Prioritizing Fish Stock Assessments

NOAA Technical Memorandum NMFS-F/SPO-152

Edited by Richard D. Methot, Jr.

August 2015

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Admininstration

National Marine Fisheries Service

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An online version is available at: http://www.st.nmfs.noaa.gov/stock-assessment/stock-assessment-prioritization

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Executive Summary

Fish stock assessments provide the quantitative scientific information required by resource managers to determine stock status and set annual catch limits to prevent overfishing (Mace et al. 2001). Thus, assessments for managed fish and shellfish stocks represent an important core activity of the National Marine Fisheries Service (NMFS). Well-established procedures for these assessments have been developed to utilize data from fishery catch monitoring, fishery-independent surveys of abundance, biological studies, and other sources to produce the highly focused deliverables required by the Magnuson-Stevens Act (MSA). These data collection and analysis activities constitute a significant portion of the NMFS budget, but resources are insufficient to assess all managed stocks each year (nor is this a realistic target). It is therefore important to provide a transparent, quantitative, and objective process for determining what appropriate assessment targets are, and how to best meet those targets by determining priorities for assessment.

This document describes a national framework for prioritization of stock assessments. Although fish stock assessment prioritization will take place under the direction of this national framework, the process will be implemented on a regional[1] level coordinating with existing regional processes and planning bodies. The process is not intended to reallocate resources between regions; instead, the focus is on ensuring efficient and transparent decision-making related to stock assessment planning within each region. Prioritization results are considered to be advisory and non-binding, allowing regions to maintain the flexibility to make departures from recommendations when necessary. However, results will have significant visibility and departures should be used judiciously and with adequate justification.

Stock assessment prioritization includes first-time assessments for previously unassessed stocks, updating existing assessments using established methods/data, and upgrading assessments to use new types of data/methods. All stocks managed under Federal Fishery Management Plans, as well as additional stocks that may be assessed using NMFS Science Center resources, may be included in assessment prioritization. For stocks that have been previously assessed, the prioritization approach sets targets for assessment completeness (level) and frequency and then determines priorities relative to meeting those targets. For previously unassessed stocks, the system provides an opportunity to periodically examine their fishery importance, ecosystem importance, biological vulnerability to overfishing, preliminary information on fishery impact level (stock status), and data availability to determine which stocks are both sufficiently at risk to warrant an assessment and have sufficient data to conduct at least a data-limited assessment.

The prioritization process includes five steps conducted at the regional level and updated as needed:

1. Determine which stocks should be included, and how to best organize stocks into groups for prioritization.
2. Collect information for stocks to develop scores for 14 prioritization factors in five themes: Fishery Importance, Stock Status, Ecosystem Importance, Assessment Information, and Stock Biology. Information may be extracted from available databases or through workshops with regional experts, and scores should be updated annually to support development of the annual priority ranks described in Step 5.
3. Identify the current and target assessment level describing the data completeness and model complexity required for each stock; initially this could be as simple as determining which previously unassessed stocks are in need of a first-time assessment.
4. Develop target assessment frequencies based on a subset of the information collected in Step 2 to establish how often each stock needs to receive an updated assessment to maintain sufficient timeliness for status determinations and annual catch limit advice; re-examine as situations change.
5. Use factor scores developed in Step 2, along with factor weights provided by a steering committee of regional managers, to calculate prioritization ranks for each stock. These ranks serve as the starting position from which regional managers subsequently determine the final set of stocks to be assessed, after accounting for additional considerations. Ranks are updated each year to inform annual selection of stocks for assessment.

Target assessment level describes the appropriate level of modeling complexity and data inputs for a stock's assessment. High level assessments directly account for more factors and provide better forecasts for annual catch limits, but also

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[1] The generic term "region" is used to refer to the group composed of a NMFS Science Center and its management partners.

typically need precise and accurate fishery independent surveys and data on fish ages from the fishery and the surveys. These increased data requirements and costs should be reserved for specific situations, such as stocks with high fishery importance, high ecosystem importance, and biological factors that lead to high natural fluctuations. Stocks at moderate levels of importance or expected fluctuations can suffice with less data-rich assessments. Some stocks will be identified as sufficiently minor components of the fishery such that their assessments need not extend beyond baseline monitoring of catch and simple indicators. At all assessment levels, there should be consideration of environmental and ecosystem factors to help distinguish natural from fishery effects on the stocks. The process for setting target assessment levels will be more fully developed after completion of the update to the Stock Assessment Improvement Plan, currently underway.

