$$

Where F (i) represents the fully exploited fishing mortality in year i while S (j) represents the exploitation pattern at age j. A least squares method is used for estimating the final F (i) and S (j) from the catch numbers at age and an estimation of M. No index of abundance is needed with this approach.

SVPA-VPA

Results from the SVPA can be used to start a traditional VPA. Besides the Atlantic mackerel, this approach was also investigated for six New England stocks and nine ICES stocks for which an analytical assessment (VPA-ADAPT, XSA and ICA) is currently performed.

XSA

The Extended Survivors Analysis (XSA) is a VPA tuned with age-specific CPUE indices. The model is fitted through a specialised robust iteration technique, rather than a general least squares approach. XSA is one of the most common assessment techniques used in Europe.

SCAA

The statistical catch at age (SCAA) model is a forward projecting, age-structured assessment model implemented in the AD Model Builder software. The characteristics are generally similar to ASAP. The SCAA model, however, is fit to aggregate catch and abundance indices in each year and the age composition of each of these data sources.

See further details in the table below

Factor	VPA	SCAA (SCAM)	ASAP	XSA	SVPA
General	Backward Projecting	Forward Projecting	Forward Projecting	Backward Projecting	Backward Projecting
Software	Fortran ADAPT-VPA (NFT)	ADMB, custom	ADMB, ASAP (NFT)	Virtual Population Analysis (V3.1)	VPA (V3.1)
Max Age (yr)	User Specified	User Specified	User Specified	User Specified	User Specified
Maturity	Constant, Age Specific	Constant, Age and Sex Specific	Constant, Age and Year Specific	Constant, Age Specific	Constant, Age Specific
Natural Mortality	Constant, Age and Year Specific	Constant, Age and Year Specific	Constant or Estimated; Age and Year Specific	Constant, Age and Year Specific	Constant, Age and Year Specific
Spatial Structure & Migration	No	No	No	No	No
Sexes	Combined	Combined (except for SSB calc)	Combined	Combined	Combined
Time period	User Specified (1962-2008 here)	User Specified (1962-2008 here)	User Specified (1962-2008 here)	User Specified (1968-2008 here)	User Specified (1968-2008 here)
Time Step	1 Year	1 Year	1 Year	1 Year	1 Year
Landings	Aggregate Fleet	Aggregate Fleet	Can be Fleet Specific	Aggregate Fleet	Aggregate Fleet
Discards	Aggregated with Landings	Aggregated with Landings	Can be Fleet Specific	Aggregated with Landings	Aggregated with Landings
Selectivity	Partial Recruitments by Age and Year Calculated from F	Constant, Age Specific inputs	Constant and Age Specific , Single Logistic, or Dbl Logistic	Partial Recruitments by Age and Year Calculated from F	Partial Recruitments by Age and Year Calculated from F
Constraints on Survey q	Constant Within Time Blocks	Constant Within Time Blocks	Constant Within Time Blocks or Can Vary Among Years	Constant Within Time Blocks or Can Vary Among Years	Constant Within Time Blocks
Tagging Data	No	No	No	No	No
Surveys	User Specified	User Specified	User Specified	User Specified	User Specified
Stock Recruitment Model	None	None; Estimates Year Specific Recruitment Deviations (Devs)	Beverton-Holt Optional	None	None

Factor	VPA	SCAA (SCAM)	ASAP	XSA	SVPA
Likelihood Emphasis Factors	None	User Specified	User Specified	None	None
Diagnostics/Retrospective	Complete	Std. Deviations Estimated; Retro Done "Manually"	Complete	Complete	Complete
Estimates of F	Iteratively Solved	Estimates Year Specific Fully Selected F Dev	Estimates Year Specific Fully Selected F (not a Dev)	Iteratively Solved	Iteratively Solved
Biological Reference Points	Projection Based	Must be Done External to Model	Internally Calculated Available	Projection Based	Projection Based

Discussion

Data used in the models started in different years. The commercial catch data series began in 1962, and the NEFSC spring survey data series began in 1968. Some models can use data sets that start at different times, but others need all of the data to start in the same year. Hence, some of the models used for the mackerel assessment differ in the number of years of input data.

TRAC Presentation: Data Inputs for Proposed Models

Working Paper: Grégoire, F., and M. Castonguay. Is the Index from the NEFSC Spring Research Vessels Bottom Trawl Surveys Representative of the Abundance of the So-Called "Northern Contingent" of Atlantic Mackerel (*Scomber scombrus* L.)? TRAC Working Paper 2010/06.

Presenter: F. Grégoire
Rapporteur: J. Nieland

Presentation Highlights

Spatial distribution of Atlantic mackerel catches and bottom temperatures data from the NEFSC spring research bottom trawl survey was investigated for the 1968-2008 period. The mean number of Atlantic mackerel per set calculated from the stratified random design was compared with kriging. Kriging was also used to calculate the mean number of mackerel per set for the areas located to the west and east of 70° of longitude W. This theoretical ''line'' is considered as the southwestern limit of the so called "*northern contingent*". As most of the catches from the NEFSC spring survey were done to the west of this line and as indicated by the kriging analysis, the NEFSC spring index as a representative index of the northern contingent of mackerel abundance is questionable.

Discussion

It was noted that the Gulf of Maine strata were not included in the analysis because these strata are not included in the spring index. This topic was discussed at length at the data meeting and it was concluded that without tagging data or a comprehensive survey it is not possible to make any conclusions about the possible influence of northern and southern contingents in the survey. One issue raised during the discussion questioned where the northern contingent is during the spring. Some TRAC members do not believe there is time for the fish to make the trip from the east coast of Newfoundland in Oct-Nov to the west of the 70 degree line during the spring survey. Other TRAC members thought the fish could move this distance in this amount of time. Without a survey on the Scotian Shelf at this time or a tagging experiment, this question remains unanswered. Since half of the total commercial catch comes from outside of the survey area (Canadian waters), it was asked whether this catch is part of a different "stock" from what is being surveyed. One suggestion was to do a model run with just the US catch and NEFSC survey from just west of 70 degrees. It was reported that this was done and the same issues were seen as with the assessment using all the data.

Data Issues

The NEFSC recently changed survey vessel and gear from the *FRV Albatross IV* to the *FSV Henry B. Bigelow*. The spring survey for 2009 used only the *Bigelow* data. The 2009

survey value was not included in most analyses due to lack of final conversion coefficients (although see specific run described below). These coefficients will need to be length-based and should be available prior to the next mackerel assessment.

Estimates of mackerel consumption in Canadian waters were not available for use in this meeting. Discussions during the meeting indicate that it may be possible in future assessments to include these estimates. This work was encouraged.

During the meeting, Chad Keith (NEFSC) produced annual maps of thermal habitat from satellite sea surface temperature (SST) data to show where mackerel might be located based on temperature during the spring survey. These maps were used to compute the proportion of area covered by the spring survey. It was noted that this proportion was high, 70-95% in March and 75-93% in April for years 2001-2009, and did not show any pattern over time. Although the analysis was limited by the strata included, it does indicate that the survey is covering the majority of thermal habitat for mackerel in most years. The survey does not cover some thermal habitat in deeper waters along the Scotian Shelf edge and in US waters, but the amount has not been quantified. Since the water is mixed in spring, the surface temperature is quite similar to the bottom temperature. An industry member reported finding pools of seven degree water at about 250 fathoms and noted that in waters less than 100 fathoms the surface and deep water are about the same temperature due to mixing. However, the relationship breaks down in waters deeper than 100 fathoms.

The catch weighted depth of mackerel in the survey shows a large change from 150 m in 1970s to 60 m since 1990s, despite the overall average depth of the survey remaining constant over the entire time period. Thus, in 1970s the population was closer to the edge of our survey area and the fishery was operating out in deep waters with relatively smaller proportions of catch in shallow waters. Over time the population "moved" inshore based on the survey catches and the commercial catch is now taken from these more inshore waters.

