# 1.0 INTRODUCTION

The Groundfish Assessment Review Meeting (GARM) is a regional scientific peer review process developed in 2002 to provide assessments for the stocks managed under the Northeast Multispecies Fishery Management Plan. The first two GARM reviews occurred in October 2002 (NEFSC, 2002) and August 2005 (NEFSC, 2005), respectively. The GARM III review is the most extensive to date and took place over four meetings held during October 2007 – August 2008:

- Data Inputs (29 Oct – 2 Nov 2007)
- Assessment Models (25 – 29 Feb 2008)
- Biological Reference Points (28 April – 2 May 2008)
- Assessments (4 – 8 August 2008)

The first three meetings focused on the data inputs (e.g. catch, sampling, surveys, etc), assessment models, and biological reference points (BRPs) to be used in the benchmark assessments and rebuilding projections of the 19 Northeast Groundfish stocks, which were the focus of the fourth meeting. The Panel Summary Reports of these three earlier GARM III meetings are available at NEFSC (2008).

This is the report of the GARM III 'Assessments' meeting which reviewed the status of the 19 Northeast Groundfish stocks through 2007, and evaluated the updated work on Gulf of Maine/Georges Bank ecosystem productivity considered at the GARM III 'Biological Reference Points' review (see Section 1.1 for the meeting Terms of Reference The meeting list of meeting participants and agenda are provided in Sections 1.2 and 1.3, respectively.

The GARM III 'Assessment' review Panel (herein termed the 'Panel') consisted of Matthew Cieri, Robert Mohn, Andrew Rosenberg, Alan Sinclair, and the chair, Robert O'Boyle. All were invited based upon their extensive expertise and experience with the issues to be considered at the meeting. A principal task of the Panel was to ensure that the findings and recommendations of the previous three GARM III reviews had been adequately addressed, and that the resultant benchmark assessments provided a sufficient basis for determination of stock status and rebuilding projections. In this report, each of the stock assessment sections was drafted by the lead assessment scientist for that stock. The ecosystem system was similarly drafted by the lead ecosystem scientist. The Panel's conclusions are provided at the end of each section. The Panel also provided observations on issues relevant to all assessments including retrospective patterns, determination of current status, and recruitment assumptions for projections and rebuilding plans. The Panel also provided comments on the treatment of historical data in the assessments and on alternative assessment methods, and provided its perspective on the ecosystem productivity work.

The first section of this report is an Executive Summary, prepared by the GARM III chair, which highlights the main scientific advances made during GARM III and the status of the 19 groundfish stocks. This is followed by an Introduction which provides information on the GARM III assessment review and a comparison of the GARM II and GARM III scientific basis for the assessments, both drafted by the GARM III chair. The main body of the report consists of the stock assessment sections drafted by the relevant lead scientist. The Panel provided observations on issues relevant to all assessments (retrospective error and the determination of current status, and recruitment assumptions and rebuilding plans) at the beginning of the stock assessment section while its conclusions and research recommendations on each stock are provided at the end of each section. The stock assessment section ends with Panel comments on the treatment of historical data in the assessments and alternative assessment methods. The next section of the report provides a synopsis of the findings on the ecosystem productivity work undertaken during GARM III, drafted by the lead scientist which is followed by the Panel's conclusions. The report ends with concluding remarks by the GARM III chair. An appendix to this report (NEFSC 2008, CRD 08-16) contains the Panel Summary Reports from the first three GARM III meeting as well as detailed information tables for some of the single species assessments.

The discussion at the GARM III 'Assessments' review was recorded by assigned rapporteurs. The rapporteur notes provided valuable reference material to the Panel in drafting its reports. These notes are not included in this report but can be obtained directly from the Northeast Fisheries Science Center (NEFSC).

### 1.1 Terms of Reference

1. Using models or proxy methods reviewed and recommended* at the previous GARM III meetings* for the stocks** listed below:
   a.) Provide updated catch and where applicable, catch-at-age estimates (landings and discards, where appropriate) through 2007
   b.) Provide updated research vessel survey indices (through spring 2008) for all appropriate surveys, including NEFSC spring and autumn bottom trawl surveys, Canadian DFO and state surveys
   c.) for stocks where sufficient data are available, estimate fishing mortality rates and spawning stock biomass through 2007, and provide associated measures of uncertainty
   d.) for the remaining stocks (i.e., those not in 1c.), use proxy methods to estimate the exploitation ratio and biomass index through 2007, and provide measures of uncertainty where possible
   e.) Update and provide estimates of the Biological Reference Points (BRPs) based on the most recent data and using methods that were reviewed and recommended at the GARM-III "BRP" meeting*. Provide any new analyses or refinements requested by previous GARM review panels
   f.) evaluate stock status by comparing the appropriate estimates of stock size and fishing mortality rate to the updated BRP estimates (from "TOR 1.e")
   g.) Identify what data and assumptions will be used for making short-term and long-term stock projections. These data include average weights, maturity at age, partial recruitment at age, and recruitment. For those stocks that are "rebuilding", compute $F_{REBUILD}$ consistent with the agreed NEFMC and NERO schedule***. Provide an estimate of predicted catches in 2009 based on current F (2007), $F_{MSY}$ and where appropriate, $F_{REBUILD}$. In making projections, assume that catches in 2008 are equal to 2007.

2. "Ecosystem approaches to Gulf of Maine/Georges Bank fisheries". Use the most recent data and BRP estimates to update the ecosystem results from the GARM-III "BRP" meeting* with respect to:
   a.) production potential of the fishery based on food chain processes and aggregate yield from the ecosystem

b.) comment on aggregate single stock yield projections in relation to overall ecosystem production

**Footnotes to the TORs:**

*: Previous GARM-III Meetings include the "Data Methods" meeting 10/29-11/2/07, "Assessment Methodology" meeting 2/25-2/29/08, and "Biological Reference Points" meeting 4/28-5/2/08. Reports and Working Papers from these meetings are available at **http://www.nefsc.noaa.gov/nefsc/saw/**. In cases where GARM reviewers have not yet recommended a particular assessment model, authors are expected to provide any new analyses or refinements requested by previous GARM review panels.

