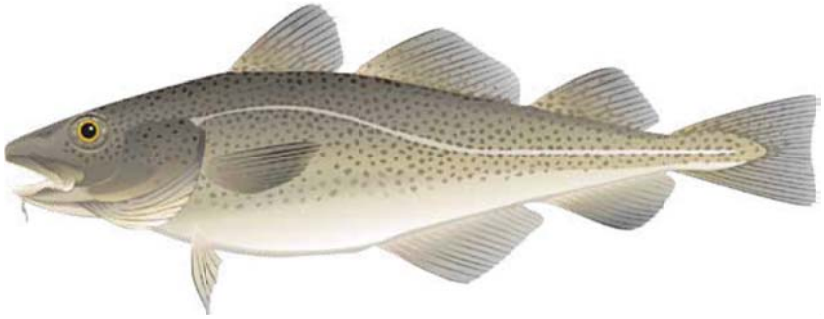
REPORT OF THE WORKSHOP

ON STOCK STRUCTURE OF ATLANTIC COD

IN THE GULF OF MAINE REGION

JUNE 12 – 14, 2012

PORTSMOUTH, NH



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Executive Summary

A Workshop on stock structure of Atlantic cod in the Gulf of Maine region was held on June 12 – 14, 2012 in Portsmouth, NH. The workshop was seen as the first phase of a three phase process.

The purpose of this workshop was as follows:

1. Review existing data, information, and results of analyses relevant to the stock structure of cod in the Scotian Shelf, Georges Bank, Gulf of Maine, and southern New England regions.
2. Based on these reviews, make recommendations on the most likely biological stock structure in these regions (including sub-stock structure if warranted), considering the current management units as a null hypothesis and other stock structure scenarios as alternative hypotheses.
3. Make recommendations for any future research required to evaluate the most likely biological stock structure developed in 2 above.
4. Provide advice on the alignment (or mis-alignment) of the current management unit boundaries vis-à-vis the most likely biological stock structure identified in 2 above

The workshop reached the following conclusions and recommendations:

Overall conclusions and recommendations on most likely stock structure and appropriate management units

The Workshop agreed on the following statements on broad-scale stock structure:

1. Conceptualizing the most likely biological stock structure is essential for the next steps of evaluating alternative management units and whether they are more likely to achieve fishery objectives.
2. Any management unit boundary will be a simplification of a more complex ecosystem, but if the simplification sufficiently reflects reality, we can meet our fishery and conservation objectives (optimum yield, preventing overfishing, etc.).
3. All information from U.S. waters indicates that there are three genetic stocks: 1) Offshore - Eastern Georges Bank (with some connectivity with the Scotian Shelf); 2) Inshore - Northern, Spring-Spawning Complex; and 3) Inshore – Southern, Winter-Spawning Complex.
4. Information from more traditional stock identification information generally supports the genetic perspective (e.g., tagging, growth, larval dispersal).
5. Cod in the eastern Gulf of Maine appear to be distinct from other groups.

The Workshop agreed on the following statements on fine-scale stock structure:

1. Larval retention and multi-year fidelity to local spawning sites suggest fine-scale meta-population structure.
2. Some traditional spawning groups were depleted, and have not been re-colonized by more productive groups.
3. Depletion of historical spawning groups is most apparent in the eastern Gulf of Maine, the Mid-Atlantic, the 'Plymouth Grounds,' and recently Nantucket Shoals.

The Workshop agreed that all genetic information available from U.S. waters is not entirely congruent with current management unit boundaries. Many of the workshop participants felt that there was compelling evidence that the current management units need to be revised. However, the Workshop did not reach any conclusions on what the most appropriate management units might be. This will require further data analysis and modeling in order to complete Phase I of the SSC recommended process.

Identify gaps in the data and analyses and recommend actions to address them

The gaps in the data and analyses were separated into two groups based on the timeframe in which they could be addressed – (1) short term (next 6 to 12 months); and (2) longer term (greater than 12 months).

Short term

1. Identify, collect, and analyse any further available key data and information required to complete Phase I and move to Phase II. Such data and analyses could include, but not be limited to, the following and should include data from the Scotian shelf and other appropriate Canadian waters:

a. Any further existing genetic data
b. Additional tagging data and estimation of movement rates from entire dataset
c. Life history parameters
d. Further consideration of larval dispersal from key spawning grounds, e.g. Georges Bank
e. Further evaluation of the advantages and disadvantages of alternative management unit scenarios on stock status and yields from the cod stocks in the region (Gulf of Maine, Georges Bank, Mid-Atlantic bight, and Scotian Shelf).

Longer term

1. Stock composition analysis in Gulf of Maine fishery (e.g., using otolith cores)
2. Collection and analysis of further genetic data from key areas, e.g. Georges Bank, eastern Gulf of Maine (including archaeological data), and perhaps Canadian waters.

Recommend next steps

The Workshop did not explicitly address and propose the next steps in the process. The Workshop Steering Committee subsequently discussed the next steps required to complete Phase I and lead up to Phase II of the recommended SSC process.

The Steering Committee recommends that an inclusive but focused Working Group meeting be held involving a small group of Canadian and US scientists to consider the results of the Workshop. This Working Group should be provided the short-term data and analyses identified as missing by the Workshop. Using that information, as well as the conclusions from the Workshop, the Working Group should determine the most appropriate representations of biological stock structure to complete Phase I of the process. The results from this Working Group meeting should be evaluated through an independent peer-review process. These peer-reviewed results should be used in Phase II of the process to make recommendations on the most appropriate management units.

Introduction

At its meeting of 25 January 2012, the Science and Statistical Committee (SSC) of the New England Fishery Management Council (NEFMC) was requested by Paul Howard, the Executive Director of the NEFMC to (a) identify information that may influence interpretation of the Gulf of Maine cod stock assessment results; (b) specify whether the possible influence of these elements warrants a closer examination at a future SSC or other meeting; and (c) provide advice on the structure and timing of any future meeting the SSC believes is warranted. Examples of such information might include:

a. Fishery dependent CPUE;
b. Natural mortality assumptions in light of evidence of predation mortality;
c. Recreational catch estimates that may be revised;
d. Assuming 100% mortality of hook caught and released fish (commercial and recreational);
e. The assumed stock structure for cod off the Northeastern US and Atlantic Canada and recent information of stock structure;
f. Uncertainty in survey calibration coefficients;
g. The assumption of flat-topped survey selectivity;
h. Report by Butterworth and Rademeyer, Jan. 2012; and
i. Any other limitation deemed important.