Length frequencies from the survey were examined and it was noted that the large catches in 1968-1976 were mainly based on a few strong cohorts. No strong truncation in length frequencies over time is evident in the survey, which is a possible indication that F has not increased strongly, although recruitment patterns can mask trends based on changes in F.

It is preferable not to blend distant water fleet (DWF) landings with those of the US commercial fleet since the DWF is believed to have used mostly small-mesh gear and have kept most of their catch, implying different selectivity patterns (i.e. different q's) between the two fleets. However, there is a perception that the DWF catches were not well reported. There have been some data rescue exercises conducted to try to resurrect the original data and these did not indicate large changes from the original reports. No additional data exist to quantify the accuracy of the DWF catches. Discards from the DWF might not be accounted for, which would imply reported values are underestimates, but no certainty exists on this point.

Some recent work by DFO scientists estimated reported Canadian catch to be approximately half of the actual catch in some areas. There is a need to quantify this underreporting as it pertains to the total Canadian catch.

Differences in the maturity ogives used by NEFSC and DFO scientists were noted. Although not large in magnitude, the different ogives do produce different estimates of SSB. It was unclear whether these differences were real differences in biology or differences in estimation procedures. This difference was not resolved and the NEFSC scientists used the US maturity ogive while the DFO scientists used the Canadian maturity ogive when presenting their results.

One comparison was made using the same model results but the two ogives and the current estimate of SSB was only slightly different (~2% change).

US mackerel landings by gear type have changed dramatically from mostly otter trawl in 1994 (94%) to mostly midwater trawl in 2001 (80.6%) to paired trawl in 2008 (83%). These changes in proportional landings by gear need to be considered when using the CPUE series as tuning indices.

TRAC Presentation: Development of ASAP Model Using a U.S.A. and Canadian Catch at Age Matrix Through 2008

Working Paper: Stock Assessment of Atlantic Mackerel in the Northwest Atlantic – 2009. TRAC Working Paper 2010/08.

Presenter: G.Shepherd
Rapporteur: C. Legault

Presentation Highlights

Catch at age data from 1962 through 2008 approved at the October TRAC meeting were added to the previous ASAP model input. The previous assessment model configuration, following the addition of 2005-2008 catch and indices at age, served as the basis for model comparison. The updated SAW42 model included ages through 7+, a catch series beginning in 1962 and NEFSC spring bottom trawl survey indices at age beginning in 1968. The survey indices were split into two series between 1984 and 1985. Selectivity in the catch was fixed at 0.2, 0.6 and 1.0 for ages 1, 2 and 3-7+, respectively. A series of alternative ASAP models were examined which included various index series splits, addition of multiple fleets (US and Canada), starting years in the catch series, estimation of selectivity, periods of changes in selectivity and fixed steepness values in stock-recruitment. The diagnostics examined included the fit to indices at age and total catch, residual patterns, retrospective patterns, selectivity patterns and the objective function.

The different model results generally showed similar patterns with peak abundance in the late 1960s-early 1970s followed by a period of high F in the mid-1970s. Recent years were characterized by high F and decreasing N since 2000. The exception to this pattern occurred when the survey index was input as a single series. The consequence of using one index series was a significant increase in abundance in recent years and a correspondingly low F (values <0.05).

The preferred standard ASAP model incorporated 2 fleets (US and Canada) with the time series beginning in 1968 (to correspond to the index series). The survey indices were split at 1991-1992 to reduce patterns in the index residuals (although with little improvement from the 1984-1985 split). Selectivity was constant through time and fitted as a logistic model for each fleet. Total CV for the US fleet was 0.1 until 1982, 0.05 from 1982 to 1989 then 0.01. Since the Canadian catch is considered underestimated, the CV for the Canadian fleet was set at 0.1 to allow greater deviation from an exact fit. Steepness in the stock recruitment was fixed at 0.6 in the model (corresponding to a $SPR_{40\%}$). Results show fishing mortality peaked at 0.79 in 1974 then decreased to 0.08 by 1978. F remained less than 0.1 until 1996 when it began increasing, peaking at 0.67 in 2006. F in 2008 was 0.49 (0.195 in US and 0.29 in Canada). Total abundance decreased from 7.8 billion in 1968 to 1.116 billion in 1978, rose to 6.1 billion with the incoming 1982 year class and has generally declined thereafter. Abundance in 2008 was 733

million fish. SSB peaked in 1985 at 1.32 million mt and steadily declined thereafter, reaching a low in 2008 of 123,100 mt.

Although the basic fit with the ASAP model was reasonable, the results showed some patterned residuals, particularly in ages 1 and 2 of the early series and 10+ in the later series. In addition, retrospective patterns in fishing mortality persisted. The influence of the under-estimated Canadian catch on retrospective pattern was also explored. Doubling the Canadian catch since 1968 (overall average total increase of 46%) had little effect on the retrospective pattern or magnitude. The model fit was heavily influenced by the steepness parameter chosen. If the stock-recruitment relationship were fit, the results were unrealistic, with steepness values 0.2 to 0.3. Fixed steepness values were inversely proportional with F. The value chosen was based on a generalized relationship and was not specifically from Atlantic mackerel. The model estimates of F, abundance and SSB from the proposed configuration are very different than the SAW42 results. However, the 2004 retrospective estimate from the current model corresponds to the 2004 SAW 42 estimates. Finally, the results of the model are dependent on the existence of a split survey series and the associated q's which vary greatly between series.

Discussion

It was noted that the option to include or not to include the likelihood constants in the calculation of the objective function made small differences in the results. Since this should not happen theoretically, the question was raised about which option is preferred. The differences observed between runs with and without the likelihood constants were considered small enough that this difference could be ignored and likelihood constants were included in all subsequent analyses.

There were two radically different types of results from this model which depended on whether the spring survey was treated as an uninterrupted index over time or if it was split. Not splitting the survey led to results of extremely large and increasing SSB associated with very low F, while splitting the survey led to a decreasing and relatively low SSB associated with an increasing trend in F since the 1980s. The previous assessment split the index based on the pattern in residuals as well as the change in doors used in the survey (1984-1985). This change in doors was the original reason for the split, based on an extensive herring analysis which justified this split. No additional work was done for mackerel; the same approach was just used by analogy. The directional change in residuals also changes with age. Based on model exploration, changing the year of the split to 1991-1992 reduced the residuals the most.

Initial model exploration estimated age-specific selectivities. Since these did not indicate any reduction in selectivity for old ages (doming), the model was fit using a single logistic selectivity to reduce the number of parameters.

There were a number of issues with the "best" run put forward for ASAP based on the initial runs. This run split the survey. The MCMC distribution of F was bimodal and showed high uncertainty. The retrospective was not unidirectional, but was large in magnitude. Splitting the survey series resulted in q estimates from the early and recent periods that differed by more than an order of magnitude. It was noted that this same pattern was observed in the previous assessment. The change in perception of SSB and F from the previous assessment could be explained by the retrospective patterns observed in both the previous assessment and this run.

TRAC Presentation: Development of ASAP Model Using a U.S.A. and Canadian Catch at Age Matrix Through 2008

Working Paper: Stock Assessment of Atlantic Mackerel in the Northwest Atlantic – 2009. TRAC Working Paper 2010/08.

Presenter: G. Shepherd
Rapporteur: C. Legault

Presentation Highlights

The inclusion of mackerel removals from predation was modeled as a separate fleet within the ASAP model. Consumption estimates were made for the eleven primary mackerel predators described in the TRAC data meeting. Predator abundance estimates were available for all predators beginning in 1982. Consumption between 1968 and 1981 was assumed equal to the time series average. Predator estimates based on survey swept area abundance were smoothed using a 3-year moving average and estimates based on assessment model results were unadjusted. Total consumption equaled the sum of annual consumption from all predators. Total mackerel removals from predation averaged 29,800 mt with a high value of 139,616 mt in 1984. Estimated predation removals averaged 30% of total removals (catch plus predation).