** :

A. Georges Bank (GB) Cod
B. Georges Bank (GB) Haddock
C. Georges Bank (GB) Yellowtail Flounder
D. Southern New England/Mid-Atlantic (SNE/MA) Yellowtail Flounder
E. Gulf of Maine/Cape Cod (GOM/CC) Yellowtail Flounder
F. Gulf of Maine (GOM) Cod
G. Witch Flounder
H. American Plaice
I. Gulf of Maine (GOM) Winter Flounder
J. Southern New England/Mid-Atlantic (SNE/MA) Winter Flounder
K. Georges Bank (GB) Winter Flounder
L. White Hake
M. Pollock
N. Acadian Redfish
O. Ocean Pout
P. Gulf of Maine/Georges Bank (No.) Windowpane
Q. Southern New England/Mid-Atlantic (So.) Windowpane
R. Gulf of Maine (GOM) Haddock
S. Atlantic Halibut

***: GARM Stocks with Northeast Region FMP Rebuilding Plans (rebuilding dates):

| | |
|---|---|
| Cod- Gulf of Maine | (4/27/04 to 4/27/2014) |
| Cod – Georges Bank | (4/27/04 to 4/27/2026) |
| Haddock – Gulf of Maine | (4/27/04 to 4/27/2014) |
| Haddock – Georges Bank | (4/27/04 to 4/27/2014) |
| American Plaice | (4/27/04 to 4/27/2014) |
| Redfish | (4/27/04 to 4/27/2051) |
| Yellowtail Flounder – SNE/MA | (4/27/04 to 4/27/2014) |
| Yellowtail Flounder – CC/GM | (4/27/04 to 4/27/2023) |
| Yellowtail Flounder –GB | (11/22/06 to 4/27/2014) |
| Ocean Pout | (4/27/04 to 4/27/2014) |
| White Hake | (4/27/04 to 4/27/2014) |
| Windowpane Flounder – SNE/MA | (4/27/04 to 4/27/2014) |
| Winter Flounder – SNE/MA | (4/27/04 to 4/27/2014) |

## 1.2 List of Meeting Participants

| Name | Affiliation | email |
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### 1.3 Meeting Agenda

| ***Date /Day*** | ***Start*** | ***End*** | ***Duration (min)*** | ***Topic*** | ***Presenter*** | ***Rapporteur*** |
|---|---|---|---|---|---|---|
| 4-Aug | 9:00 | 9:10 | 10 | Introduction | Weinberg (SAW Chair) | |
| 1 | 9:10 | 9:30 | 20 | Overview of GARM and objectives of this meeting | O'Boyle (GARM Chair) | |
| | | | | **TOR #1 Estimate Stock Status for 19 Groundfish stocks.** | | |
| 1 | 9:30 | 9:45 | 15 | *Working Paper 1.1* Review of previous GARM I and II Results | Rago | Wigley |
| 1 | 9:45 | 10:30 | 45 | *Working Paper 1.2* When should time series be split: potential changes in catchability, natural mortality and catches. | Legault | Wigley |
| 1 | 10:30 | 10:45 | 15 | Break | | |
| 1 | 10:45 | 11:15 | 30 | Discussion | | |
| 1 | 11:15 | 12:00 | 45 | *WP 1.C* Georges Bank Yellowtail Flounder | Legault | Richards |
| 1 | 12:00 | 12:30 | 30 | Discussion | | |
| 1 | 12:30 | 13:30 | 60 | Lunch | | |
| 1 | 13:30 | 14:15 | 45 | *WP1.D* Southern New England Yellowtail Flounder | Alade | Richards |
| 1 | 14:15 | 14:30 | 15 | Discussion | | |
| 1 | 14:30 | 15:15 | 45 | *WP 1.E* Gulf of Maine-Cape Cod Yellowtail Flounder | Legault | Richards |
| 1 | 15:15 | 15:30 | 15 | Discussion | | |
| 1 | 15:30 | 15:45 | 15 | Break | | |
| 1 | 15:45 | 16:45 | 60 | *WP 1.B* Georges Bank Haddock | Brooks | Mayo |
| 1 | 16:45 | 17:00 | 15 | Discussion | | |
| 1 | 17:00 | 17:35 | 35 | *WP 1.R* Gulf of Maine Haddock | Palmer | Mayo |
| 1 | 17:35 | 17:50 | 15 | Discussion | | |
| 1 | 17:50 | 18:00 | 10 | Summary/Followup Chair | O'Boyle | |
| | | | | | | |