Due to time limitations, the SSC was not able to reach consensus on the majority of topics identified in the list above. While many opinions were expressed by individual SSC members on a wide range of topics that could influence assessment results, consensus could only be achieved regarding four topics as warranting further investigation:

1. stock structure (including spatial aspects),
2. the change from MRFSS to MRIP recreational catch estimates,
3. discard mortality rate, and
4. use of catch per unit effort (CPUE) information.

In a memo from the SSC to Paul J. Howard, Executive Director, NEFMC, dated 27 February 2012, the SSC proposed a three-phase process for re-evaluating, and possibly revising, the spatial basis for assessment and management of Atlantic cod, including the following objectives at each step:

Phase I

- Summarize the potential implications of defining inappropriate stock boundaries and ignoring sub-stock structure within stock units, as well as the potential advantages and disadvantages for both science and management of revising the status quo units, in order to provide a commonly understood rationale for this investigation.
- Overlay tagging, genetic, life history, and other data on the current management units to estimate rates of mixing and, conversely, independence and evaluate key assumptions of assessment models, essentially testing the "null hypothesis" of the status quo configuration.
- Develop a synthesis of those same tagging, genetic, life history, and other data to determine whether one or more alternative spatial configurations are more likely than the status quo. This synthesis should include the Gulf of Maine, George's Bank, the Mid-Atlantic Bight, and the Scotian Shelf.
- Characterize the mechanisms that drive spatial finer scale dynamics of cod populations and the fishing fleet, including habitat status and distribution, behavioral diversity, oceanography, predator-prey dynamics, and other factors.
- Provide advice on spatially-explicit management goals and strategies based on the synthesis of processes driving finer scale patterns, whether a new spatial configuration is adopted or not.

Phase II

- Summarize the practical limitations of changing stock units for both science and management.
- Analyze the advantages and disadvantages of either maintaining the status quo or adopting different spatial configurations through simulation modeling.

Phase III

- Conduct new assessments on new stock units, if warranted.

The SSC memo was forwarded by the NEFMC to the Northeast Fisheries Science Center (NEFSC). The Gulf of Maine Research Institute was subsequently asked by the Acting Director of NEFSC, Dr. William Karp, to convene a workshop to address the recommendations concerning cod stock structure in the SSC report. Based on follow-up conversations and correspondence with staff from NEFSC and the workshop steering committee members, it was decided to focus the workshop primarily on addressing the objectives outlined by the SSC for Phase I of the proposed 3 phase process. This proposal is a response to the request from Dr. Karp.

Purpose and Objectives of the Workshop

A Workshop Steering Committee was established composed of the following members:

- John Annala, GMRI (chair)
- Kevin Friedland, NEFSC
- Steve Cadrin, SMAST
- Jake Kritzer, EDF
- Tom Nies, NEFMC
- David Goethel, F/V Ellen Diane

The Workshop Steering Committee, in conjunction with the NEFSC management, developed the following Purpose and Objectives to address the SSC's recommended Phase I objectives.

Purpose

1. Review existing data, information, and results of analyses relevant to the stock structure of cod in the Scotian Shelf, Georges Bank, Gulf of Maine, and southern New England regions.
2. Based on these reviews, make recommendations on the most likely biological stock structure in these regions (including sub-stock structure if warranted), considering the current management units as a null hypothesis and other stock structure scenarios as alternative hypotheses.
3. Make recommendations for any future research required to evaluate the most likely biological stock structure developed in 2 above.
4. Provide advice on the alignment (or mis-alignment) of the current management unit boundaries vis-à-vis the most likely biological stock structure identified in 2 above

Objectives

1. Summarize the potential implications of defining inappropriate stock boundaries and ignoring sub-stock structure within stock units, as well as the potential advantages and disadvantages for both science and management of revising the status quo units.
2. Review tagging, genetic, life history, and other data on the current management units to estimate rates of mixing and, conversely, independence. This synthesis should include the Gulf of Maine, George's Bank, the Mid-Atlantic Bight, and the Scotian Shelf.
3. Synthesize those same tagging, genetic, life history, and other data to determine whether one or more alternative spatial configurations are more likely than the status quo.

4. Characterize the mechanisms that drive spatial finer scale dynamics of cod populations and the fishing fleet, including habitat status and distribution, behavioral diversity, oceanography, predator-prey dynamics, and other factors.
5. Evaluate key stock structure assumptions of assessment models, essentially testing the "null hypothesis" of the status quo stock configuration.
6. Provide advice on spatially-explicit management goals and strategies based on the synthesis of processes driving finer scale patterns, whether a new spatial configuration is adopted or not.
7. Provide advice on what information and data are required to analyze the advantages and disadvantages of either maintaining the status quo or adopting different spatial configurations through simulation modeling.
8. Determine the data gaps for 1 – 7 above and identify the future work required to address these gaps.

Overall Workshop Format

The workshop was organized as a series of sessions, in which the general session topic was briefly introduced, and the available data on cod off New England was summarized and synthesized in the context of current management units and alternative scenarios of biological stock structure. At the end of each session there was a discussion, led by the session chair, on the issues raised by each session speaker. The aim of the discussion was to build consensus interpretations of the information presented in that particular session.

Session format

Presentations

There was a brief (15 – 20 minutes) presentation by each invited speaker that summarized the available information for their specialty topic, synthesized the major conclusions with regard to cod stock structure based on this information, and summarized the additional work that needs to be done to better inform the determination of cod stock structure.

Background information

Each speaker provided the following materials in advance of the workshop and these were posted on the workshop website (hosted by GMRI):

1. Reading list of 5-6 key papers in the area of specialty of the speaker
2. A copy of the speaker's Powerpoint presentation
3. Written summary and synthesis of the specialty area that includes:
   a. Summary of the major points from the key papers
   b. Synthesis of the major conclusions with regard to cod stock structure based on the available information and analyses for the specialty area

c. Summary of additional work that needs to be done in the specialty area of research to better inform the determination of cod stock structure

The submitted summaries and syntheses are found in Appendix A (http://www.gmri.org/mini/index.asp?ID=52&p=145).

Session summary and synthesis

At the end of the session, the session chair provided a summary and synthesis of the session. Each session had one or more rapporteurs to assist the session chair with preparing a summary and synthesis of the session.

Workshop Sessions

Session 1 Summary: General Implications

Summary of the potential implications of defining inappropriate stock boundaries and ignoring sub-stock structure within stock units, as well as the potential advantages and disadvantages for both science and management of revising the status quo units.