Predation in ASAP was modeled as total removals paired with an assumed selectivity. Selectivity was fixed at 1.0 for ages 1 and 2, 0.75 at age 3 and 0.2 at age 4 based on size of mackerel measured from stomach samples. A higher proportion at age 4 resulted in a situation where a model solution was not found. The model which provided appropriate diagnostics included three fleets (US, Canada and predators), with similar settings as the non-predation model. Natural mortality (M1) was fixed as 0.1 although the final M at age is the sum of M1 and predator F (fleet 3). Survey series was split at 1984-1985.

Results from the predation model followed the same pattern as the non-predation model, with a peak fishery F in 1975 at 0.63 and 2006 at 0.47, declining in 2008 to 0.26. SSB peaked in 1972 at 1,304,000 mt but since declined to 202,250 mt. The natural mortality (M1 plus M2) at ages 1 and 2 was time variant and averaged 0.45, peaking in 1987 at 0.87. Natural mortality dropped below average in 2000 but has since risen to 0.64 in 2008. $F_{0.1}= 0.21$, with average M of 0.45 varying by age and the associated SSB/R of 0.508. Assuming average recruitment (688.5 million age 1 fish) from the time series (1968-2008), SSB at $F_{0.1}$ would equal 350,000 mt. Consequently, the stock would be not be considered overfished (<1/2 SSBMSY) but overfishing would be occurring.

The addition of removals by predators had the most influence on the estimates of abundance and spawning biomass in the mid-1980s. Fishing mortality was less influenced since predation in the model was primarily on ages 1 and 2 whereas full recruitment to the fishery of both fleets did not occur until age five. The addition of predation data is limited by the availability of annual consumption estimates from only the NEFSC bottom trawl survey. Predation by larger predators not captured in the survey trawl, as well as consumption in Canadian waters, limits the model to a minimal estimate of the predatory removals. Nevertheless, it does provide some additional information not considered with a time and age invariant application of natural mortality rate.

Discussion

A number of modifications to the time series of mackerel consumption by fish predators since the data meeting were noted. Spiny dogfish were the primary predator of mackerel among those

considered. Predator information was used starting only in 1982. The average consumption for years 1982-2008 was used for years 1968-1981 within the ASAP with predation runs. Generally consumption was less than catch.

The consumption time series was entered as an additional fleet in ASAP. The US and Canadian catches were also split into separate fleets. The survey was split in 1984-1985. Base M (M1) was set to 0.1 for all ages, predation M added to ages 1-4 based on a fixed selectivity pattern of 1.0, 1.0, 0.75, and 0.2, respectively. Total M (M1+predation M) for age 1 averaged approximately 0.5 without strong time trend. The retrospective pattern was still strong and now more unidirectional than the no predation case.

These results demonstrate a higher M on younger age classes, by design, which is similar to the Lorenzen approach to estimate M at age based on life history characteristics. It was discussed whether a directly calculated Lorenzen M should be used instead. The disadvantage of this approach is that it does not allow time-varying M nor does it take advantage of the large consumption database available for mackerel from the NEFSC bottom trawl survey. A difficulty with using the time-varying approach is how to estimate reference points. There are ways to do this, but they require assumptions about what will happen in the future to the predators. However, it was agreed that is it better to get updated reference points from a model that includes predation, rather than simply having a consumption model as a side to the assessment.

It was noted that the consumption time series was a minimal estimate because many predators were not included, such as highly migratory tuna species, marine mammals, birds, and fish in Canadian waters outside the US survey. It was suggested that inclusion of additional predation would improve the model by accounting for more removals directly. The age composition of the predation mortality could also be expanded through inclusion of additional predators.

It was asked whether the peaks and valleys in the predation M correspond to weak and strong year-classes. No correspondence was seen between predation M and year class strength.

There was discussion about how predation mortality should be characterized. Questions were asked such as: There is a large increase in predation M in the last few years; would this remain if other predators were added? Is predation mortality a significant determinant of stock status? How should we use it? How should we move forward? It was decided that the answers to these questions would depend on which modeling approach for predation mortality is accepted, if any, and the group would have to address these issues once a final run was agreed upon.

A request was made to see the age-1 relative retrospective pattern both with and without predation, although the model formulations were not exactly the same. These were examined on screen and the magnitude of retrospective pattern on age-1 was reduced by about half when predation mortality was included.

TRAC Presentation: Development of a Baseline Virtual Population Analysis, Consideration of a Statistical Catch at Age Model, and Reference Point and Stock Status Conclusions for Atlantic Mackerel

Working Paper: Stock Assessment of Atlantic Mackerel in the Northwest Atlantic – 2009. TRAC Working Paper 2010/08

Presenter: J. Deroba
Rapporteur: C. Legault

Presentation Highlights

Input data used in the suggested "baseline" virtual population analysis (VPA) were total commercial catch at age (000s) and mean weight (kg) at age during 1962-2008, NMFS spring bottom trawl survey index data during 1968-2008 (split twice: 1968-1984, 1985-1992, 1993-2008), bottom fished otter trawl CPUE during 1978-2008 (split once: 1978-1988, 1989-2008), and mid-water otter trawl CPUE during 1994-2008. Natural mortality equaled 0.2 and was constant among ages and years. Maturity at age was set equal to the values used in the last assessment and was similar to the mean proportion of fish mature at age in NMFS spring survey data during recent years. The splits noted above for each index of abundance were arrived at by conducting a systematic search of potential splits, and the final splits provided the best residual and retrospective patterns of those splits considered. The baseline VPA was fit using data on fish age-1 to an age-7 plus group. Preliminary VPA models could not be fit using an older age for the plus group, likely due to the lack of older ages in the catch data and NMFS spring survey.

SSB from the suggested baseline VPA generally declined during 1972-2008. Average fishing mortality (ages 4-6) was relatively high (0.35) in the mid-1970s, but increased during 1978 to 2006 to an all-time high (0.8), before declining through 2008 (0.4). Age-1 recruitment estimates were highest during the 1970s, but have been relatively low recently with only one above average year class since 1984 (1999 year class). Residual patterns were still present for the age-6 and age-7 indices of abundance from the NMFS spring survey during 1993-2008, with generally positive residuals before 2000 and negative residuals after. Abundance estimates at age in the terminal year+1 were imprecise, with CVs greater than one for all ages except age-4, which had a value of 0.94. Catchability of the NMFS spring survey generally declined with age for all three time blocks and increased by at least an order of magnitude from the earliest time block to the most recent time block. The mechanisms to explain the large temporal change in catchability of the NMFS spring survey have not been fully resolved. These large temporal changes in catchability, however, are indicative of the opposing trends that are suggested by the commercial catch data and the NMFS spring survey. More specifically, commercial catch was highest during the mid-1970s when the NMFS spring survey was relatively low and unresponsive. The pattern in recent years, however, has been the opposite, with relatively low commercial catches and some of the highest survey catches ever recorded. In order to resolve this tension, multiple splits in the spring survey were required and the implication of these splits was an order of magnitude change in catchability in the spring survey among time blocks. VPA model runs without the splits had poor diagnostic plots, with patterned residuals and relatively severe retrospective patterns.

The declining trend in SSB suggested by the baseline VPA may have been caused by several factors, several of which are related to the lack of older aged fish in the commercial catch and NMFS spring survey. In response to more frequent warmer water temperatures, mackerel may be distributed over a broader spatial area, which may make them less available to the fishery.