| ***Date /Day*** | ***Start*** | ***End*** | ***Duration (min)*** | ***Topic*** | ***Presenter*** | |
|---|---|---|---|---|---|---|
| 5-Aug | ***9:00*** | 9:15 | 15 | Progress review and Order of the Day (Chair) | O'Boyle | |
| | | | | **TOR #1 Estimate Stock Status for 19 Groundfish stocks. (cont.)** | | |
| 2 | 9:15 | 10:15 | 60 | *WP 1.A* Georges Bank Cod | O'Brien | Brooks |
| 2 | 10:15 | 10:30 | 15 | Discussion | | |
| 2 | 10:30 | 10:45 | 15 | Break | | |
| 2 | 10:45 | 11:35 | 50 | *WP 1.F-a* Gulf of Maine Cod | Mayo | Shepherd |
| 2 | 11:35 | 11:50 | 15 | Discussion | | |
| 2 | 11:50 | 12:40 | 50 | *WP 1.F-b* Gulf of Maine Cod | Butterworth | Shepherd |
| 2 | 12:40 | 13:40 | 60 | Lunch | | |
| 2 | 13:40 | 14:40 | 60 | Discussion of GOM cod (both) | | |
| 2 | 14:40 | 15:30 | 50 | *WP 1.L-a* White Hake | Sosebee | Palmer |
| 2 | 15:30 | 15:40 | 10 | Discussion | | |
| 2 | 15:40 | 15:55 | 15 | Break | | |
| 2 | 15:55 | 16:45 | 50 | *WP 1.L-b.* White Hake | Butterworth | Palmer |
| 2 | 16:45 | 17:15 | 30 | Discussion of white hake (both 1.La, 1.Lb) | | |
| 2 | 17:15 | 17:30 | 15 | Summary/Followup | O'Boyle | |
| | | | | | | |
| ***Date /Day*** | ***Start*** | ***End*** | ***Duration (min)*** | ***Topic*** | ***Presenter*** | |
| 6-Aug | ***9:00*** | 9:15 | 15 | Progress review and Order of the Day (Chair) | O'Boyle | |
| 3 | 9:15 | 10:00 | 45 | *WP 1.G.* Witch Flounder | Wigley | Col |
| 3 | 10:00 | 10:15 | 15 | Discussion | | |
| 3 | 10:15 | 11:00 | 45 | *WP 4.H.* Gulf of Maine/Georges Bank American Plaice | O'Brien | Nitschke |
| | 11:00 | 11:15 | 15 | Break | | |
| | 11:15 | 11:30 | 15 | Discussion | | |
| 3 | 11:30 | 12:15 | 45 | *WP 1.J.* Southern New England Winter flounder | Terceiro | Traver |
| 3 | 12:15 | 12:30 | 15 | Discussion | | |
| 3 | 12:30 | 13:30 | 60 | Lunch | | |
| 3 | 13:30 | 14:15 | 45 | *WP 1.I.* Gulf of Maine Winter Flounder | Nitschke | Blaylock |
| 3 | 14:15 | 14:30 | 15 | *Discussion* | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | 14:30 | 15:15 | 45 | *WP 1.K.* Georges Bank Winter Flounder | Hendrickson | Alade |
| 3 | 15:15 | 15:30 | 15 | Discussion | | |
| 3 | 15:30 | 15:45 | 15 | Break | | |
| 3 | 15:45 | 16:30 | 45 | *WP 1.N.* Gulf of Maine/ Georges Bank Acadian Redfish | Miller | Sosebee |
| 3 | 16:30 | 16:45 | 15 | Discussion | | |
| 3 | 16:45 | 17:30 | 45 | *WP 1.S.* Atlantic Halibut | Col | Sosebee |
| 3 | 17:30 | 17:45 | 15 | Discussion | | |
| 3 | 17:45 | 18:00 | 15 | Summary/Followup | O'Boyle | |
| | | | | | | |
| ***Date /Day*** | ***Start*** | ***End*** | ***Duration (min)*** | ***Topic*** | ***Presenter*** | |
| 7-Aug | ***9:00*** | 9:15 | 15 | Progress review and Order of the Day | O'Boyle | |
| | | | | **TOR #2. Ecosystem approaches to Gulf of Maine/Georges Bank fisheries** | | |
| 4 | 9:15 | 10:15 | 60 | *WP 2.1* US NE Shelf LME Biomass, target biological reference points for fish and worldwide cross-system comparisons: Implications for single species reference points | Overholtz | Chute |
| 4 | 10:15 | 10:30 | 15 | Discussion | | |
| 4 | 10:30 | 10:45 | 15 | Break | | |
| 4 | 10:45 | 11:15 | 30 | Discussion (cont.) | | |
| 4 | 11:15 | 11:45 | 30 | *WP 1.O.* Ocean Pout | Wigley | Col |
| | 11:45 | 12:00 | 15 | Discussion | | |
| 4 | 12:00 | 13:00 | 60 | Lunch | | |
| | | | | **TOR #1 Estimate Stock Status for 19 Groundfish stocks. (cont.)** | | |
| 4 | 13:00 | 13:30 | 30 | *WP 1.M* Pollock | Mayo | Miller |
| 4 | 13:30 | 13:45 | 15 | Discussion | | |
| 4 | 13:45 | 14:15 | 30 | *WP 1.Q.* Southern New England – Mid-Atlantic Windowpane | Hendrickson | Blaylock |
| 4 | 14:15 | 14:30 | 15 | Discussion | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | 14:30 | 15:00 | 30 | *WP 1.P.* Gulf of Maine/Georges Bank Windowpane Flounder | Hendrickson | Blaylock |
| 4 | 15:00 | 15:15 | 15 | Break | | |
| 4 | 15:15 | 15:30 | 15 | Discussion | | |
| 4 | 15:30 | 17:30 | 120 | Review/Revisits/Revisions | | |
| 4 | 17:30 | 18:00 | 30 | Summary/Followup (Chair) | Chair | |
| | | | | | | |
| 8-Aug | ***9:00*** | 9:15 | 15 | Progress review and Order of the Day | O'Boyle | |
| 5 | 9:15 | 10:15 | 60 | Review of Outstanding Issues as necessary | TBD | |
| 5 | 10:15 | 10:30 | 15 | Break | | |
| 5 | 10:30 | 11:45 | 75 | Report Development [CLOSED] | | |
| 5 | 11:45 | 12:45 | 60 | Lunch | | |
| 5 | 12:45 | 16:00 | 195 | Report Development, Summary and Assignments [CLOSED] | | |
| 5 | 16:00 | 16:00 | 0 | Adjourn | | |