Target assessment frequency defines the ideal interval between updates for a stock's assessments. It is driven by a stock's biology (intrinsic variability over time), as well as its importance to the fishery and ecosystem. The greatest fluctuations are expected for stocks with short life spans and high variability in productivity. Stocks with longer life spans tend to fluctuate less because of the many age classes in the population. High fluctuations create a greater need for frequent updates in annual catch limits. Stocks with high fishery and/or ecosystem importance need more frequent assessment updates to quickly provide access to increases in abundance while keeping the chance of overfishing at an acceptable level. Target update periods are expected to typically be 1-3 years, but some may range up to a maximum of 10 years. In addition to these prioritized assessments, regions may conduct simpler partial updates for many stocks to account for actual recent catches when recalculating upcoming catch limits. These partial updates are not undertaken as part of the assessment prioritization process, but are generally encouraged whenever assessments are not updated annually.

Annual assessment priorities are driven by the combination of 12 factors. Stocks that are more overdue, more important and closer to reference points will have higher priority for updates. In addition, the recent history of new data acquisition and assessment updates contribute to deciding whether the next assessment should be conducted as an update (using the same approach as previous assessments and simply incorporating new data points) or as a benchmark (introducing new methods or data types and requiring a more thorough investigation). Each factor used to assign annual assessment priorities is assigned a relative weight by regional managers, within set ranges intended to maintain consistency. Ranked priorities are then calculated as the weighted sum of the relative scores of applicable factors and used to guide decisions on assessment planning for the upcoming assessment cycle.

As stock assessment prioritization is implemented and each regional Science Center works to develop preliminary targets and annual assessment priorities with their respective management groups (Fishery Management Council, regional or international commission, NMFS Regional Office or Headquarters), a higher level of effort will likely be initially required; subsequent updates will be straightforward and streamlined. The process described in this document is expected to advance over time as efficiencies are identified through regional implementation. A portfolio of assessments is expected to evolve, with some activity directed towards first-time assessments, some towards baseline monitoring of low priority stocks, some towards high quality assessments of high priority stocks, and some towards more intensive investigation of ecosystem linkages where needed. To maintain the high pace of assessments currently required to meet management demands, it is expected that most of a region's assessments will be completed as updates/operational assessments using previously reviewed, standardized methods.

Management strategy evaluations (MSEs) will be an important tool to refine the prioritization process. MSEs on a few representative stocks in each region can be used to simulate the whole data-assessment-management process. MSEs also provide a logical way to more completely include economic considerations into the prioritization process. Ideally, an economically-based prioritization system would evolve towards a portfolio analysis that accounts for the costs of various types of assessments as well as the marginal benefits from those assessments. This would help scientists and managers better understand the implications of stock variability, assessment imprecision, assessment frequency, and time lags between assessment and management implementation.

Although the described prioritization process may not get more assessments done each year or improve the data available for assessments, it does give NMFS a way to identify the needs that are beyond our current program capacity and identify efficiencies that may improve assessment throughput. In the future, this prioritization process can provide the necessary framework to guide wise national investments in improving survey and staffing capabilities for more accurate, precise, and timely scientific information in support of stock assessment requirements.

Introduction

The Magnuson-Stevens Act (MSA) establishes regional Fishery Management Councils (FMCs) to manage and conserve fishery resources through development of Fishery Management Plans (FMPs). Each FMP lists the fish stocks managed under the plan, and then specifies an optimum yield for that fishery as well as criteria to determine whether overfishing is occurring or if any of the stocks have become overfished (depleted) and annual catch limits (ACLs) such that overfishing does not occur. The MSA also requires that management measures be guided by the best scientific information available. Fish stock assessments are designed to provide exactly the quantitative scientific information needed to determine the status of fish stocks and guide ACLs.