The US fishery also generally operates in shelf waters of the mid-Atlantic, which differs from the foreign fleets of the mid-1970s that operated more frequently in slope waters and just off the shelf. So, more recent commercial catch data may cover a relatively smaller area of the distribution of the mackerel stock and may not catch the older aged fish that appeared in catches during the 1970s. The lack of older aged fish in the NMFS spring survey may be caused by the ability of larger, older fish to avoid the survey gear. Lastly, the declining SSB may be explained by relatively poor recruitment in recent years, and so fish are not surviving to older ages.

Several hypotheses have been suggested for the order of magnitude change in catchability of the NMFS spring survey among time blocks. The NMFS spring survey switched to the use of a polyvalent door in 1985, which may have been more effective for sampling mackerel. Another possibility is that mackerel, in response to warmer water temperatures and a subsequent expansion of the stock range, have more frequently inhabited shallow strata in recent years, where catchability may be higher than in deeper strata. Lastly, mackerel may be occurring near the ocean floor with greater frequency in response to low cod abundance, which would make the mackerel more available to the bottom trawl gear. None of the above hypotheses, however, have been adequately explored.

Discussion

VPA was put forward as the preferred US model based on better diagnostics than the ASAP runs. As in the ASAP runs, there were two different sets of results from the VPA depending on whether the survey was split or not. Not splitting the survey led to the large and increasing SSB trend while splitting the survey led to the small and declining SSB trend, as seen in the ASAP runs. The VPA proposed model run split the survey in 1984-1985 on the basis of the door change and additionally split the survey in 1992-1993 to reduce the retrospective pattern. The VPA could not use age 10+, as in the ASAP runs, because there are too many zeros at old ages in catch data in recent years. So the VPA runs used age 7+.

The VPA runs also had problematic diagnostics. The retrospective pattern was in the opposite direction relative to the ASAP runs, but still relatively large in magnitude. The uncertainty in the parameter estimates was high (CV >1 for all ages except one age which was 0.94), which resulted in a large confidence interval for F in 2008. The residual pattern in 2004 appeared to be a year-effect in the survey, with large residuals seen for many ages. Age 7+ in the most recent period (1993-2008) had a bad residual pattern. Catchability at age by time period showed the same large changes as seen in the ASAP runs, especially at younger ages.

Survey data shows recruitment has increased over time, as opposed to the model which shows recruitment has declined. It is the changes in catchability that are causing the impression that recruitment has declined in the model results.

The VPA cannot treat the consumption time series as a separate fleet, as was done in ASAP. One way to incorporate predation mortality is to change the M matrix used in VPA based on results from the ASAP with predation. While this creates a dependence of VPA on ASAP, it is one way to move towards multispecies considerations. Alternatively, a full multispecies assessment (MSVPA) could be conducted including mackerel.

It was noted that a different number of years was presented in the retrospective analysis for VPA than for ASAP. Use of the same number of years in retrospective analyses was recommended as it allows direct comparison between runs.

A concern was raised that using only age 7+ in the yield-per-recruit calculations for reference points based on the VPA output might bias the reference points relative to using age 10+ in the calculations. The yield-per-recruit calculations were repeated with age 10+ instead of age 7+ and only very minor differences were found. It was concluded that this is not an issue because mackerel are not growing significantly beyond age 7.

TRAC Presentation: SVPA

Working Paper: Grégoire, F., and J.-J. Maguire. Separable VPA and Trends in the Instantaneous Rates of Fishing Mortality, Population Abundance and Spawning Stock Biomass for the Northwest Atlantic Mackerel (*Scomber scombrus* L.) Between 1968 and 2008. TRAC Working Paper 2010/05.

Presenter: F. Grégoire
Rapporteur: C. Legault

Presentation Highlights

The Separable VPA (SVPA) was used to describe the catch at age. The input parameters were: (1) natural mortality (M) fixed at 0.2 for all years and ages; (2) catch at age; (3) terminal fishing mortality (F_y); and (4) terminal selectivity (S_a). Many runs were produced and the selected model was the one that gave the lowest mean squared residuals. Results indicated the presence of an increasing trend in the fishing mortality and a decreasing trend in SSB.

The selected SVPA model was used to start an ordinary VPA. Results were identical to the SVPA. This approach was also used, for illustrative purpose, with six New England groundfish/flatfish stocks and nine European stocks.

SVPA shows the same trends as VPA (started from SVPA) and XSA. However, it seems that the absolute values for abundance and SSB are too low. Underestimated values for M and the catch at age could be responsible for this problem of scale.

Discussion

Results of the SVPA, in which tuning indices were not used, were brought forward. This work was exploratory and was conducted to determine if the survey was driving results. The estimated trend matched the split survey ASAP and VPA results, with a small and declining SSB trend. These results provided confidence in the trends, but this method was not able to estimate the magnitude well.

The range of possible S_a and F_y values considered resulted in "best" fits at the extremes. It was suggested that the range of values considered could be expanded to see if even better fits could be generated.

The time series comparisons resulting from plugging values from SVPA into VPA would be expected to converge to the same values rapidly due to the calculations within VPA. It was recommended to only look at the values in the last year instead of the full time series when comparing the SVPA and VPA results.

The presenters noted that a sudden change in F would not be detected using this approach.

Another TRAC member tried an iterative approach to VPA with no tuning index whereby they picked a starting guess for F in the terminal year, computed the cohort equations, and then set a new terminal year F as the average of recent years. This approach also generated the pattern of increasing F and decreasing SSB seen in other models and provided support for this trend.

TRAC Presentation: XSA

Working Paper: Grégoire, F., and J.-J. Maguire. An Assessment of the Northwest Atlantic Mackerel (*Scomber scombrus* L.) with XSA (Extended Survivors Analysis). TRAC Working Paper 2010/07.

Presenter: F. Grégoire
Rapporteur: C. Legault

Presentation Highlights

XSA is one of the main methods of assessment used in Europe. The spring index survey was used as a calibration index within XSA.

SVPA, VPA (started from SVPA) and XSA show the same trends. However, it seems that the absolute values for abundance and SSB are too low. Underestimated values for M and the catch at age could be responsible for this problem of scale.

Discussion

Results were presented from a number of XSA runs. These were not brought forward for consideration as a basis for management decisions, but rather for comparative purposes. The best XSA run was quite similar to the ASAP and VPA results of increasing F and decreasing SSB. The XSA run did not split the spring survey. However, the use of the default time taper in fitting residuals is essentially a split because the 1970s survey values do not contribute to the fitting. The retrospective pattern was not as bad as other models, but still large and similar in pattern to VPA.

The XSA model was also used to examine changes in survey catchability over time by creating distinct input files for small sets of consecutive years. The time blocking experiment results showed the catchability estimates were different early relative to recent, as seen in the ASAP and VPA runs which split the survey series. This analysis provided support for a change in the survey catchability over time.

TRAC Presentation: Production Models

Presenter: J-J. Maguire
Rapporteur: C. Legault

Presentation Highlights

Production models require only catch and an index of stock size and they are, therefore, not influenced by information on the age composition of the catch. The index of biomass from the NEFSC spring survey (kg/tow) generally declined from the late 1960s to the mid 1980s and gradually increased subsequently showing little trend since the mid 1990s. The spring survey kg/tow does not suggest that stock size has decreased in recent years.