## 1.4 List of Working Papers

### List of Working Papers for the GARM III Final Meeting
### August 4-8, 2008

| WP | Description | Author |
|---|---|---|
| 1.1 | Review of Previous GARM I & II Results | Rago |
| 1.2 | When should time series be split | Legault |
| 1.A | Georges Bank Cod | O'Brien |
| App 1.A | Appendix Georges Bank Cod | O'Brien |
| 1.B | Georges Bank Haddock | Brooks |
| App 1.B | Appendix Georges Bank Haddock | Brooks |
| 1.C | Georges Bank Yellowtail Flounder | Legault |
| App 1.C | Appendix Georges Bank Yellowtail Flounder | Legault |
| 1.D | Southern New England Yellowtail Flounder | Alade |
| App 1.D | Appendix Southern New England Yellowtail Flounder | Alade |
| 1.E | Gulf of Maine-Cape Cod Yellowtail Flounder | Legault |
| App 1.E | Appendix Gulf of Maine CC Yellowtail Flounder | Legault |
| 1.F.a | Gulf of Maine Cod | Mayo |
| App 1.F.a | Appendix Gulf of Maine Cod | Mayo |
| 1.F.b | Gulf of Maine Cod | Butterworth |
| 1.G | Witch Flounder | Wigley |
| App 1.G | Appendix Witch Flounder | Wigley |
| 1.H | Gulf of Maine/Georges Bank American Plaice | O'Brien |
| App 1.H | Appendix Gulf of Maine Georges Bank Plaice | O'Brien |
| 1.I | Gulf of Maine Winter Flounder | Nitschke |
| App 1.I | Appendix Gulf of Maine Winter Flounder | Nitschke |
| 1.J | Southern New England Winter Flounder | Terceiro |
| App 1.J | Appendix Southern New England Winter Flounder | Terceiro |
| 1.K | Georges Bank Winter Flounder | Hendrickson |
| App 1.K | Appendix Georges Bank Winter Flounder | Hendrickson |
| 1.L.a | White Hake | Sosebee |
| App 1.L.a | Appendix White Hake | Sosebee |
| 1.L.b | White Hake | Butterworth |
| 1.M | Pollock | Mayo |
| App 1.M | Appendix Pollock | Mayo |
| 1.N | Gulf of Maine/Georges Bank Acadian Redfish | Miller |
| App 1.N | Appendix Gulf of Maine/Georges Bank Redfish | Miller |
| 1.O | Ocean Pout | Wigley |
| App 1.O | Appendix Ocean Pout | Wigley |
| 1.P | Gulf of Maine/Georges Bank Windowpane | Hendrickson |
| 1.Q | Southern New England/Mid Atlantic Windowpane | Hendrickson |
| 1.R | Gulf of Maine Haddock | Palmer |
| App 1.R | Appendix Gulf of Maine Haddock | Palmer |
| 1.S | Atlantic Halibut | Col |
| App 1.S | Appendix Atlantic Halibut | Col |
| 2.1 | US NE Shelf LME Biomass | Fogarty, Overholtz, Link |
| 2.2.a | Statistical Catch at Age Analysis ADAPT vs VPA | Butterworth |
| 2.2.b | Retrospective Analysis for the Gulf of Maine cod | Butterworth |

## 1.5 List of Stock Abbreviations

This report represents the work of over 20 authors and a variety of abbreviations are used throughout the report. These are necessary for both graphical and tabular summaries. For clarity, a list of abbreviation is provided below.

| Chapter | Stock | Abbreviation |
|---|---|---|
| A. | Georges Bank Cod | GB COD |
| B. | Georges Bank Haddock | GB Had, GB Haddock |
| C. | Georges Bank Yellowtail Flounder | GBYT,<br>GBYT1—refers to base model<br>GBYT2—refers to “major change” model |
| D. | So. New England/Mid-AtlanticYellowtail Flounder | SNE/MA YT |
| | So. New England Yellowtail Flounder (before 2003) | SNE YT |
| | Mid-Atlantic Yellowtail Flounder (before 2003) | MA YT |
| E. | Gulf of Maine/Cape Cod Yellowtail Flounder | CC/GOM YT |
| | Cape Cod Yellowtail Flounder | CC YT |
| F. | Gulf of Maine Cod | GOM Cod |
| G. | Witch Flounder | Witch |
| H. | American Plaice | Plaice |
| I. | Gulf of Maine Winter Flounder | GOM Win, GM Wint |
| J. | So. New England/Mid-Atlantic Winter Flounder | SNE/MA Wint, SNE Wint |
| K. | Georges Bank Winter Flounder | GB Wint |
| L. | White Hake | W Hake |
| M. | Pollock | Pollock |
| N. | Acadian Redfish | Redfish, |
| O. | Ocean Pout | Pout |
| P. | Gulf of Maine/Georges Bank Windowpane | No. Window, N Wind |
| Q. | So. New England/Mid-Atlantic Windowpane | So. Window, S Wind |
| R. | Gulf of Maine Haddock | GOM Had |
| S. | Atlantic Halibut | Halibut |

## 1.6 Comparison of GARM II and GARM III Basis for Assessment

As noted earlier, GARM I occurred in October 2002 (NEFSC, 2002) and was convened to (a) address stock status with respect to newly revised BRPs and (b) consider the effects of asymmetric trawl warps on the stock assessments. GARM II occurred in August 2005 (NEFSC, 2005) and focused on updating stock status using catch data through 2004. Potential revisions to models and BRPs were not part of the GARM II terms of reference. Instead, the updated assessments were used to track the changes in stock status at a waypoint on the rebuilding schedules as required by Amendment 13 to the Northeast Multispecies (Groundfish) Management Plan.

GARM III comprised an in-depth review of the data, models and BRPs for the 19 Northeast groundfish stocks. Rather than just updating the stock assessments, GARM III developed new benchmark assessments for each of the groundfish stocks which will be used until the next benchmark reviews.