Stock assessments analyze fish population dynamics. Full assessments utilize catch data from fishery monitoring programs, stock abundance data from fishery-independent surveys or fishery catch rates, and data on the biology of the stock from various sources. These data feed into stock assessment models which integrate information from various sources and provide estimates of stock abundance, stock productivity, and fishing mortality over time. If an assessment is based on weak, imprecise data or has not been updated recently, there is a chance that it is providing guidance that is either allowing overfishing or forgoing available fishing opportunities. It is difficult to prevent overfishing while attempting to attain the maximum sustainable yield (MSY) without having an accurate, precise and timely stock assessment to guide frequent adjustments to catch levels. With accurate and precise stock assessments, the recommended catch can approach the theoretical MSY while having only a small chance of overfishing. Thus, it is important that stocks for which the fishery strives to achieve as large an optimum yield as possible are supported by data-rich, frequently updated stock assessments.

Stock assessments for Federally-managed stocks are conducted principally by the six National Marine Fisheries Service (NMFS) Science Centers in collaboration with FMCs, state and interstate fishery commissions, international, and academic partners. Assessment results are delivered to NMFS' fishery managers, FMCs, interstate fishery commissions, and international fishery management organizations for use in developing recommendations for fishery management. The MSA's National Standard 2 Guidelines require that management be based on the best scientific information available. The reauthorization of the MSA in 2006 specifically addresses this issue by establishing an opportunity for the Secretary of Commerce to establish a peer review process with each FMC. The MSA also designates the FMC's Scientific and Statistical Committee (SSC) with specific roles in providing the FMC with scientific advice on fishing levels, including the acceptable biological catch that would prevent overfishing. The relationship between NMFS' science programs

Definitions

Full Assessment Level: Utilizes catch data from fishery monitoring programs, stock abundance data from fishery-independent surveys or fishery catch rates, and data on the biology of the stock from various sources to feed into models which integrate the information and provide estimates of stock abundance, productivity, and fishing mortality over time.

Baseline Monitoring / Data-Limited Assessment Level: Utilizes just catch, and perhaps some simple indicators, to track stock status.

Ecosystem-Linked Assessment: Includes ecosystem factors (e.g. habitat, climate, other species, etc.) in the assessment to help explain and forecast population fluctuations.

Benchmark / Prototype / Research Assessment Approach: An assessment effort that introduces new methods or data types, and may involve a thorough investigation of all aspects of the assessment. Requires substantially greater staff time and review effort relative to update assessments.

Full Update / Operational / Standard Assessment Approach: Assessments completed using previously reviewed modeling approaches/data types; updates the assessment using the most recent data and may introduce minor improvements. Less extensive review is required.

Partial Update Assessment: Executive summaries that advance assessment projections by one year, usually adding the most recent year of catch data in the process. Much less effort to prepare than a full update and not considered in this prioritization system.

and the FMCs, NMFS regulatory offices, and various international partners for highly migratory and other treaty-managed stocks (e.g. those off Antarctica) is important for successfully turning assessment data into useful management advice on a timely basis. These relationships should include an objective process to determine which stocks are priorities for assessment, and then to effectively conduct, review, and communicate the assessment results to interested stakeholders and constituents.

Stock Assessment Improvement Plan

Since publication of the Marine Fish Stock Assessment Improvement Plan (SAIP; Mace et al. 2001), numerous national programs and working groups have been developed to improve assessments. These include:

- ***National Stock Assessment Workshops (NSAW)***[1] and ***National Scientific and Statistical Committee (SSC) Workshops*** provide a forum for development and advancement of scientific approaches and protocols.
- The ***Advanced Sampling Technology Working Group (ASTWG)*** develops improved data collection and processing technologies.
- The ***Fisheries Information System (FIS)***[2] program management team coordinates catch monitoring nationally.
- The ***National Observer Program (NOP)***[3] and ***Marine Recreational Information Program (MRIP)***[4] coordinates at-sea observers and recreational fishery catch monitoring, respectively.
- The ***Assessment Methods Working Group*** focuses on improvement of analytical stock assessment methods.
- The ***Species Information System (SIS)***[5] tracks data on assessments, stock status, and ACLs via a web-based user interface with easy and efficient reporting at the regional and national levels and value-added data products available to the public.
- ***Fisheries and the Environment (FATE)***[6] and the ***Habitat Assessment Improvement Plan (HAIP)***[7] work to improve the inclusion of environmental, ecosystem, and habitat information in assessments.

Collectively, these national programs and teams achieve a federated stock assessment enterprise under the leadership of the NMFS Science Board. This assessment enterprise meets national mandates established under MSA and other legislation and executive orders, and is responsive to regional assessment needs and opportunities.