The production model was fit using both a spreadsheet developed by FAO, and ASPIC. Initial biomass in the FAO spreadsheet was set at 1,277,000 mt, the converged value of the tentative base VPA when the production model runs were made. The results of this model fit are given in the graph below.
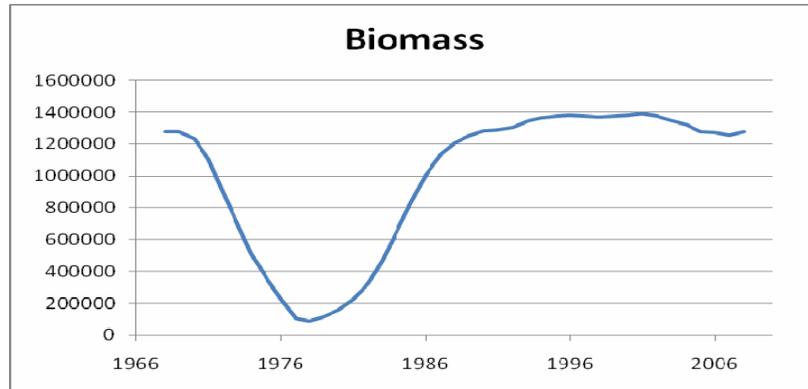
A second run was made where the spring survey index was split in 1984-1985. The results showed higher biomass in recent years, as indicated in the graph below:
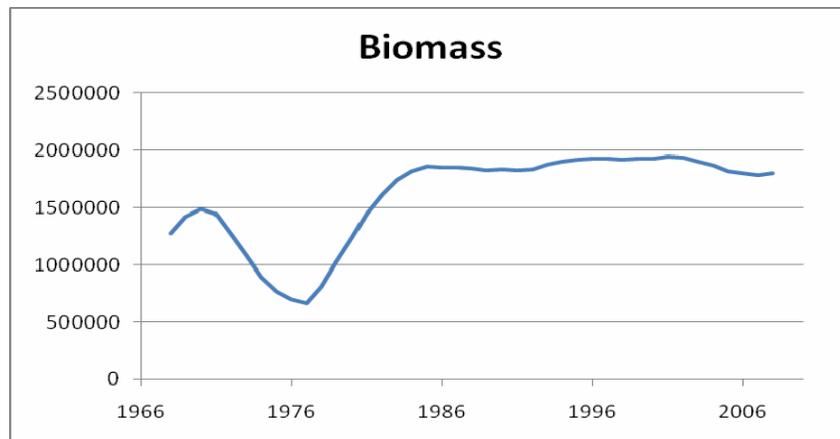
Discussion

Both implementations of production models, a spreadsheet version developed by FAO and ASPIC, produced similar results with very low F and biomass near K in recent years. It was suggested that calculation of the implied age structure from these results could be compared to the observed catch and survey at age proportions since age composition is not included in production models. This was not done, but it follows that the low F from the production model would produce many more old fish than have been observed in either the catch or survey in the past decade. These runs were done without splitting the survey series, but a run splitting the survey in 1984-85 produced similarly high biomass and low fishing mortality in recent years. This is consistent with the high survey index in recent years, but the production model does not take into account that the high survey indices comprised only young mackerel.

TRAC Presentation: General Discussion about Models and Model Results

Rapporteur: C. Legault

Splitting the NEFSC spring survey generated a lot of discussion throughout the meeting due to its importance in determining the trends in SSB and F. No splits resulted in low F and high biomass currently with strong residuals and retrospective pattern. Splitting the survey resulted in high F and low biomass currently with improved residual pattern and reduced (but not eliminated) retrospective pattern. A second split was used in the VPA to further reduce the retrospective pattern. The previous assessment split the survey in 1984-1985.

Justification for splitting the survey in 1984-1985 was based on a change in the doors used with the trawl. Some, but not all, species have estimated conversion coefficients to account for the change in doors. However, there were insufficient data for mackerel to allow estimation of this conversion coefficient. One hypothesis presented for why this change in doors would be so strong is that the older doors were more likely to fall over during a tow and thus would not catch fish located off the bottom such as mackerel. The newer doors also have better bottom contact than the old doors, thereby making more noise which could potentially cause a schooling species such as mackerel to bunch up in front of the net. The change in catch weighted distribution of mackerel in the NEFSC spring survey also occurred around this time. Additionally, there used to be a recreational fishery along the mid-Atlantic that has disappeared, which has been hypothesized to be due to temperature change. It may be that mackerel were located more inshore during the early period at young ages, and then moved out of the inshore strata in later years making them more available to the NEFSC survey. Another hypothesis is that there have been behavioral changes in mackerel relative to distance from bottom due to changes in cod abundance, and thus catchability changes. These multiple hypotheses are examples of many ways that the survey catchability can change from sources other than changes in survey protocols.

Other years for splits were based on reducing retrospective patterns, without real-world justification for the split. This type of split has been used in groundfish assessments to reduce the retrospective pattern. Moving window analysis can determine the timing of a change in an underlying process that leads to a retrospective pattern, but cannot identify the source. Management strategy evaluations have been examined which demonstrated that regardless of the source of the retrospective pattern, splitting the survey series generated the correct catch advice to achieve the intended fishing mortality rate. Thus, the addition of a split in the survey time series in response to a strong retrospective pattern can be supported.

It was noted that there are differences in the change in estimated catchability from the different time periods as well as patterning in residuals which depend on age. The youngest ages, 1 and 2, along with the plus group, 7+, have the worst residual patterns. Given there are two contingents, it was hypothesized that the survey is indexing mainly the southern contingent for youngest ages, but that intermixing of contingents will allow indexing of the entire adult stock. Perhaps the model issues are due to combining two contingents with different productivity in a single model. It was suggested to try a model that ignores the survey values for young ages and does not split the survey for older ages. This run was conducted and was similar to the results with no splits using all ages. A similar run which split the survey time series for young ages but not old ages produced similar results. The group concluded that splitting the survey time series for the older ages determined the difference in results.

Since all of the problems seem to be starting in 1980s, it was asked whether starting the VPA in 1985 was an option. This is essentially the same as splitting the survey due to the convergence properties of VPA, except one loses the perception of higher abundance in the earlier period.

The age structure of populations was examined comparing a constant M=0.2 to the predation based M vector (M1+predation M). The base M1 was found such that the number of survivors at age 30 was the same, resulting in M1=0.15 instead of the original M1=0.1.

The question was asked about natural mortality rate for similar species elsewhere. In the southeast US, M for king mackerel is 0.17 and M for Spanish mackerel is 0.30, both based on Hoenig's approach. But it should be noted, that those species of mackerel are functionally distinct from the Atlantic mackerel here; a better contrast would be to herring, butterfish, and similar small pelagics. ICES assessments use M=0.15 for the Northeast Atlantic stock of Atlantic mackerel for most ages but a bit higher at younger ages. This lent support to use of the predation based M vector for this stock.

Comparison of effort between DWF (~500,000 days fished) and current US commercial fleet (approximately 1,000 days fished) lends more credence towards low current F (or at least current F much lower than DWF F). The DWF fished in areas based on water temperature, but mostly on the slope edge. The joint venture (JV) fleet fished during the late 1970s and early 1980s right along the slope edge and moved depending on temperature. The NEFSC survey is not efficient at these depths (>120 meters). The current fishery does not operate on the slope edge. Currently only about 10 boats are directly dependent on mackerel, and another 1-2 dozen that jump in when the fish are available close to their port. There is no reason to transit over the deep slope water, so current fleets can't accidently run into the fish. DWF was fishing deeper water due to the gear they used relative to the current fleet. Very few boats are currently capable of fishing deep water because they do not carry enough wire (80-250 fathoms). This raises the question whether there is another contingent that is in deep water not available to the commercial fleet and survey. It was suggested to examine length samples from the JV fishery to examine this question.

Resilient versus transitory year classes were mentioned by Sette. The 1999 year class was no longer observed by age 8, in contrast to the 1982 year class which was observed past age 10. It is not clear whether this is an availability issue or a mortality issue.

It was asked how the 1992 - 1993 split was chosen. The choice was made qualitatively based on change in residual pattern by eye. The analysis could instead use the 1994 - 1995 split from the GARM or use the moving window approach described in the GARM to determine the timing of the split. It was decided to stick with the 1992 - 1993 split because there was insufficient time to conduct a full moving window analysis.