Session Chair: John Annala

Rob Stephenson began his keynote presentation by stating that it is important to differentiate between biological structure (in an evolutionary sense) and stock/population structure of relevance to management because they are on different time scales. Biological (population) structure is ultimately linked to the genetic basis of populations. In the case of fish populations this is complicated by incomplete understanding of genetic structure, although that is an area of active research and considerable progress. Fish populations differ in their structure (complexity or 'richness'), and in the rigidity of that structure.

Rob provided the following definitions:

- Population discreteness - refers to the degree of isolation of subpopulations (Sinclair and Iles (1982) refer to ...the discreteness and discontinuity of gene pools, which are the essence of biological identity
- Population integrity refers to the tendency to remain discrete and to resist connectivity (idea of rigidity is also used)
- Population connectivity refers to the exchange of individuals among geographically separate subpopulations…' (Cowen et al 2007).
- Population complexity/richness - a measure of the diversity of subunits in the resulting pattern (e.g. 'biocomplexity' Ruzzante et al 2006)

He then presented his views on why stock structure needs to be considered:

1. Population structure is the basis for assessment and management. A 'unit stock' is assumed in most current models and in management. Future management is likely to build on that with additional consideration of both productivity and within-species diversity.
2. Management units (recognized as being a compromise of ecological, political and practical considerations) may not be serving us sufficiently.
3. Specifically (and more recently) recognition of within unit structure (substructure…complex structure) and the possibility of erosion of structure within stocks. While not proven, subtleties of stock structure (complexity) is widely presumed to be linked to resilience.
4. Recent developments in management (Ecosystem Approach, Precautionary Approach, etc.) have increased attention to biodiversity including within-species diversity (as it relates to resilience, etc).

The following are the potential advantages and disadvantages for both science and management of revising the status quo stock boundaries:

Science
Potential advantages
- increased credibility of evaluations and advice
- reduced error in advice

Potential disadvantages
- requires research
- disrupts time series
- more complex assessments

Management
Potential advantages
- reduced risk
- increased success of management

Potential disadvantage
- more onerous/complex management

Session 2 Summary: Development of current management units

Summary of the basis for and historical development of the current management units for cod in the Scotian shelf, Georges Bank, Gulf of Maine, and southern New England regions.

Session Chair: Steve Cadrin

Fred Serchuk reminded the workshop that the Magnuson Act mandates that a stock should be managed as a unit throughout its range, but he also summarized several publications that conclude that that there is no single definition of the term 'stock.' He provided a comprehensive and interdisciplinary stock identification with information available through the early 1990s. His presentation included information on geographic distribution from the fishery (e.g., fishing grounds, regional landings), survey patterns, and larval distributions; geographic variation in spawning seasons, growth, maturity and morphology; as well as information on movement from historical tagging and hydrographic patterns. Fred reminded the workshop that the matter of cod stock identity had been considered and debated for decades. For example, separate management of inshore and offshore cod stocks were considered by ICNAF, but the decision was to maintain existing management unit boundaries because they were sufficient and there were benefits to consistency. Fred presented the information in the context of population modeling for stock assessment and provided a detailed timeline of fishery management.

Discussion and Summary

The challenge of the workshop was to reconcile information from traditional approaches to stock identity with information developed since the current management boundaries were formed. In framing the session of discussion three similar challenges were described. In their review of geographic variation, Stephen Jay Gould and R.F. Johnston (1972) credited fisheries scientists, Saul Saila and J.M. Flowers (1968) as the first to apply discriminant analysis to the investigation of spatial population structure. Despite their legacy in developing a widely used technique for stock identification, Saul Saila responded with great grace and professionalism when his conclusions on lobster stock structure were refined (Cadrin 1995) by advising that we should expect scientific inferences to improve as new methods are developed. The second experience was Mike Sissenwine's foreword of the book on Stock Identification Methods (Sissenwine 2005) which stated that "Although this volume will be a valuable reference for years to come, I think that we should all be excited by the prospect of innovative advances in the near future that surely will render some of the conclusions in the book out of date." Although that statement was humbling at the time of publication, the book is currently being revised to address the many out-of-date aspects of the first edition. Finally, the Workshop on Redfish Stocks (ICES 2009) faced a similar challenge, and successfully reconciled recent genetic results with all information from traditional approaches to stock identity to form a conclusion about the most likely stock structure and appropriate management units.

Workshop participants asked if there was a legal definition of 'stock.' Although the Magnuson Act defines stock as "a species, subspecies, geographical grouping, or other category of fish capable of management as a unit" a recent NOAA workshop provided more guidance. Eagle et

al. (2008) concluded that fishery stocks have significant demographic independence from other stocks and are reproductively isolated on an ecological timescale (e.g., decades).

References

Cadrin, S.X. 1995. Discrimination of American lobster stocks off southern New England based on secondary sex character allometry. Canadian Journal of Fisheries and Aquatic Science 52(12): 2712-2723.

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Session 3 Summary: Broad Scale Stock Structure

Review of tagging, genetic, life history, and other data on the current management units to estimate rates of mixing and, conversely, independence. This synthesis should include the Gulf of Maine, George's Bank, the Mid-Atlantic Bight, and the Scotian Shelf.

Session chair: Steve Cadrin

Adrienne Kovach described the importance of patterns in genetic variation for identifying reproductively isolated groups. Reproductive isolation is a critical assumption of stock assessment (e.g., stock-recruit relationships) and the effectiveness of fishery management (e.g., optimum yield, rebuilding plans). In addition to reproductive isolation indicated by neutral genetic markers, meaningful adaptive differences among groups can also be indicated by selected genetic characters, which are also variable among cod spawning groups. The four studies Adrienne reviewed support a perspective of three temporally-stable genetic groups (or stock complexes) of cod in US waters: 1) eastern Georges Bank; 2) inshore spring-spawners, distributed from off western Maine to Massachusetts Bay; and 3) inshore winter spawners, distributed from Ipswich Bay to southern New England, including the Great South Channel. These genetic patterns are consistent with information from recent tagging (e.g., connectivity

between the Great South Channel and western Gulf of Maine) and larval dispersal (e.g., greater retention in the western Gulf of Maine during spring than winter, and dispersal from the western Gulf of Maine to southern coastal waters in winter).

Shelly Tallack presented recent information on cod movement patterns from her perspective as the coordinator of the large-scale Northeast Regional Cod Tagging Program in which over 180,000 cod were tagged, and 11,000 tagged cod were recaptured and reported. Movement patterns were visualized as rose plots to identify directional movements and bag plots to describe dispersal. Further work is required to quantify mixing rates of tagged fish.