*Data Inputs*

An essential input to each assessment is the landings data. The current Vessel Trip Report (VTR) system was implemented in 1994, before which landings were obtained from the dealer weigh-out system, apportioned to stock area by information from a voluntary interview system of captains and crew members. Until a unique identifier was put in place in 2004, matching of the VTRs (to obtain area of catch) with the Dealer Reports (to obtain amount of catch) was not straightforward. The GARM III assessments benefited from development of a new four level, trip-based hierarchical algorithm, which is comprehensive, consistent across species, provides continuity with the previous interview system, uses a common data source for all species, and provides a finer scale of spatial resolution than was previously available. During the GARM III 'Data Inputs' meeting, attention was focused on changes to the landings dataset that might ensue under the new system. It was noted that 87% of the records in the database had information comprehensive enough to allow VTR – Dealer Report matching, without resorting to the probabilistic matching required when information was incomplete (the remaining 13% of the cases). Overall, there was little impact on the landings allocation amongst stocks, with landings unchanged from GARM II. However, if allocation problems were to occur these likely would occur in small stocks located geographically adjacent to larger ones. A benefit of the new landings allocation system is that it provides the opportunity for future assessments to explore the impact of uncertainty in reported stock area of the landings.

The GARM III 'Data Inputs' review also considered how best to estimate discards. All of the GARM III assessments used a common approach is estimating discards. A number of discard estimators were initially considered, all dependent upon analysis of the extensive Northeast Fisheries Observer Program (NEFOP) dataset. The 'Data Inputs' review indicated that the Ratio of Sums method (sum of discards divided by sum of total landings) was the most appropriate approach for estimating discards. Alternative ways of estimating discards (e.g. mean discard per trip multiplied by the total number of trips) depend upon having accurate estimates of the total number of trips, which is often not the case. Total landings estimates were deemed more reliable than total number of trips. The review also made recommendations on which landings data to use in the discard estimation, suggesting that the observer data base be analyzed to develop a suite of harvested species associated with discards of the species of interest. Discards could then be estimated based on expansion of the observed discards associated with the landings of the particular suite of associated species. Regarding historical (pre-NEFOP) estimates of discards, these have generally been based upon analyses of bottom trawl survey data to infer discard rates with no one common approach employed for all stocks. This issue might be explored in more detail for future reviews. On balance, the discard estimates in GARM III are similar to those in GARM II.

Since GARM II, results from a number of tagging studies have become available to inform the stock assessments through quantification of migration patterns and by providing independent estimates of fishing and natural mortality. However, the migration models that were reviewed were considered too preliminary to accurately provide quantified estimates of migration rates. Tagging data proved most useful in interpreting trends in fishery partial recruitment in several assessments (e.g., GOM cod and white hake) illustrating one aspect of the utility of these data in stock assessments.

The GARM III 'Data Inputs' review also examined a number of issues related to the NMFS/NEFSC bottom trawl surveys, including the interpretation of stratified mean catch per tow values of zero. When such values occur for a species, the implication is that abundance is too low to be detected by the survey - rather than being truly zero. As such, it was recommended that zero values should be interpreted as being missing. Another issue discussed was the use in model tuning of swept area estimates of abundance (rather than numbers per tow) as this allows examination of survey catchability estimates which sometimes unexpectedly may be greater than 1.0. This approach was accepted as it provides a diagnostic in interpreting the assessment results. Overall, the GARM review of the NMFS surveys did not result in any significant changes to the time series of survey data.

The "Data Inputs' review also reviewed the data from various industry-based resource surveys, which were used in some of the groundfish assessments. It was noted that such surveys provide extremely valuable information on fish distributions, spawning areas, age-length keys, maturity and maturation rates, and other biological characteristics on a finer scale (in many cases) than is often available from the NMFS surveys. Further development of these surveys and studies on their applicability was therefore encouraged.

Also reviewed at the 'Data Inputs' meeting was an extensive analysis, by stock, of temporal trends in various biological and population dynamics parameters such as length-at-age, weight-at-age, maturity-at-age, and condition. Many of the groundfish stocks exhibit long term declines in weight-at-age which have significant implications for biological reference points. Unfortunately, without an understanding of the underlying causes for these patterns, it is difficult to determine how best to address these phenomena. Nonetheless, the review recommended specific ways to address these trends in the estimation of BRPs and stock projections. For instance, it was recommended that estimation of maturity-at-age use a multi-year smoothing average, with the size of the smoothing window determined separately for each stock based on influential biological processes. This approach allows for slow change in maturity at age which may be due to some as yet unknown process – but, by using a smoothed average, also recognizes the possibility that the observed patterns may be purely random. In general, to reflect the influence of recent changes in biological and population dynamics parameters, the groundfish assessments used the most recent 5-year average of weights-at-age in both the stock status determination and rebuilding projections.

*Assessment Methodology*

At the GARM III 'Assessment Models' meeting, the analytical framework proposed to be used to assess each stock was reviewed. A number of different types of assessment models are available including relative trends, production, length-based, and age-based (see NEFSC, 2008 for a glossary of terms). For each stock, attention was focused on data limitations and model assumptions and uncertainties to determine the most appropriate assessment model for that stock. For instance, for data-limited stocks situations such pollock, ocean pout, and the two windowpane stocks, it is only possible to use a relative trends assessment model (e.g. AIM). For more data-rich stocks, one of the principal uncertainties is the error in the catch-at-age information. In cases where this error is substantial, it is necessary to make assumptions on the age- and year-specific pattern of fishery exploitation (termed the 'partial recruitment' pattern). Statistical Catch at Age (SCAA) formulations can be used that predict, in a forward-projecting mode, catch-at-age proportions given estimates of partial recruitment. This class of models allows exploration of a number of processes through software such as ASAP, ASPM and SCALE. When the error in the catch-at-age is considered small, the fishery partial recruitment pattern can be derived from fishing mortality-at-age estimates using backward calculating procedures such as VPA.