TRAC Presentation: Specific Model Comparisons

Rapporteur: C. Legault

A number of additional analyses were requested in order to directly compare the ASAP and VPA results under a number of scenarios using the same data. The egg survey data were not used, while both CPUE indices and the NEFSC spring survey at age indices were used to tune the model. Some runs used constant M=0.2, while others estimated predation mortality in ASAP then created an age specific M vector for use in both models. The scenarios were denoted by letters with both VPA and ASAP run for each scenario.

Scenario A (only one split 84/85) had extreme retrospective patterns (SSB relative differences 1000%-1200%) for both VPA and ASAP which were similar in pattern, direction, and magnitude. The trends in F and SSB were similar, but showed some differences in recent years. The poor diagnostics of strong retrospective patterns, inability to estimate CVs, and patterns in residuals caused this scenario to be dropped from consideration as the base run.

Scenario B (two splits 84/85 and 92/93) for VPA caused SSB in recent period to be lower (about half) while the rest of time series was the same and thus F was higher in recent years. The VPA CVs for estimated N in the terminal year plus one were all >1 but the retrospective pattern was much reduced and switched in direction. It was noted that this directional change in retrospective pattern should not be judged "better" than model A, as it is still an indication that the model cannot sufficiently explain the observations. The estimated catchability coefficients are orders of magnitude larger than the earliest period. When Mohn's rho (the average change in terminal estimates from assessments with earlier terminal years relative to the current assessment) was used to adjust the 2008 SSB from scenarios A and B using VPA, the estimates went past each other such that the adjusted SSB(B) was close to the original SSB(A) while the adjusted SSB(A) was close to the original SSB(B). It was questioned whether the reduction in retrospective pattern was sufficient to justify the additional split in the VPA given that a relatively strong retrospective pattern remained. It was concluded that the second split was justified for the VPA. The ASAP scenario B SSB in 2008 was considered to be too low (~76,000 mt) to be accepted as a plausible model.

Scenario C (no splits at all) exhibited very large differences in the amount of retrospective pattern in SSB between VPA (10 fold) and ASAP (0.8 fold). In both models SSB increased dramatically from the 1980s to 2008 with an associated decrease in F to very low values (<0.05) in recent years for ASAP and low values (<0.1) for VPA. Neither model was considered feasible for use as base run, but it was recommended to include these results in the research document to demonstrate the possible alternative state of nature.

Scenario D (Scenario A with consumption) was first run in ASAP with consumption as an additional fleet to estimate a time-varying M. The average M at age since 1982 (the first year consumption estimates are available) was then used in all years in VPA. Both models exhibited large retrospective patterns and the ASAP model did not converge for two years (2001, 2002). However, the recent SSB retrospective pattern was not too bad in recent years. There was a somewhat different SSB pattern over time from the two models, with lower SSB for ASAP, which can be explained by the different approaches used for M in the two models. The inclusion of predation in some form was considered a step in the right direction, but its full inclusion as a fleet was not supported by available data.

Scenario E (Scenario B with consumption) was run only with VPA. The M at age vector was derived from an earlier ASAP run and modified so that the expected number of survivors at age 30 was the same as assuming a constant M=0.2 at all ages. This resulted in M for ages 5+ being set to 0.15, with younger ages having a higher M. There was a slight improvement in the retrospective pattern (Mohn rho for SSB changed from -0.39 to -0.35), but no obvious change in trend in SSB or F relative compared to Scenario B. In addition, this approach did not significantly improve any of the other diagnostics such as residual patterns or the magnitude of the change in survey catchabilities among time periods. However, it was considered to be a step in the right direction and further work on including predation in the assessment was recommended.

TRAC Presentation: Notes on Other Model Runs

Rapporteur:　　　C. Legault

An ASAP run was made which doubled the predator component of catch to see if additional predation mortality would solve some of the diagnostic problems. There was a large decrease in recent F, but the retrospective pattern approximately doubled (magnitude around 1200%). It was concluded this was not the solution and that estimates of consumption for older mackerel should be developed instead.

A VPA run was made which included the Canadian egg survey as an index of SSB. This caused the estimated SSB to be lower in recent years, as expected due to the strong trend in the egg survey, but did not improve any diagnostics. The egg survey was not recommended as a tuning index for the whole stock due to its limited spatial coverage.

A VPA run was made which included the 2009 spring survey values. These 2009 values were converted from *Bigelow* to *Albatross* using a constant conversion coefficient. The resulting F was very high in recent years (~2 in 2008), which was expected because there were no old fish in the survey catch in 2009. Even once a length-based conversion coefficient is estimated, it will not create fish at the old ages, so this lack of old fish in the survey for 2009 will remain. However, since the length-based conversion has not been estimated yet, it was decided to not use the 2009 spring survey values in the final run.

Exploratory ASAP runs found that fitting the age 7+ index was highly influential in determining the trend in SSB and F. When the age 7+ index was fit more closely by decreasing its CV then the low and decreasing SSB pattern resulted even without a split in the survey. When this index used the same CV as the other indices, 0.4, but no split in the survey, then the large and increasing trend in SSB resulted. It was noted that there is a lot of noise in the age 7+ index when one looks at the entire time series: large up and down swings are apparent, which are not biologically plausible.

The NFT VPA program has multiple options for treating the plus group during estimation. The original VPA runs all used the forward calculation approach which resulted in a strong dome in the partial recruitment for age 7+. When the backward calculation approach was used, the age 6 and 7+ partial recruitments were the same, as they must be due to the calculations, and resulted in a slight dome for ages 6 and 7+ relative to younger ages in some years but an overall relatively flat-topped selectivity pattern. The forward approach had higher SSB in 2008 than the backward approach. The retrospective patterns were a bit different but neither was obviously better than the other. The CVs from the backward approach were slightly lower (but still large) than the CVs from the forward approach. Since the default is to use flat-topped selectivity unless there is strong evidence for a dome, it was decided to use the backward calculation.

In the VPA runs, the average of ages 4-6 was used to define fully recruited F and in the calculation of F on the oldest true age. A question was raised about age 3. Examination of partial recruitment patterns for a number of years indicated that age 3 was not fully selected.

An assessment approach which explicitly accounted for the two contingents with a mixed fishery could be attempted in something like the VPA2Box program available in the NOAA Fisheries Toolbox. However, this approach requires tagging information to allow estimation of migration or diffusion. Alternatively, one could conduct completely different assessments for the two contingents making assumptions about the amount of catch from the mixed fishery associated

with each contingent, as done in king mackerel assessments. This approach would require tagging information to determine the relative proportion of catch from each contingent. These suggestions are for the distant future as both require substantial tagging programs.

B. REFERENCE POINTS AND PROJECTONS

TRAC Presentation: Reference Points and Projections

Presenter: J. Deroba
Rapporteur: C. Legault

Presentation Highlights

Fishing mortality rate per recruit reference points F_{max}, $F_{0.1}$, and $F_{40\%}$ were calculated assuming the same age specific natural mortality rates and maturity ogive as the final TRAC accepted VPA model. Weights at age were estimated as the average over the last five years of data and selectivity at age was estimated as the average VPA estimated F ratio (age specific F/maximum age specific F) over the last five years.

Age	Natural Mortality Rate	Fraction Mature	Weights	Selectivity
1	0.51	0.1	0.15	0.05
2	0.51	0.6	0.24	0.27
3	0.42	1.0	0.34	0.65
4	0.22	1.0	0.40	0.91
5	0.15	1.0	0.47	1.00
6	0.15	1.0	0.51	0.84
7	0.15	1.0	0.61	0.84

F_{max} was undefined, $F_{0.1}$ equaled 0.29, and $F_{40\%}$ equaled 0.25.