Recaptures of cod tagged in the western Gulf of Maine were distributed in a general south-southwest direction within the western Gulf of Maine. Those that moved offshore or south to southern Cape/Great South Channel waters were outliers. Recaptures from cod tagged on the Scotian Shelf and Eastern Georges Bank suggest connectivity between the two areas and little mixing with the Gulf of Maine. Recaptures from cod tagged in the Great South Channel were distributed into the western Gulf of Maine with a north-northwest directional movement. The relatively few movement observations from southern New England suggest relatively local movement within the region. These tagging data suggest that alternative management units would be more consistent with movement patterns. Alternatives to be considered are two US management units: 1) Eastern Georges Bank and 2) inshore waters from the Gulf of Maine to the Mid Atlantic, including the Great South Channel; or three US management units: 1) Eastern Georges Bank, 2) the Gulf of Maine, and 3) southern inshore waters from the Great South Channel to the Mid Atlantic Bight. Shelly suggested two possible alternative management unit boundaries to the current structure, but also indicated that it was premature to make these changes now and that additional research was required to confirm these alternatives.

Graham Sherwood discussed his experience in researching northern cod, and the stock structure in which there were two distinct groups of cod: a resident type that had a more robust body shape and a migratory type that was more streamlined. He used his experiences in Newfoundland to investigate if the same pattern exists in the Gulf of Maine region. He found that there were significant morphometric differences between current management units, but even stronger differences within management units (e.g., between cod from the Great South Channel and Eastern Georges Bank; and between coastal Maine and Cashes Ledge. He concluded that there is considerable diversity within management units and discussed the implications for management (e.g., effectiveness of areas closed to fishing).

Discussion and Summary

The workshop discussion recognized some similarities in broad-scale patterns of genetic and morphometric variation that were consistent with the mixing patterns suggested from tagging data. For example the genetic and morphometric differences between cod sampled in the Great

South Channel and northeastern Georges Bank are consistent with the lower frequency of observed movement between the areas; and the genetic similarities between the Great South Channel and the western Gulf of Maine are consistent with tagging observations that suggest considerable movement between those areas. Unfortunately, little information on genetics, phenotypic variation or tagging is available from the eastern Gulf of Maine and western Georges Bank because sampling opportunities have been so limited in the last few decades as the abundance of cod has decreased in these areas.

Session 4 Summary: Fine Scale Population Structure

Characterize the mechanisms that drive finer scale spatial dynamics of cod populations and the fishing fleet, including habitat status and distribution, behavioral diversity, oceanography, predator-prey dynamics, and other factors.

Session chair: Graham Sherwood

The purpose of this session was to provide a summary of fine-scale population structure in New England cod and more specifically characterize the mechanisms that drive finer-scale dynamics in cod populations and the fishing fleet, including habitat status and distribution, behavioral diversity, oceanography, predator-prey dynamics, and other factors.

Jeff Runge referenced a paper authored by himself and 20 other investigators from the region that provided a framework for considering fine-scale population structure in Gulf of Maine (GOM)/Georges Bank (GB) cod that makes use of oceanographic monitoring data and modeling, fish behavior and genetics among other factors. He focused on the spring versus winter spawned cod in the western GOM. Differences in timing of spawning (known to be genetically distinct) can lead to major differences in advection patterns of eggs and larvae; young stages from winter spawned cod advect offshore from the western GOM to points south of Cape Cod and also onto GB whereas young cod stages spawned in the spring generally advect into Massachusetts Bay. These differences in spawning time and advection patterns of eggs and larvae likely set the stage for behavioral differences among the two populations with the spring cod representing a more resident strategy and the winter cod representing a more migrant strategy.

In order for these two “ecotypes” to persist, homing must be demonstrated. In other words, it must be shown that the winter spawned cod that advect over a much larger area (and over the current stock boundary) have the capacity to return to spawn in their natal region. This has been called “closing the loop” and is required for the genetic population structure described by Adrienne Kovach to persist (i.e., to be evolutionarily stable).

Doug Zemeckis presented work on homing behavior of cod from the western Gulf of Maine that are within the spring spawning complex. He also reviewed published studies that show homing behavior is a common feature in cod populations throughout the north Atlantic (including previous work in the GOM by Siceloff and Howell). Doug’s work, in collaboration with the Massachusetts Division of Marine Fisheries, similarly shows a high degree of multi-year homing

to the Spring Cod Conservation Zone (SCCZ) in the western GOM using acoustic tracking technology. The adjusted rate of spawning site fidelity was estimated to be 74%. In many cases, homing was within 100 m in successive years. This level of homing is consistent with the expectation that spring and winter spawning cod in the GOM spawn at specific times and locations. Next steps should include demonstration of homing in the winter spawned cod. A number of techniques can be brought to bear on this problem including tagging (e.g., data storage tags, DST's, and acoustic tags) as well as otolith microchemistry and growth analyses (e.g., winter spawned cod should have larger 0 band in their otoliths). The advantage of DST's is that algorithms are available to estimate where cod go outside of the spawning season.

Kevin Friedland provided information on habitat conditions, including thermal ranges and prey availability that spring and winter spawned cod from the western GOM are likely to encounter at young stages (larvae and juveniles). Differences in habitat characteristics may impact each spawning group differently as they vary both in space and time. The Northeast Shelf Large Marine Ecosystem is experiencing a period of increasing temperature levels and range, which is impacting the quantity of thermal habitats within the ecosystem. With increasing temperatures, warm water thermal habitats (16 - 27°C) have increased while there has been a reciprocal decline in cool water habitats (5 - 15°C). These cool water habitats are the most abundant and thus comprise the core habitats of the ecosystem. However, the coldest thermals habitats (1 - 4°C) have increased or remained constant, reflecting a discontinuity in the progression of warming along a latitudinal gradient. This discontinuity may be the result of recent changes in the circulation of water masses in the northern Gulf of Maine (GOM) associated with changes in the Labrador Current. The contraction of core thermal habitats appears to have had biological consequences on multiple trophic levels. In particular, two zooplankton species associated with the larval feeding of Atlantic cod have declined in abundance in spatially discrete areas where cod populations have failed to respond to stock recovery measures. The zooplankton species group *Pseudocalanus* spp, which is associated with winter spawning cod, has declined on GB and in the eastern GOM. The zooplankton *Centropages typicus* has declined in the GOM during fall, potentially affecting spring spawning cod in that area. These observations are consistent with the hypothesis that portions of the population complex of cod are suffering reduced reproductive productivity due to thermally induced changes in zooplankton abundance. In regard to current management units used in the assessments, the data suggest that cod populations in the western GOM are more productive than in the eastern GOM, based on a putative linkage between zooplankton abundance and larval survivorship. Similarly, the data suggest that the Nantucket Shoals population within the GB management unit is more productive than the unit as a whole.