The SAIP in 2001 provided a initial description of the NMFS stock assessment enterprise. It set the goal of at least baseline monitoring (catch and perhaps some simple indicators) for all stocks, full assessments for core stocks, and ecosystem-linked assessments for select stocks. The 2001 SAIP defined five levels at which an assessment could be conducted (note that these levels are being revised with the updated SAIP currently under development):

- ***Level 1:*** Based on empirical trends in relative stock abundance.
- ***Level 2:*** Based on a snapshot equilibrium calculation.
- ***Level 3:*** Based on time series of catch and an abundance index to support application of a dynamic model.
- ***Level 4:*** Age-structured, requiring time series of age and/or size data; models are able to estimate changes in fishery characteristics over time and fluctuations in annual recruitment, and provide direct information on the fishing mortality of each year class entering the stock.

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1 http://www.st.nmfs.noaa.gov/StockAssessment/NationalStockAssessmentWorkshop.html
2 http://www.st.nmfs.noaa.gov/data/fis/
3 http://www.st.nmfs.noaa.gov/observer-home/
4 http://www.st.nmfs.noaa.gov/recreational-fisheries/index
5 https://www.st.nmfs.noaa.gov/sisPortal/
6 http://www.st.nmfs.noaa.gov/fate/
7 http://www.st.nmfs.noaa.gov/ecosystems/habitat/index

- *Level 5:* Link to ecosystem, habitat or climate factors to help explain and forecast the fluctuations that are empirically measured in a Level 3 or 4 assessment.

Today, assessments at Level 3 are generally considered to be 'full assessments' because they are able to determine overfishing and overfished status, but are marginal for the purpose of forecasting changes in ACLs. Most assessments are conducted at Level 4 today and a few have achieved a Level 5 status. A range of modeling approaches are used, but there has been evolution towards models that are internally age-structured but very flexible in data requirements.

Updating the Stock Assessment Improvement Plan

The SAIP is being updated in 2015 to refresh the concepts developed in the original version (Mace et al. 2001) and provide a rationale and plan for expanding the linkage between stock assessments and ecosystem factors. Once completed, the updated SAIP will be a companion reference to this assessment prioritization document. In particular, the updated SAIP will provide additional information to help set target assessment levels for stocks to incorporate into the assessment prioritization process.

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Need for Prioritization

Demands for more frequent updating of assessments have become even more acute with the requirement for annual catch limits (ACLs) in all fisheries. While the most important stocks are assessed frequently, often with a thorough re-investigation of many assessment factors, other stocks are assessed infrequently, raising questions about the timeliness of their ACLs. Additionally, many data-limited stocks have ACLs set on the basis of scant data (Newman et al. 2015).

ACLs are intended to provide an implementable catch target that will maintain a target level of fishing mortality. Thus, ACLs must be adjusted often enough to track changes in stock abundance. For example, stocks with large fluctuations in abundance between years (e.g. short-lived species) must be updated on a regular basis and sufficiently close to the onset of the fishing season to take advantage of timely forecasts of available stock biomass (*B*) for setting the stock's ACL at the level that will attain a target level of fishing mortality (*F*). When the actual *B* in the upcoming year differs from the forecast *B*, fisheries will over- or under-achieve the target *F* level, leading to a risk of overfishing or underutilized fishing opportunities. The time it takes to make management updates based on new information from assessment results should be considered when determining how frequently a stock should be assessed. Some regions have developed shortened time frames between data collection and management implementation for short-lived, highly variable species. For example, the assessment-to-management transition is just a few months for Pacific salmon managed by the Pacific Fishery Management Council and for Pacific hake managed under a joint U.S.-Canada process. However, there are insufficient resources to assess all stocks on an annual basis, and many stocks do not need updates to their stock assessments on an annual basis. An objective and quantitative approach is needed to establish assessment targets and annual priorities.

How Much Does an Assessment Cost?

Tabulating the costs associated with conducting an individual assessment is complicated. Stock assessments are not singular tasks but rather the culmination of a collection of biological studies and data collection efforts over time that are required to provide the data that support an assessment. There is a complex relationship in each region between the number and type of assessments conducted and the available data sources that support those assessments. Most assessment-related funds go into large scale, long-term data collection programs that simultaneously collect data on many co-occurring stocks. Assessment programs encompass a broad portfolio of activities from basic fishery data collection and surveys, to conducting assessments, to research investigating ways to improve consideration of ecosystem, environmental and habitat effects on fish stocks. Further, the costs of conducting assessments vary tremendously depending on the size of the stock, its range and habitat, and the assessment requirements. It is extremely challenging to identify returns on investment in terms of new or improved assessments for specific stocks at a specific time.