SSB reference points were based on stochastic projections. Input data was the same as above and with recruitment values re-sampled from a continuous cumulative distribution function based on the 1985-2008 annual age-1 recruitment estimates from the final VPA. $SSB_{40\%}$ equaled 194,000 mt, which implies an MSY proxy of 37,200 mt.

Discussion

The US management requires both F and SSB reference points, while Canadian management requires an F reference point and some indication of the probability of stock decline under different catches. The F reference points were based on per recruit analyses ($F_{0.1}$ and $F_{40\%SPR}$) while the SSB reference points were found by stochastically projecting the population many generations under a given F with recruitment resampled from a cumulative distribution function of observed values from the assessment. The weights, maturity, and selectivity at age were all computed as the average of the last five years.

The yield per recruit analysis indicated there was no F_{max}, so this was not considered further. The two F references were $F_{0.1} = 0.288$ and $F_{40\%} = 0.25$, either could be a proxy for F_{MSY}. The group recommends $F_{40\%}$ as the proxy for F_{MSY}, based on precedent of groundfish.

Projections, with stochastic sampling of recruits from 1985-2008, produced an estimate of $SSB_{40\%}$ (proxy for SSB_{MSY}) of 194,000 mt (10-90th percentiles of 143,500 mt to 296,600 mt). This implies an MSY proxy (yield at $F_{40\%}$) of 37,200 mt (27,400 to 55,300), which is well below

recently observed catches and far below the DWF catches. Confidence intervals provided here incorporate only a fraction of the uncertainty. Both $SSB_{40\%}$ and $MSY_{40\%}$ are dependent on the model results and are highly uncertain.

Projections were also done using the 1962-2008 recruitment series, producing an estimate of $SSB_{40\%}$ of 441,000 mt due to the much higher recruitment estimated during the 1970s. The group questioned whether these recruitment levels would be expected in the near future due to not seeing them for the past 30 years. Therefore, the group concluded that use of the 1985-2008 time period was more appropriate for setting SSB_{MSY}.

The methodology to adjust recruitment relative to Mohn's rho has not been developed. This would only impact the recent recruitment values and was not expected to cause a large change in the SSB_{MSY}, especially relative to the large uncertainty already present in the estimate.

B. STOCK STATUS

TRAC Presentation: Stock Status Determination

Presenter: J. Deroba
Rapporteur: J. Nieland

Presentation Highlights

The 2008 estimate of SSB (96,968 mt; unadjusted for the retrospective pattern) was just under 1/2 SSB_{MSY}, while the F estimate (0.51; unadjusted) was nearly twice as high as F_{MSY}. These point estimates suggest that the stock is overfished and that overfishing is occurring. The upper and lower confidence intervals, however, based on the 10th and 90th percentiles of the point estimate for SSB were wide, with the confidence interval for the ratio of 2008 SSB to SSB_{MSY} ranging from 0.37 to 0.73. Similar calculations for the ratio of F in 2008 to F_{MSY} also resulted in wide confidence intervals ranging from 1.34 to 7.71. Adjusting the 2008 estimates of SSB and F for the retrospective pattern using Mohn's rho (based on the average of a "7 year peel") resulted in an estimate of SSB equal to 153,525 mt and an F of 0.18. The ratio of these values to SSB_{MSY} and F_{MSY} equaled 0.79 and 0.74 respectively, which suggests that overfishing is not occurring and the stock is not overfished. None of these results account for uncertainty in the MSY reference points (SSB_{MSY} and F_{MSY}). These results suggest that stock status is highly uncertain.

Discussion

The plot of SSB/ SSB_{MSY}, vs F/ F_{MSY} with confidence intervals and Mohn's rho adjustment indicated high uncertainty in stock status. Point estimates changed from overfished and overfishing to not overfished and not overfishing when the base model was adjusted for retrospective pattern through application of Mohn's rho. There were large confidence intervals for the unadjusted ratios based on the bootstrapped confidence intervals of 2008 SSB and F. If the uncertainty in the reference points was also considered, the confidence intervals for the ratios would be even larger, making determination of status even more difficult.

It was noted that in the final run, during the middle of the time series there was a period of low F (<0.25), but the SSB continued to decrease. It was questioned whether this assessment result made sense.

Industry members were shocked there is even a possibility that they have been overfishing the stock in recent years given the low amount of effort and the results of the previous assessment.

The TRAC carried through the exercise to meet the TORs, but concluded that a stock status determination could not be made due to too much uncertainty in the point estimates.

B. BENCHMARK MODEL CONSENSUS

There was not an obvious choice as the best model to use as the final run. The two main contenders were VPA with two splits in the survey series and ASAP with only one split in the survey series. Both models used an M at age vector held constant over time as a step towards including predation mortality in the assessment. Some advantages of ASAP were that it was the model used in the previous US assessment, it can handle estimation of predation mortality by treating it as a fleet, it is a more flexible modeling platform, and it can handle an older plus group. These advantages of ASAP were offset by a larger retrospective pattern than the VPA and an implied SSB from ASAP that when adjusted for the retrospective pattern was deemed to be too low to be believed.

The TRAC consensus was to go forward with the VPA model. The tuning indices selected were (a) the spring NEFSC survey index split in 1984-1985 and 1992-1993; (b) the bottom trawl CPUE index split in 1988-1989 and the mid-water trawl CPUE index with no split and (c) using a variable natural mortality (M) at age (from the ASAP model) to account for predation. The VPA model exhibits a strong retrospective pattern with the terminal year population estimates uncertain (high CV) and perhaps biased.

The assessment model was faced with resolving disparate trends between the NEFSC spring survey and CPUE indices and total landings. Despite very large annual catches in the 1970s, there was very little change in the spring survey index during these years. Later in the assessment time series, a generally increasing trend in the survey index was co-incident with a rapid disappearance of older age classes in both the survey catches and the commercial landings. This situation contributed to a large retrospective pattern (aliasing survey catchability with the two opposing trends).

The retrospective patterns in the model were addressed by applying a survey split in 1984-1985 (which was used in the 2005 USA assessment), as well as applying an additional split in 1992-1993. The 1984-1985 split is justified by a change in survey trawl door at this time, as well as indications in the survey of changing mackerel distribution from deeper to shallower water. The mechanism for the 1992-1993 split has not yet been established; however, this split improved model diagnostics. In both instances, the splits may be aliasing other factors. Simulations presented at previous USA groundfish assessments indicated that more reliable catch advice (i.e., closer to F_{ref} in the simulated population) was provided by splitting the survey time series in assessments that exhibit strong retrospective pattern), regardless of the cause of the retrospective pattern (ICES 2008)

Based on precedent set by the Groundfish Assessment Review Meeting (GARM) the approach used to determine whether a correction was needed to account for the retrospective pattern was made through the use of a combination bootstrap and retrospective analysis. Non-overlapping bootstrapped distributions of SSB in a given year from separate retrospective runs were found, which demonstrated the presence of a strong retrospective and required an adjustment. The adjustment was based on the average Mohn's rho from seven years of "peels." The adjustment increased SSB and decreased F, the opposite pattern from what is most commonly seen in assessments.

B. RESEARCH RECOMMENDATIONS

- Explore opportunities for the development of alternative indices of abundance. Attempt to develop total stock abundance estimates.

- Initiate broad scale international egg surveys covering potential spawning habitat that is consistently representative of the total stock area, including the shelf break. Investigate potential to conduct work in cooperation with commercial fishing industry (priority: high, medium-long term).

- Explore spatial distribution of stock relative to the mixing of the northern and southern 'contingents' of mackerel i.e. tagging, genetics, chemical assay, microchemistry of otoliths (priority:high, medium-long term).

- Explore influence of environmental factors on spatial distribution of the stock e.g. rate of mixing and distribution of stock relative to the survey area (high priority, short term).