Loretta O'Brien reviewed available information of life-history parameters in GOM and GB cod, however, similar analyzes for the Southern New England (SNE) area and Scotian Shelf were not available. An overview of egg, larvae, and juvenile life history was presented with the focus on adult life history. The physical and environmental differences between GB and the GOM are reflected in the different life history strategies for maturation and growth of Atlantic cod stocks from each area. The warmer temperatures in the autumn and the high productivity of the GB area may contribute to the faster growth and earlier maturation of cod on GB compared to the lower growth and later maturation of cod from the GOM. Differences in growth between the sexes within each stock are not as pronounced as differences between the stocks. In the

warmer waters of GB growth of cod is accelerated; however, as adults, GOM fish attain a larger size and have higher life-time fecundity. Mean weight of fish in both stocks is higher in the autumn prior to spawning than in the spring. On GB, maturity occurs at an earlier median age, larger median length and smaller median weight than fish in the GOM. Recruitment in the two areas does not appear to by synchronous. Condition has declined in both stocks but at a higher rate for Georges Bank fish. Life history parameters can inform decisions on how populations can be disaggregated into management units. Historical and contemporary differences in life history characteristics of cod in the GB and GOM area support the current stock structure definition. The life history parameters of finer scale population units would need to be analyzed to determine similarities or differences to the current stocks.

Discussion and Summary

The purpose of this session was to provide a summary of fine-scale population structure of cod in the wider Gulf of Maine region, and more specifically characterize the mechanisms that drive finer-scale dynamics in cod populations and the fishing fleet, including habitat status and distribution, behavioral diversity, oceanography, predator-prey dynamics, and other factors. Jeff Runge presented results showing differences in advection patterns of spring- versus winter-spawned cod larvae from the western Gulf of Maine (GOM); due to differences in wind and currents among seasons, spring-spawned larvae tend to end up in Massachusetts Bay (residents), whereas winter-spawned larvae (migrants) tend to be advected over much larger areas including south of Cape Cod and western Georges Bank. Doug Zemeckis presented results from fine-scale acoustic monitoring of spawning cod in the western GOM which show a high degree of multi-year homing to specific spawning sites. These results tie into Runge's results in the sense that in order for two spawning groups to persist in the GOM, homing to specific locations at specific times must be demonstrated. Ongoing work by Zemeckis and colleagues may shed light on homing patterns of winter spawning cod. Overall, both Jeff Runge and Doug Zemeckis provided both an empirical and modeling framework for how fine-scale cod population structure can exist in the western GOM. Kevin Friedland presented results on thermal habitats which have been increasing both in temperature and temperature range. These observations are consistent with the hypothesis that portions of the population complex of cod (notably, eastern GOM and Georges Bank) are suffering reduced reproductive productivity due to thermally induced changes in zooplankton abundance. Finally, Loretta O'Brien reviewed available information on life-history parameters that show differences among GOM and GB cod. However, further work to explore life-history variation within these two stocks is warranted and was touched on in Session 3.

Session 5 Summary: Evaluation of past and present fish and fisheries distributions

This session focused on the distribution of fishing effort and whether that information is helpful in defining stock structure for cod. Early stock boundaries often considered fishing activity as an indicator of the geographic structure of fishery resources. Five presentations addressed this issue.

Session chair: Tom Nies

Heather Deese noted that examining fishing patterns in the Gulf of Maine on multiple temporal and spatial scales might be used to inform not only cod stock structure but the impacts of stock revisions on fishermen and their communities. While historical information may be subject to inaccuracies (both intentional and unintentional) it can provide insights on the distribution of resources over time. More recent information can indicate how fishermen reacted to changes in management measures and changing stock conditions. It also can be used to highlight the link between areas of fishing activity and shoreside communities. Heather summarized a number of published reports and ongoing projects that are mapping fishing distributions (both past and present). But given recent advances in identifying stocks using genetics, tagging data, morphometrics, and other techniques, she asked a key question: should fisheries distributions be used to help define stock boundaries, and if so, how and to what extent?

Karen Alexander noted that historical marine ecology uses data that extend far back in time to explore environmental conditions in the past, and learn how and why conditions have changed. She described an ongoing project using historic data from the Gulf of Maine cod fishery and reported on part of the project describing the cod fishery from Frenchman's Bay, Maine, to Grand Manan in the Bay of Fundy, much of the eastern Gulf of Maine. This large, primarily coastal fishery landed more than 12,000 mt of cod in that region in 1861. Average fish size, time period and location of catch has allowed some reconstruction of population structure, suggesting far more complex and larger stock at this time, with an estimated population of more than 52,000 spawning cod more than 8 years old. A high mortality rate of 1.3 in the Eastern Gulf of Maine may have been supported by replenishment from the Bay of Fundy. Scaling up for total fishing effort, overall landings in the Gulf of Maine were estimated at about 70,000 mt in 1861. Further work using Bureau of Fisheries Statistics from 1928-1969 describes the fishery as data aggregation changed from named fishing grounds to statistical areas.

Ted Ames described efforts to better understand the dramatic decline of cod off the coast of eastern Maine over the last fifty years. Previous work had documented that in the past there had been many spawning sub-stocks in this area that had long since been eradicated. Ted examined the links between the decline in these stocks (or sub-stocks) and changes in prey species. He described a possible interaction between young-of-the-year alewives that remained in the coastal area over the winter, serving as prey for cod, haddock, pollock, and other species. Using data from Muscongous Bay he estimated the amount of alewives that may have been produced by this single bay that were available for gadids. The decline in cod stocks appears to be coincident with declines in alewives.

Michael Palmer addressed two related issues: 1) limitations of the existing fishery independent sampling design and fishery dependent information collection systems and possible implications for redefining stock definitions; and, 2) temporal and spatial trends in fisheries independent and dependent data. Survey data is based on a stratified random design, collected at the stratum level; post-stratification of the data can run into difficulties in the distribution of survey tows.

Fisheries dependent data collection systems have changed over time. Landings data for the period 1964-1982 are only available at the statistical area/30-minute square level; 1982-1993 data are available at the ten-minute square level, and since 1994 most data are available at the latitude/longitude level (reflecting general areas of fishing activity, not tow locations). These data scales may limit the ability to apportion survey or landings data to specific locations and argue for stock boundaries that can use the data available. Additionally, fishery reporting practices may limit the accuracy of fishery landings statistics, particularly under stock definitions other than the status quo. The impacts of this should be quantitatively evaluated in Phase II.