For most of the groundfish assessments, the SCAA or VPA results were not substantially different, suggesting that neither error in the catch-at-age nor departures from a stable partial recruitment pattern was critically important. Consequently, most of the assessments used a VPA formulation (Table 5). In two cases, GOM haddock and GB winter flounder, new age-based VPA formulations replaced previous AIM and ASPIC formulations. Both VPA and SCALE were attempted on GOM winter flounder. Given the uncertainty with the catch-at-age of white hake, SCAA was used replacing ASPIC and AIM formulations. The relative trends assessment formulations used for pollock, the two windowpane stocks and for ocean pout remained unchanged from previous assessments due to continuing data limitations. However, a new replacement yield model was developed for Atlantic halibut, a stock which previously lacked an assessment formulation.

Table 5. Comparison of Assessment Models used in GARM II and GARM III

| ***Species*** | ***Stock*** | ***GARM II*** | ***GARM III*** |
|---|---|---|---|
| **Cod** | **GB** | **VPA** | **VPA** |
| **Cod** | **GOM** | **VPA** | **VPA** |
| **Haddock** | **GB** | **VPA** | **VPA** |
| **Haddock** | **GOM** | **AIM** | **VPA** |
| **Yellowtail Flounder** | **GB** | **VPA** | **VPA** |
| **Yellowtail Flounder** | **SNE/MA** | **VPA** | **VPA** |
| **Yellowtail Flounder** | **CC/GOM** | **VPA** | **VPA** |
| **American Plaice** | **GB/GOM** | **VPA** | **VPA** |
| **Witch Flounder** | | **VPA** | **VPA** |
| **Winter Flounder** | **GB** | **ASPIC** | **VPA** |
| **Winter Flounder** | **GOM** | **VPA** | **VPA & SCALE** |
| **Winter Flounder** | **SNE/MA** | **VPA** | **VPA** |
| **Redfish** | | **RED** | **SCAA** |
| **White Hake** | **GB/GOM** | **ASPIC & AIM** | **SCAA** |
| **Pollock** | **GB/GOM** | **AIM** | **AIM** |
| **Windowpane Flounder** | **GOM/GB** | **AIM** | **AIM** |
| **Windowpane Flounder** | **SNE/MA** | **AIM** | **AIM** |
| **Ocean Pout** | | **Index Method** | **Index Method** |
| **Altantic Halibut** | | **None** | **Replacement Yield** |

Retrospective patterns (systematic over or under-estimation of population parameters in recent years) were evident in many of groundfish analytical assessments. One potential cause of a retrospective pattern is mis-specification of the partial recruitment on the oldest age groups in the fishery. The 'Assessment Models' review noted that while dome-shaped fishery and survey partial recruitments may resolve retrospective patterns, these may also lead to what was termed 'cryptic' biomass – biomass generated by the model that has not been observed in either the fishery or surveys. Throughout the GARM III review, the burden of proof was placed upon analysts to convincingly demonstrate that fish existed in the population when not observed in the fishery and surveys, even if the model fit with dome-shaped partial recruitment appeared superior. In some cases, additional information (data and/or assumptions) external to the model was requested. For example, tagging information was explored to determine whether a domed partial recruitment pattern could be detected, and catch-at-age information was extended out to include as many age groups as reliably possible (from seven to eleven for GOM cod). In just two stocks (GOM cod and white hake) were domed fishery partial recruitment patterns accepted as part of the final assessment formulation.

Several other technical issues related to the stock assessment models (e.g. plus group algorithm, and weighting of model components) were considered at the "Assessment Models' review; these are described in the Panel Summary Report available at NEFSC (2008).

Overall, significant advances were made in the assessment models for the 19 Northeast groundfish stocks through the GARM III process.

*Biological Reference Points*

The GARM III 'Biological Reference Points' reviewed and evaluated $B_{MSY}$ and $F_{MSY}$ reference points of each of the 19 groundfish stocks. Table 6 (reproduced from the GARM III 'BRP' Panel Summary Report; see NEFSC 2008) provides a comparison of the methodology used to produce these BRPs in GARM II and GARM III.

Table 6. Comparison of Methodology to Estimate Biological Reference Points in GARM II and GARM III