Rebuilding stocks provide another example; these stocks are required under the Magnuson-Stevens Act (MSA) to be monitored every two years to determine if adequate progress towards rebuilding is being made. Although adequate progress can be monitored by comparing catch limits to the ACL associated with the rebuilding plan, stock assessments can provide a more accurate estimate of fishing effort and whether the population is meeting rebuilding targets.

National Marine Fisheries Service (NMFS) Science Centers have recognized the need for prioritization and streamlining of the assessment process. The prioritization framework described here, to be implemented across all NMFS regions, incorporates many of the concepts embodied in existing regional processes. For example, the Northeast Fisheries Science Center, at the request of the Northeast Regional Coordinating Committee, proposed a revised process in conducting assessment updates (NEFSC 2012). A particular focus of this revision was an effort to transition more assessments from a time-intensive benchmark assessment process to a streamlined operational assessment process.

Other nations have also recognized the need for coordinating the pace of assessments and the expectations for timeliness of management updates. In Australia, Dowling et al. (2013) investigated the historical patterns of investment to attempt to better understand the trade-off between research and management costs, risk to the stock and ecosystem, and level of allowable catch. In Europe, the International Council for Exploration of the Sea (ICES) formed a working group (WKFREQ) to investigate factors that could allow for reduced frequency from their typical annual assessment updates (ICES 2012). In 2011, ICES conducted annual assessment updates for 144 stocks and biennial assessments for 48 stocks. The ICES report (2012) reached the following conclusion with regard to reducing assessment frequency and deriving multi-year management advice from some assessments:

> *WKFREQ suggests that multiannual management approaches can only be considered for a limited subset of ICES stocks, namely those with robust assessments and modest exploitation, those with a limited amount of new information each year, those with very noisy data, those in which management is only weakly directed by assessments, and those in which individuals are very long lived and exploitation is (again) modest. Stocks in any other circumstances are unlikely to be suitable for a multiannual approach.*
>
> *Even in suitable cases, the risk of changing to a multiannual system needs to be evaluated using a quantitative approach such as an Management Strategy Evaluation. Such an evaluation needs to consider the assessment model used and its uncertainty, survey and recruitment variability, the initial state and trajectory of the stock, the management approach used, how well the fishery performs economically, and more qualitative aspects such as political sensitivity. An evaluation that ignores one or more of these aspects in determining suitability may well reach the wrong conclusion, with potentially damaging consequences.*

The WKFREQ recommendation for Management Strategy Evaluation (MSE) holds true for the United States as well. A prioritization system informed by MSEs will be more objective and transparent as to its expected benefits.

Benchmark vs. Update Assessments

Most of a region's assessments need to be conducted as operational updates if a high pace of assessments is to be accomplished. The fact that a stock has high importance or a poor status should not be a primary driver for committing the time and resources required for the full investigation of a benchmark assessment. Conducting a new benchmark should be avoided unless there is a reasonable expectation that improvements to certainty or resolution will result relative to the previous effort. When benchmarks are completed without fundamentally new information to consider, the assessment generally treads over the same, difficult to resolve issues from earlier assessments, pulling resources away from other needs. Below is a brief comparison of benchmark and full update assessments:

Benchmark	Update
May also be called 'Research' or 'Prototype' assessments	Also known as 'Operational' or 'Standard' assessments
Establishes scientific credibility of new data types or analysis methods	Builds upon approaches developed in previous benchmark and supports incremental improvements
Typically involves extensive investigation of model performance	Adds new data points to existing time series and updates model forecasts
Extensive staff time to produce	Requires less staff time
Extensive review commensurate with the degree of novelty and controversy	Streamlined review process
Requires thorough documentation of new data/methods/ performance	Briefer documentation for consistent, standardized public presentation of results
Provides a prototype approach that can then be used with timely data in subsequent updates	Efficiently provides management advice based on approved and established methods

Stocks Included in Prioritization

The stocks to be considered in the assessment prioritization scheme are numerous and diverse (Table 1). Across the nation, Fishery Management Councils (FMCs) vary tremendously in the degree to which they include species within their Fishery Management Plans (FMPs) from single-species FMPs to some FMPs that include a wide diversity of 100s of species. In some cases, a managed stock is a geographic subset of a species. In other cases, the stock is a management complex containing a few to many species. Still other species are listed in FMPs but not actively managed under the Fishery Management Unit, instead being designated as Data Collection Only or Ecosystem Component Species stocks. Regardless, all managed stocks need some level of monitoring and the fact that some species have been grouped together into complexes for management purposes does not discharge the National Marine Fisheries Service's (NMFS) stewardship responsibilities to assure that managed resources are not being overfished.