Across the Northeast Shelf, the overall abundance of cod has declined, even when examined at scales finer than stock areas (i.e., sub-regions). Additionally, the range of cod and the cod/groundfish fishery has generally contracted over the last 30-40 years both in response to declines in cod abundance and management measures. Lastly, a better understanding of fine-scale dynamics are needed to fully interpret the trends observed in both the cod population(s) and fishery as evidenced by the influence of the impact of a small region on overall Gulf of Maine cod landings per unit effort (LPUE) indices.

Aaron Dority and Anna Henry described a longline Sentinel Survey Fishery, now entering its third year, in the eastern Gulf of Maine (GOM) to collect data important to groundfish stock assessments and management. In recent years the eastern Gulf of Maine has had low stock sizes of cod and other groundfish species. Accurate assessment of the area using trawl surveys is difficult because of the complex bottom characteristics and the presence of lobster gear. The sentinel survey provides an alternative to the trawl survey and may provide a better understanding of the spatial dynamics of groundfish stocks. The project is moving into it second phase, which will be a combined scientific survey and commercial fishery. The information collected will help inform assessment and management of the GOM cod stock.

Discussion and Summary

The five presentations were similar in that each illustrated that commercial fisheries data can provide information on the past and present distribution of fishing activity. These data, however, have not been collected with consistent levels of accuracy and precision. The selection of stock boundaries may need to consider these limitations so the data will support assessment and management needs. Historical data is also useful in understanding the changes in the ecosystem that have occurred over time, and may provide insights into the potential productivity of the cod resource. This historic information also suggests that the complex nature of cod structure should not be subsumed into management of broad stock areas; this structure should be considered in the management program. But a key question remains unanswered: how should this information be used when defining stocks? One concern raised in the discussion was that approximately half of the landings from the Georges Bank management unit were taken from the Great South Channel (area 521) for the entire time series of information, but cod in that area appear to be

genetically more similar to the Gulf of Maine than to Eastern Georges Bank, and re-assigning that catch to the Gulf of Maine would have profound effects on both stock assessments.

Session 6 Summary: Identification of Likely Stock Structure Scenarios

Synthesize the data and analyses presented in 2 through 5 above to determine whether one or more alternative spatial configurations are more likely than the status quo.

Session chair: John Annala

The workshop chair asked Steve Cadrin to develop a strawman to generate workshop discussion in preparation for the Day 3 discussion. In response, Steve asked all workshop participants to submit statements to be considered for consensus workshop statements. The strawman was presented with some background on process, a reminder of the purpose of the workshop, and candidate consensus statements on broad-scale structure and fine-scale structure, including alternative scenarios of population structure for the development of a workshop consensus on the most likely scenario of stock structure.

As background information, Steve summarized the first three National Standards for Fisheries Conservation and Management from the Magnuson Act:

1. "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."
2. "Conservation and management measures shall be based upon the best scientific information available."
3. "To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination."

Operationally, 'best scientific information available' is determined by regional peer review processes (NS2 draft guidelines). The Northeast Region Coordinating Council decided that the issue of cod stock structure should be evaluated through the 'research track' of the newly revised Northeast Regional Stock Assessment process (tentatively scheduled for fall of 2013). In lieu of a determination from the regional peer review process, the New England Fishery Management Council tasked its Scientific and Statistical Committee to develop a workplan to address the issue.

A three-phase process for "Re-evaluating the spatial basis for management of Atlantic cod" was adopted by the New England Council's Executive Committee. This workshop is to address the objectives for Phase I (most likely stock structure), and the conclusions from Phase I will be used to design Phase II (considerations of practical limitations, advantages and disadvantages of status quo or alternatives) and possibly Phase III (development of new stock assessments).

The potential for sub-stock structure within existing or revised stock units relates to the ecological concept of a *metapopulation*. A metapopulation is often defined as a "population of populations", wherein individual subpopulations exhibit dynamics that are largely determined by local demography (growth, mortality, reproduction, recruitment), but are also influenced to a non-trivial degree by exchange with other populations (dispersal of larvae and/or migration of post-settlement fish).

Although there will inevitably be some degree of exchange among stock units, this should be low enough as to have negligible effects on population dynamics, and therefore justifiably ignored by assessment and management. In contrast, sub-structure within a stock (or, metapopulation) might warrant consideration. Most metapopulations exhibit structure at multiple scales, and the choice of the scale at which to define sub-stocks/subpopulations will depend upon a variety of ecological and practical (i.e., analytical, management) issues. For example, sub-ACLs could be assigned for a small number of sub-stocks, which could also potentially be modeled during assessment. However, dozens or even hundreds of local spawning groups are unlikely to have separate ACLs and to be treated separately during assessment, so other management measures are needed to account for structure at this scale.

The Workshop agreed on the following statements on broad-scale stock structure:

1. Conceptualizing the most likely biological stock structure is essential for the next steps of evaluating alternative management units and whether they are more likely to achieve fishery objectives.
2. Any management unit boundary will be a simplification of a more complex ecosystem, but if the simplification sufficiently reflects reality, we can meet our fishery and conservation objectives (optimum yield, preventing overfishing, etc.).
3. All information from U.S. waters indicates that there are three genetic stocks: 1) Offshore - Eastern Georges Bank (with some connectivity with the Scotian Shelf); 2) Inshore - Northern, Spring-Spawning Complex; and 3) Inshore – Southern, Winter-Spawning Complex.
4. Information from more traditional stock identification information generally supports the genetic perspective (e.g., tagging, growth, larval dispersal).
5. Cod in the eastern Gulf of Maine appear to be distinct from other groups.

The Workshop agreed on the following statements on fine-scale stock structure:

1. Larval retention and multi-year fidelity to local spawning sites suggest fine-scale meta-population structure.
2. Some traditional spawning groups were depleted, and have not been re-colonized by more productive groups.
3. Depletion of historical spawning groups is most apparent in the eastern Gulf of Maine, the Mid-Atlantic, the 'Plymouth Grounds,' and recently Nantucket Shoals.

The Workshop agreed on the following research recommendations to address information gaps:

1. Further consideration of larval dispersal from spawning on Georges Bank

2. Further consideration of Scotian Shelf cod
3. More extensive spatial sampling of genetics, particularly on Georges Bank
4. Further simulation modeling would be useful in evaluating alternative stock structure scenarios
5. Stock composition analysis in Gulf of Maine fishery (e.g., using otolith cores)

Session 7 Summary: Implications for Stock Assessment

Evaluate the outcomes of alternative stock structure assumptions on stock status and yields.