| Species | Stock | GARM II<br>S_R Model | <br>Bmsy or proxy | <br>Fmsy or proxy |
|---|---|---|---|---|
| Cod | GB | Parametric | BH SSBmsy | BH Fmsy |
| Cod | GOM | Parametric | BH SSBmsy | BH Fmsy |
| Haddock | GB | Non-parametric | SSB/R (F40%MSP) avg R | F 40% MSP |
| Haddock | GOM | Equilibrium point | Fall RV msy (5100t) Frep (0.23) | Rel F at Rep |
| Yellowtail Flounder | GB | Non-parametric | SSB/R (F40%MSP) avg R | F 40% MSP |
| Yellowtail Flounder | SNE/MA | Non-parametric | SSB/R (F40%MSP) avg R | F 40% MSP |
| Yellowtail Flounder | CC/GOM | Non-parametric | SSB/R (F40%MSP) avg R | F 40% MSP |
| American Plaice | GB/GOM | Non-parametric | SSB/R (F40%MSP) avg R | F 40% MSP |
| Witch Flounder | | Non-parametric | SSB/R (F40%MSP) avg R | F 40% MSP |
| Winter Flounder | GB | NA | SP Bmsy | SP Fmsy |
| Winter Flounder | GOM | Parametric | BH SSBmsy | BH Fmsy |
| Winter Flounder | SNE/MA | Parametric | BH SSBmsy | BH Fmsy |
| Redfish | | Non-parametric | SSB/R (F50%MSP) avg R | F 50% MSP |
| White Hake | GB/GOM | Equilibrium point | SP Bmsy | Rel F at Rep |
| Pollock | GB/GOM | Equilibrium point | Fall RV | Rel F at Rep |
| Windowpane Flounder | GOM/GB | Equilibrium point | Fall RV | Rel F |
| Windowpane Flounder | SNE/MA | Equilibrium point | Fall RV | Rel F at Rep |
| Ocean Pout | | Equilibrium point | Spring RV | Rel F at Rep |
| Altantic Halibut | | NA | External: MSY/F0.1 | Proxy F 0.1 MSY (300t) |
| **Species** | **Stock** | **GARM III<br>S_R Model** | **<br>Bmsy or proxy** | **<br>Fmsy or proxy** |
| Cod | GB | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Cod | GOM | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Haddock | GB | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Haddock | GOM | Non-parametric | SSB/R (40%MSP | F40%MSP |
| Yellowtail Flounder | GB | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Yellowtail Flounder | SNE/MA | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Yellowtail Flounder | CC/GOM | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| American Plaice | GB/GOM | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Witch Flounder | | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Winter Flounder | GB | Non-parametric | SSB/R(40%MSP) | F40%MSP |
| Winter Flounder | GOM | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Winter Flounder | SNE/MA | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Redfish | | Non-parametric | SSB/R (50%MSP) | F50%MSP |
| White Hake | GB/GOM | Non-parametric | SSB/R (40%MSP) | F40%MSP |
| Pollock | GB/GOM | Visual interpretation | External | Rel F at replacement |
| Windowpane Flounder | GOM/GB | Visual interpretation | External | Rel F at replacement |
| Windowpane Flounder | SNE/MA | Visual interpretation | External | Rel F at replacement |
| Ocean Pout | | Visual interpretation | External | Rel F at replacement |
| Altantic Halibut | | Implied | Internal | F0.1 |

Whereas an array of methods was used to compute BRPs in GARM II, the principal method used in GARM III was to (a) estimate $F_{MSY}$ based upon $F_{40\%MSP}$ (50% for redfish) from a spawning biomass per recruit analysis, and (b) to estimate the associated $B_{MSY}$ using the complete population recruitment time series in a 100 year forward projection. Although a parametric approach was recommended in deriving BRPs when the stock-recruitment relationship derived from an assessment was informative, most of the groundfish assessments did not display compelling support for any particular functional form of stock recruitment (SR) relationship, and the SR parameters were generally poorly determined. Hence, for all 14 groundfish stocks assessed using an analytical framework, $F_{40\%MSP}$ was recommended as a proxy for $F_{MSY}$ and a $B_{MSY}$ proxy computed using a stochastic projection approach (termed the 'non-parametric' approach). The 'non-parametric' approach required inspection of the stock-recruitment relationship from the available historical population time series to select the stream of recruitments for the stochastic stock and rebuilding plan projections. Specifically, it required a decision on whether there was a spawning stock biomass level (termed the 'breakpoint') below which recruitment would be significantly reduced. It also required determination of whether exceptionally large year-classes occurred that were unrelated to the size of the spawning stock biomass, perhaps as a consequence of some environmental process. These breakpoints are a new feature of BRPs estimated for half of the GARM III stocks.

The GARM III recognized that long-term changes in productivity may have had an impact on the BRPs but considered that firm evidence was required to suggest that BRPs have changed due to environmental factors rather than fishery effects. Consequently, when a recruitment time series was selected to use in the estimation of the BRPs, this was related more to data and model estimation issues than to potential long-term changes in ecosystem and stock productivity. For stocks in which there were no long-term trends in the biological parameters (most commonly the maturity at age), the entire recruitment time series was used. This was considered to provide the best estimates of short to medium term stock productivity, and therefore to be most appropriate for calculating BRPs. For stocks exhibiting strong recent trends in biological parameters (e.g. GB haddock weight-at-age), the most recent estimates of these parameters - or the forward projection of these trends – was considered to provide the more accurate estimates of future, short-term conditions.

For some of the groundfish stocks, the BRP values reviewed and evaluated at the 'Biological Reference Points' meeting review were deemed provisional and subject to modification at the final GARM III meeting (the 'Assessments' meeting). The final set of BRPs for all 19 groundfish stocks is provided in Table 7. While some stocks previously (in GARM I and GARM II) had BRPs based upon index approaches (e.g. GOM haddock), many of these stocks now have BRPs based upon age-based models. This was not possible in all cases (e.g. windowpane and ocean pout) due to data and/or modeling constraints. The data sets for some of the stocks were extended considerably back in time (1913 for redfish, and 1893 for Atlantic halibut).

Most of the GARM III biomass reference points are lower and the fishing mortality reference points higher than those determined in GARM II. However, a direct one-to-one comparison between the old and new BRPs is inappropriate due to changes in weights-at-age and partial recruitment at age. For example, if through a combination of lower growth rates and fishery management regulations (e.g., increased mesh sizes), the fishery is now exploiting older individuals, the fishing mortality reference point would be expected to be higher simply based upon yield per recruit considerations alone.

It is therefore important that the nature and reasons for the changes in BRPs be clearly explained and communicated.