The Fish Stock Sustainability Index (FSSI) is a measure implemented by NMFS in 2005 to track performance of U.S. federal fisheries. The FSSI was first implemented in 2005 and currently includes 199 fish stocks selected because of their importance to commercial and recreational fisheries. Both FSSI and non-FSSI stocks are to be included for consideration in stock assessment prioritization.

The lists of stocks to be included in the prioritization process will be developed cooperatively with input from regional experts from NMFS and FMC committees/teams as an initial step for stock assessment prioritization. Composition of these regional expert groups will vary regionally and be determined by the steering committee of regional managers. An important consideration is comparability and to some degree transferability of assessment capacity among species considered. This may necessitate treating some stocks in a region separately from other stocks (e.g. Pacific coast salmon use a highly specialized assessment approach with state and tribal partners that is very dissimilar from that for other Pacific coast stocks). In some regions, there are multiple management bodies with distinct jurisdictions, FMPs, and priorities that are not easily reconciled. In such cases it may be necessary to treat each jurisdiction separately. In other cases, it may make sense to use a merged prioritization process across FMPs or even Science Centers where significant commonalities are present. These decisions will need to be part of the initial steps of the process.

Stock assessment prioritization includes stocks that have been previously assessed and have more quantitative information available to support prioritization, as well as stocks that have never been assessed and will need to use data-limited methods to obtain some of the supporting information. For these data-limited stocks, the prioritization process will provide an important opportunity to determine which unassessed stocks might have relevant assessment data available, and which stocks are showing signs of poor stock condition or high fishing rates.

Data-Limited Stocks

Many stocks (most with low amounts of catch) have never been assessed and have little or no data suitable for use in an assessment. For these stocks, it can be difficult to be confident that overfishing is not occurring and the stock is not overfished. However, these unassessed stocks can still be included in the prioritization process to determine their relative priority for assessment. Specific instructions (where necessary) are included in the Prioritization Scoring Factors section beginning on page 11 for assigning scores to data-limited stocks. The most important step for these stocks is to determine which might have relevant assessment data available, and which are showing signs of poor stock condition or high fishing rates. Even those data-limited stocks with seemingly healthy status should be re-examined every 5-10 years to verify that finding.

Table 1. The distribution of Fish Stock Sustainability Index (FSSI) and non-FSSI stocks among NMFS Science Centers and regional Fishery Management Councils (FMCs) in 2015. For simplicity, stocks jointly managed by the Gulf of Mexico and South Atlantic FMCs are included in counts for the South Atlantic FMC; stocks jointly managed by the New England and Mid-Atlantic FMCs are included in the counts for the New England FMC.

FMC	Science Center(s)	FSSI	Non-FSSI	Total
Caribbean	SE	10	32	42
Highly Migratory Species	SE	15	14	29
Gulf of Mexico	SE	13	14	27
South Atlantic	SE	29	21	50
New England	NE	38	1	39
Mid-Atlantic	NE	11	0	11
North Pacific	AK	35	30	65
Pacific - Salmon	NW/SW	2	65	67
Pacific - Other Species	NW/SW	41	18	59
Pacific Highly Migratory	SW/PI	0	32	32
Western Pacific	PI	4	45	49
All	All	199	271	470

Overview of Prioritization Process

Stock assessment prioritization (Figure 1) will take place under the direction of this national framework, and will be implemented on the regional level coordinating with existing regional processes. Prioritization is not intended to reallocate resources between regions; instead the process is meant to ensure efficient use of those resources and transparency in decision making related to stock assessments. While it may seem desirable to address prioritization nationally, the needs to manage fisheries for each region are strong and it is not feasible to quantitatively define absolute priorities for stock assessment at a national level. In addition to facilitating standardization of regional prioritization, the process described here will also provide a national reporting system for the results of regional prioritization.