Session chair: Kevin Friedland

Yong Chen reported that most stock assessment models assume, implicitly or explicitly, that all fish in a stock have the same probability of encountering fishing gears at the spatial and/or temporal scale defined in the model. However spatial and temporal structure of fish stocks and/or fishing effort may violate this assumption. Violation of this assumption may result in errors in stock assessment. Two approaches can be used to address this assumption: (1) develop a spatially explicit model to incorporate the spatial structure of fish stocks and fishing effort; and (2) conduct computer simulation studies to evaluate potential consequences of violating such an assumption.

A spatially explicit model requires data to be collected in a manner consistent with the defined spatial and temporal scale of the model, which may make the use of the model inconsistent with the actual stock assessment. A well designed computer simulation study is a useful approach to evaluate the robustness of stock assessment results to mis-specification of fish stock structure.

In preliminary work, Chen et al. found that failure to consider stock mixing among the GOM, GB, and 4X cod stocks had limited impacts on ASAP-based stock assessment for GOM cod, perhaps resulting from limited mixing between GOM cod and other two stocks. Data quality associated with catch and abundance indices might have larger impacts on stock assessment results. In some cases, improving quality of these data may be more important for the GOM cod stock assessment, compared with considering mixing with GB and 4X stocks. Although mixing with GB and 4X stocks was shown to have limited impacts on the quality of the GOM stock assessment, impacts of meta-population structure within the GOM cod stock on the stock assessment needs to be evaluated in the future.

Lisa Kerr summarized several studies that have explored the potential consequences of a mismatch between biological population structure and spatially-defined management units on our perception of stock status and yield of cod resources within the Atlantic. The studies utilized models of varying complexity to examine the outcome of alternative stock structure assumptions. These studies illustrate that simulation modeling can be a useful tool in examining the perception

of fish stocks when underlying complex population structure is considered or when regarded as a unit stock. The simulation studies described potentially adverse consequences of aggregating data across spawning populations in assessments (e.g. misperception of the productivity and dynamics of the fish resource). Stock status estimated from data pooled across spatial components can result in an over- or under-estimate of productivity depending on the manner of data collection. Ignoring the spatial complexities of population structure and connectivity can lead to misperceptions of stock status and subsequent mismanagement of the resource. Furthermore, management decisions based on inaccurate and non-conservative biological reference points can potentially lead to overfishing and depletion of sub-stocks.

Genetic and tagging data suggest that the spatially-defined stock units for cod in U.S. waters include more than one spawning population (i.e., the Gulf of Maine stock unit includes the northern and a portion of the southern spawning group and the Georges Bank stock unit includes the eastern Georges Bank and a portion of southern spawning group). Ongoing work by Kerr et al. described simulation modeling comparing the perception of productivity and yield of the cod resource based on the biological unit and management unit view. Overall, the regional productivity and maximum sustainable yield of the biological unit model was lower compared to the management unit model. The biological model indicated a different distribution of productivity, with the eastern Georges Bank region being considerably less productive than suggested by the management unit model. Depending on assumptions about the portion of the southern spawning group (SSG) contained within the Gulf of Maine management unit, the biological unit model suggests that productivity in the region is either slightly overestimated (assuming 25% of SSG is contained within the Gulf of Maine stock unit) or underestimated (>45 % of SSG) by the management unit model. Overall, this simulation study indicated that consideration of biological structure of cod changed our perception of the magnitude and distribution of productivity in the region, suggesting that expectations of regional and local yield of cod in U.S. waters should be reconsidered.

Discussion and Summary

The information presented in Session 7 will have applicability to the work to be carried out in phase II of the cod stock alignment process. Any consideration of modified stock boundaries should be evaluated in light of whether it would have a measurable impact on the estimates of stock and fishing levels and on the reference points generated from the assessments. As Yong Chen's preliminary simulation modeling suggests, movement across existing stock boundaries is not as important a factor as measurement error within existing data. However, as suggested by simulation using sub-stock structure and observations reported in other sessions of the workshop, productivity does not appear to be uniform between populations within the existing stock boundaries. Again, the consequences of these and other scenarios will have to be evaluated in term of their functionality within existing data constraints and management constructs.

Session 8 Summary: Evaluation of potential future changes

Session chair: Steve Cadrin

Mike Fogarty considered stock structure in the context of complex ecosystems and ecosystem-based fishery management. The New England Fishery Management Council is developing an ecosystem plan that includes spatially-defined ecosystem production units for multispecies assessment and management. The anticipated transition to ecosystem-based fishery management and possibly spatially defined ecosystem production units should be considered in recommendations for most appropriate management units.

Mike also presented the topic of climate change and its influence on spatial distribution of fishery resources in the Northeast US continental shelf. Ecosystem monitoring indicates changes in thermal environments, salinity, circulation and primary production. Under the high emission scenario in the climate forecast model, the loss of cod thermal habitat is expected in the Mid-Atlantic region and on Georges Bank. Yield estimates and biological reference points for cod are likely to be affected by increasing temperatures. In the context of climate change, stock structure may need to be viewed as a dynamic process.

Tom Nies presented the implications and challenges for fishery management of changing cod management units. Tom reminded the workshop that the first New England groundfish plan approached fishery management from a multispecies perspective in an attempt to avoid single-stock management. Revisions to the Magnuson Act and associated National Guidelines for status determination and more recently for Annual Catch Limits require a single-species approach. He described the anticipated challenges with catch allocations in which catch histories were affected by different regulations in different areas. Stakeholders have criticized management changes, because they made investment decisions on previous conditions. Tom suggested that evaluation of possible new stock areas should include analysis of the following:

- Impacts of new stock areas on calculation of potential sector contributions for each permit using the Amendment 16 allocation criteria. The analyses should evaluate whether available data sources can support allocations using the new boundaries.
- Impacts of new boundaries on the ability of sectors to fish for other stocks.
- Impacts of new stock area boundaries on recreational and commercial cod allocations. The analyses should evaluate whether available data source can support allocations using the new boundaries.
- Influence of stock mixing on the apportionment of catches to stock areas.
- Impacts on the U.S./Canada Resource Sharing Understanding

Tom raised the question of whether data on fine-scale stock structure necessarily requires smaller management units or can similar benefits be achieved by simpler management responses instead.

Discussion and Summary
The SSC's guidance on the workshop was to separate recommendations on most likely biological stock structure from recommendations on most appropriate management units in sequential phases, because scientific inference of stock structure should not be constrained by

practicalities of management (although those practicalities are critically important for recommendations of appropriate management units). Rob Stephenson suggested that the workshop distinguish between: 1) biological stocks, 2) assessment units, and 3) management units. In an ideal world, assessment and management units reflect biological stocks, but there may be many practical reasons that the three are different.