- Extend predation estimates to include DFO data and entire predator spectrum (marine mammals, highly migratory species).

- Examine methodology for incorporating consumptions estimates in the assessment.

- Quantify the magnitude of additional sources of mortality in Canada including the bait fishery, recreational catch and discards (high priority, short term).

- Explorations of bottom trawl characteristics for catchability of mackerel.

- Participate with industry in investigating the contemporary overlap of survey stock area, commercial fishery, and mackerel distribution and explore historical databases for the same purpose to better understand interpretation of abundance indices (survey, CPUE) (medium term).

- Collaborate with industry to investigate alternative sampling gear (i.e. jigging) to survey adult abundance (long term).

- Explore MARMAP database relative to spatial distribution of survey indices.

- Investigate alternative assessment models that incorporate spatial structure (i.e. northern and southern contingents, different age groups).

- Explore alternative assessment models that incorporate covariates.

- Initiate a technical TRAC WG in order to advance and monitor progress of research recommendations.

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APPENDICES

Appendix 1. Participants at Atlantic Mackerel Data Inputs Meeting (22-23 October 2009)

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Appendix 2. Terms of Reference.

Transboundary Resource Assessment Committee (TRAC)
Mackerel Benchmark and Assessment

October 22-23, 2009 (DATA)
March 1-4, 2010 (MODEL)

TERMS OF REFERENCE

Context

The TRAC was established in 1998 to peer review assessments of transboundary resources in the Georges Bank area and thus to ensure that the management efforts of both Canada and USA, pursued either independently or cooperatively, are founded on a common understanding of resource status

Prior to 2009, scientists from both countries participated in the peer review of each other's mackerel assessments. The last meeting occurred during December 2005. At that meeting, after reviewing several model formulations, consensus was reached on using an Age Structured Assessment Program (ASAP) model to assess the current status of the Northwest Atlantic mackerel stock.

At the Canada / US Scientific Discussions in April 2007 it was agreed that a TRAC benchmark and assessment of mackerel would be conducted in 2009, with a data inputs meetings to be held in the summer/fall of 2009 and the modeling review and assessment to be held in December 2009.

The purpose of these meetings is to review and incorporate any new information from survey indices and the fisheries, revisit any model formulation issues and recommend a suitable approach upon which to base management advice.

Objectives

Data Inputs Meetings

- Update results with the latest information from fisheries and research surveys.
    - Description of the US and Canadian mackerel fisheries,
    - Review adequacy of the sampling coverage of mackerel fisheries of NMFS, DFO, and industry sampling programs
    - Update landings and discards at age
    - Review of indices of abundance, including update of the Canadian Egg survey.
    - Description of the US index of abundance and the implications of the change in the NEFSC trawl vessel.
    - Identify or consider other abundance indices.
    - Review results of the otolith exchange study.
    - Review temporal and spatial distribution of the stock in both US and Canadian waters.

- Review progress made on the recommendations from previous assessments.

Modeling Meeting and Assessment

- Review the assessment model formulation issues and recommend an approach for stock status determination.

  o Exploration of VPA models, forward projection models (e.g. ASAP), and other relevant approaches.
  o Review the retrospective pattern and consider alternative model formulations to address its impact on uncertainty in status determination and harvest forecast.

- Apply the agreed assessment approach to update the status Northwest Atlantic mackerel stock through 2008 and characterize the uncertainty of estimates.

- Review the harvest strategy biological reference points to meet management requirements of both countries.

- Review approach for the provision of projections to meet the management requirements of both countries.

- Consider the stock implications of unattained short-term yields.

- Identify potential future work (International egg survey, tagging and genetic studies, and other collaboration between both countries) that would improve the determination of stock status.

- Consider role of mackerel as forage for predators and evaluate feasibility of incorporating predatory consumptive removals into assessment models.

Outputs

TRAC Proceedings, which will document the details of the review and summarize the consensus results

TRAC Reference Documents

Participants

NEFSC and DFO Stock Assessment teams and other
Invited external reviewers
Representatives from US and Canadian management
US State and Canadian provincial representatives
US and Canadian fishing industry participants

Appendix 3. Data Inputs Meeting Agenda – October 22-23, 2009.

Transboundary Resource Assessment Committee
Atlantic Mackerel Assessment Framework

DATA INPUTS MEETING

By Videoconference
22-23 October 2009

DRAFT AGENDA

22 October 2009 – Thursday

12:30 – 4:30 EST   /   1:30 – 5:30 AST

> Introductions
>
> Temporal and spatial distribution of the stock
> Otolith exchange study
>
> Description of Canadian fishery (including landings & discards at age)
> Description of US fishery (including landings & discards at age)
> Discussion
>
> Break
>
> Sampling adequacy and discussion
>
> Consumption rate/predation mortality & associated uncertainty
>
> Pelagic fish outburst or suprabenthic occupation: legacy of the Atlantic Canada
> cod collapse

23 October 2009 – Friday

8:30 – 11:30 EST   /   9:30 – 12:30 AST

> Review of previous day's discussion
>
> Description of Canadian surveys (DFO & industry surveys)
> Description of US surveys (NMFS & industry surveys)
>
> Break
>
> Canadian indices of abundance (including Canadian egg survey)
> NEFSC larval mackerel index abundance
> Other indices of abundance

11:30 – 12:30 EST   /   12:30 – 1:30 AST

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Lunch

12:30 – 4:30 EST   /   1:30 – 5:30 AST

Other issues and data gaps

Models to be potentially explored given available data

Planning for model meeting

Appendix 4. Participants Atlantic Mackerel Modeling Meeting (1-4 March 2010).

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Appendix 5. Model Meeting Agenda – March 1-4, 2010.

**Transboundary Resources Assessment Committee
Mackerel Benchmark Model Review**

NEFSC Woods Hole Laboratory, Woods Hole, Ma. USA
Clark Conference Room

1-4 March 2010

Draft Agenda

<u>**1 March 2010 – Monday**</u>

9:00 – 10:30	Welcome and Introduction (Chairs; Loretta)
	Review data meeting consensus (Tana)
	Review of updates/modifications to data (Gary)
	Review tagging; stock structure; Sette's work (Martin)
	Distributions: Shelf/slope waters (Gary)
10:30 – 10:45	Break
10:45 – 12:15	CPUE analysis (Jon)
	Survey analyses (Jon and François)
	Brief overview of Benchmark models to be reviewed: ASAP, ADAPT-VPA, SVPA, XSA, other SCAA
	Data inputs for proposed models
12:15 – 1:15	Lunch
1:15 – 3:00	Model formulations, results, diagnostics
3:00 – 3:15	Break
3:15 – 5:30	Continue Model presentation

<u>**2 March 2010 – Tuesday**</u>

9:00 – 10:30	Model formulations, results, diagnostics
10:30 – 10:45	Break
10:45 – 12:30	Model formulations, results, diagnostics
12:30 – 1:30	Lunch
1:30 – 3:00	Model formulations, results, diagnostics
3:00 – 3:15	Break
3:15 – 5:30	Model formulations, results, diagnostics
	possible late night for consensus on models/ reruns

<u>**3 March 2010 – Wednesday**</u>

08:30 – 10:00	Review additional work
10:00 – 10:15	Break
10:15 – 12:00	Review additional work:
12:00 – 1:00	Lunch
1:00 – 3:15	Model Selection
3:15 – 3:30	Break
3:30 – 5:30	Reference Points and Projections 4

4 March 2010 – Thursday

08:30 – 10:00	Final reviews
10:00 – 10:15	Break
10:15 – 12:00	Stock Status Report Writing
12:00 – 1:00	Lunch
1:00 – 3:15	Stock Status Report Writing
3:15 – 3:30	Break
3:30 – 5:30	Report Writing and Adjournment