Table 7. Biological Reference Points from GARM II and GARM III for 19 Northeast Groundfish Stocks (from GARM III 'BRP' review with updates from the final GARM III 'assessment' review meeting). $B_{MSY}$ or proxies for GARM II were rounded to the nearest 100 mt. $F_{MSY}$ or proxies for GARM II and III were rounded to nearest hundredth. $B_{MSY}$ estimates are in mt unless indicated otherwise. "c/i"= catch (000's mt)/survey index (kg/tow).

| | | **GARM II** | | | |
|---|---|---|---|---|---|
| ***Species*** | ***Stock*** | ***Model*** | ***Bmsy or proxy (mt)*** | ***Fmsy or proxy*** | ***MSY (mt)*** |
| **Cod** | **GB** | VPA | 216,800 | 0.18 | 35,200 |
| **Cod** | **GOM** | VPA | 82,800 | 0.23 | 16,600 |
| **Haddock** | **GB** | VPA | 250,300 | 0.26 | 52,900 |
| **Haddock** | **GOM** | Landings & Survey | 22.17 kg/tow | 0.23c/i | 5,100 |
| **Yellowtail Flounder** | **GB** | VPA | 58,800 | 0.25 | 12,900 |
| **Yellowtail Flounder** | **SNE/MA** | VPA | 69,500 | 0.26 | 14,200 |
| **Yellowtail Flounder** | **CC/GOM** | VPA | 12,600 | 0.17 | 2,300 |
| **American Plaice** | **GB/GOM** | VPA | 28,600 | 0.17 | 4,900 |
| **Witch Flounder** | | VPA | 25,250 | 0.23 | 4,375 |
| **Winter Flounder** | **GB** | ASPIC | 9,400 | 0.32 | 3,000 |
| **Winter Flounder** | **GOM** | VPA | 4,100 | 0.43 | 1,500 |
| **Winter Flounder** | **SNE/MA** | VPA | 30,100 | 0.32 | 10,600 |
| **Redfish** | | RED | 236,700 | 0.04 | 8,200 |
| **White Hake** | **GB/GOM** | AIM | 14,700 | 0.29 | 4,200 |
| **Pollock** | **GB/GOM** | AIM | 3.00 kg/tow | 5.88 c/i | 17,600 |
| **Windowpane Flounder** | **GOM/GB** | AIM | 0.94 kg/tow | 1.11 c/i | 1,000 |
| **Windowpane Flounder** | **SNE/MA** | AIM | 0.92 kg/tow | 0.98 c/i | 900 |
| **Ocean Pout** | | Index Method | 4.9 kg/tow | 0.31 c/i | 1,500 |
| **Altantic Halibut** | | None | 5,400 | 0.06 | 300 |
| | | **GARM III** | | | |
| ***Species*** | ***Stock*** | ***Model*** | ***Bmsy or proxy (mt)*** | ***Fmsy or proxy*** | ***MSY (mt)*** |
| **Cod** | **GB** | VPA | 148,084 | 0.25 | 31,159 |
| **Cod** | **GOM** | VPA | 58,248 | 0.24 | 10,014 |
| **Haddock** | **GB** | VPA | 158,873 | 0.35 | 32,746 |
| **Haddock** | **GOM** | VPA | 5,900 | 0.43 | 1,360 |
| **Yellowtail Flounder** | **GB** | VPA | 43,200 | 0.25 | 9,400 |
| **Yellowtail Flounder** | **SNE/MA** | VPA | 27,400 | 0.25 | 6,100 |
| **Yellowtail Flounder** | **CC/GOM** | VPA | 7,790 | 0.24 | 1,720 |
| **American Plaice** | **GB/GOM** | VPA | 21,940 | 0.19 | 4,011 |
| **Witch Flounder** | | VPA | 11,447 | 0.20 | 2,352 |
| **Winter Flounder** | **GB** | VPA | 16,000 | 0.26 | 3,500 |
| **Winter Flounder** | **GOM** | VPA | 3,792 | 0.28 | 917 |
| **Winter Flounder** | **SNE/MA** | VPA | 38,761 | 0.25 | 9,742 |
| **Redfish** | | ASAP | 271,000 | 0.04 | 10,139 |
| **White Hake** | **GB/GOM** | SCAA | 56,254 | 0.13 | 5,800 |
| **Pollock** | **GB/GOM** | AIM | 2.00 kg/tow | 5.66 c/i | 11,320 |
| **Windowpane Flounder** | **GOM/GB** | AIM | 1.40 kg/tow | 0.50 c/i | 700 |
| **Windowpane Flounder** | **SNE/MA** | AIM | 0.34 kg/tow | 1.47 c/i | 500 |
| **Ocean Pout** | | Index Method | 4.94 kg/tow | 0.76 c/i | 3,754 |
| **Altantic Halibut** | | Replacement Yield | 49,000 | 0.07 | 3,500 |

*Stock and Rebuilding Plan Projections*

The GARM III considered how best to undertake the stock and rebuilding plan projections. A key element was to use the same assumptions for growth, maturity, natural mortality, and recruitment in the projections as used in estimating the BRPs - but with additional consideration of recruitment values in the available population time series when SSBs were below the breakpoint (see section below "Recruitment Assumptions and Rebuilding Plans") during the rebuilding period.

As with the BRPs, a direct comparison of the GARM II and GARM III $F_{REBUILD}$ estimates is inappropriate due to changes in a number of the assumptions on the biological and fishery parameters during the rebuilding period.

*Ecosystem Considerations*

Unlike the GARM II process, the GARM III process was able review an examination of the productivity of the Northeast Shelf ecosystem with particular regard to the joint sustainability of the 19 Northeast groundfish stocks - and also relative to several other species groups (invertebrates, pelagics and elasmobranchs). The review indicated that at the current low biomass of many of the groundfish stocks, the aggregate MSY is almost equivalent to the sum of the MSY estimates for each stock. However, as the biomasses of the groundfish stocks increase, the estimated aggregate MSY could be significantly less than the sum of the individual stock MSY estimates. The ecosystem work was recognized as being innovative, but too early in its development for implementation. Notwithstanding this, efforts are encouraged that explore how broader ecosystem considerations could be used to complement and enhance single stock management in the Northeast Region.