The delineation of management units will need to reconcile a tradeoff between historical information and spatial resolution. Historical data is from fishing grounds, while fishery sampling data was initially from broad statistical areas that were intended to delineate fishing grounds, and greater resolution (e.g., 10-minute or 30-minute squares) is only available back to 1982.

Session 9: Recommendations for Phase 2 (Evaluation of Status Quo and Alternatives)

Provide advice on what information and data are required to analyze the advantages and disadvantages of either maintaining the status quo or adopting different spatial configurations through simulation modeling.

Session chair: Steve Cadrin

The final task of the workshop was to provide advice on what information and data are required to analyze the advantages and disadvantages of either maintaining the status quo or adopting different spatial configurations through simulation modeling. The discussion from previous sessions indicated that fishery management objectives are expected to be achieved if management units reflect biological stock structure. However, practicalities of fishery monitoring, assessment and management require some simplification. Greater complexity of management unit boundaries, assessment of spatially-complex populations and spatial management do not necessarily perform better for achieving objectives. The scientific inference on biological stocks should be considered in Phase 2 with a focus on improving performance of fishery management.

Specifically, Phase 2 should consider Phase 1 conclusions on broad-scale stock structure. All information from U.S. waters indicates that there are three genetic stocks: 1) Offshore - Eastern Georges Bank (with some connectivity with the Scotian Shelf); 2) Inshore - Northern, Spring-Spawning Complex; and 3) Inshore – Southern, Winter-Spawning Complex; and cod in the eastern Gulf of Maine appear to be distinct from other groups.

Phase 2 should also consider Phase 1 conclusions on fine-scale stock structure: larval retention and multi-year fidelity to local spawning sites suggest fine-scale meta-population structure; and that some traditional spawning groups were depleted, and have not been re-colonized by more productive groups.

Phase 2 should also consider the following results presented at this workshop:

- There is a general decline in survey abundance for cod in the wider region even if data are binned by alternative stock boundaries at scales finer than the current stock areas
- Preliminary simulation modeling results suggest that failure to consider stock mixing among the GOM, GB, and 4X cod stocks had limited impacts on ASAP-based stock assessment for GOM cod, perhaps resulting from limited mixing between GOM cod and the other two stocks. Data quality associated with catch and abundance indices might have larger impacts on stock assessment results.
- Other preliminary simulation modeling indicated that stock status estimated from data pooled across spatial components can result in an over- or under-estimate of productivity depending on the manner of data collection. Ignoring the spatial complexities of population structure and connectivity can lead to misperceptions of stock status and subsequent mismanagement of the resource.

Session 10 Summary: Overall Conclusions and Recommendations

- Overall conclusions and recommendations on most likely stock structure and appropriate management units
- Identify gaps in the data and analyses and recommend actions to address them
- Recommend next steps

Session chair: Steve Cadrin

Overall conclusions and recommendations on most likely stock structure and appropriate management units

The Workshop agreed on the following statements on broad-scale stock structure:

1. Conceptualizing the most likely biological stock structure is essential for the next steps of evaluating alternative management units and whether they are more likely to achieve fishery objectives.
2. Any management unit boundary will be a simplification of a more complex ecosystem, but if the simplification sufficiently reflects reality, we can meet our fishery and conservation objectives (optimum yield, preventing overfishing, etc.).
3. All information from U.S. waters indicates that there are three genetic stocks: 1) Offshore - Eastern Georges Bank (with some connectivity with the Scotian Shelf); 2) Inshore - Northern, Spring-Spawning Complex; and 3) Inshore – Southern, Winter-Spawning Complex.
4. Information from more traditional stock identification information generally supports the genetic perspective (e.g., tagging, growth, larval dispersal).
5. Cod in the eastern Gulf of Maine appear to be distinct from other groups.

The Workshop agreed on the following statements on fine-scale stock structure:

1. Larval retention and multi-year fidelity to local spawning sites suggest fine-scale meta-population structure.

2. Some traditional spawning groups were depleted, and have not been re-colonized by more productive groups.
3. Depletion of historical spawning groups is most apparent in the eastern Gulf of Maine, the Mid-Atlantic, the 'Plymouth Grounds,' and recently Nantucket Shoals.

The Workshop agreed that all genetic information available from U.S. waters is not entirely congruent with current management unit boundaries. Many of the workshop participants felt that there was compelling evidence that the current management units need to be revised. However, some participants felt that there were data gaps that needed a closer examination before biological stock boundaries could be defined. Therefore, the Workshop did not reach any conclusions on what the most appropriate representation of biological stock units might be. This will require further data analysis and modeling in order to complete Phase I of the SSC recommended process.

Identify gaps in the data and analyses and recommend actions to address them

The gaps in the data and analyses were separated into two groups based on the timeframe in which they could be addressed – (1) short term (next 6 to 12 months); and (2) longer term (greater than 12 months).

Short term

1. Identify, collect, and analyse any further available key data and information required to complete Phase I and move to Phase II. Such data and analyses could include, but not be limited to, the following and should include data from the Scotian shelf and other appropriate Canadian waters:
    a. Any further existing genetic data
    b. Additional tagging data and estimation of movement rates from entire dataset
    c. Life history parameters
    d. Further consideration of larval dispersal from key spawning grounds, e.g. Georges Bank
    e. Further evaluation of the advantages and disadvantages of alternative management unit scenarios on stock status and yields from the cod stocks in the region (Gulf of Maine, Georges Bank, Mid-Atlantic bight, and Scotian Shelf).

Longer term

1. Stock composition analysis in Gulf of Maine fishery (e.g., using otolith cores)
2. Collection and analysis of further genetic data from key areas, e.g. Georges Bank, eastern Gulf of Maine (including archaeological data), and perhaps Canadian waters.

Recommend next steps

The Workshop did not explicitly address and propose the next steps in the process. The Workshop Steering Committee subsequently discussed the next steps required to complete Phase I and lead up to Phase II of the recommended SSC process.

The Steering Committee recommends that an inclusive but focused Working Group meeting be held involving a small group of Canadian and US scientists to consider the results of the Workshop. This Working Group should be provided the short-term data and analyses identified as missing by the Workshop. Using that information, as well as the conclusions from the Workshop, the Working Group should determine the most appropriate representations of biological stock structure to complete Phase I of the process. The results from this Working Group meeting should be evaluated through an independent peer-review process. These peer-reviewed results should be used in Phase II of the process to make recommendations on the most appropriate management units.