Prioritization results are advisory and non-binding; regions will maintain the flexibility to make departures from prioritization recommendations when necessary. However, there is significant demand for improved transparency in decision making and a standardized national framework for stock assessment prioritization. Thus, it is expected that prioritization results will have significant visibility; the results of a standardized, data-based process may also help regions respond to public or political pressures to the scientific process. Once fully implemented, departures from prioritization recommendations should be used judiciously and with adequate justification. The timing of the prioritization process will need to be tailored to the timing of the annual or multi-year management cycles for the various Fishery Management Plans (FMPs) within each region. Ideally, the research and development of in-depth benchmark investigations will occur off-cycle, with update assessments scheduled to align closely with management cycles.

The initial step for prioritization involves determining the list of stocks that will be prioritized for assessment. Next, information is collected on each stock from available databases or regional fishery experts to support target setting and prioritization scoring. The prioritization process utilizes a total of 14 factors in five themes (described in detail beginning on page 11):

<u>Fishery Importance</u>

- *Commercial Fishery Importance*
- *Recreational Fishery Importance*
- *Importance to Subsistence*
- *Rebuilding Status*
- *Constituent Demand*
- *Non-Catch Value*

<u>Stock Status</u>

- *Relative Stock Abundance*
- *Relative Fishing Mortality*

<u>Ecosystem Importance</u>

- *Key Role in Ecosystem*

<u>Assessment Information</u>

- *Unexpected Changes in Stock Indicators*
- *New Type of Information*
- *Years Assessment Overdue*

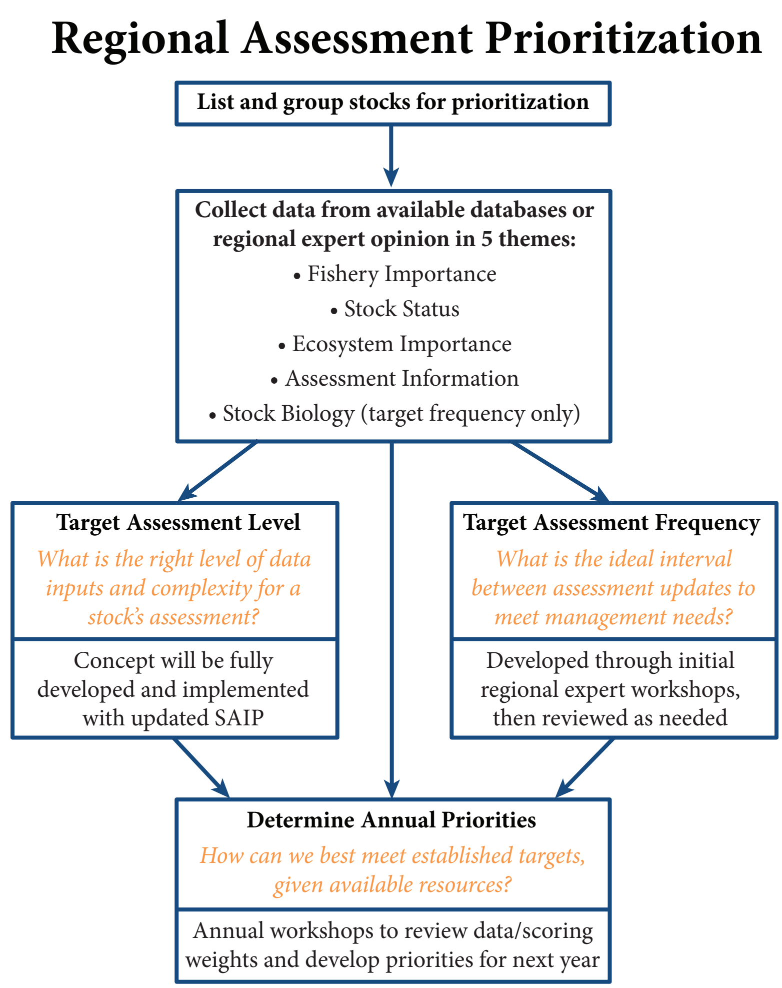

Figure 1. Overview of the assessment prioritization process.

Stock Biology (used for target frequency only)

- *Mean Age in Catch (or proxy)*
- *Recruitment Variability*

Targets are established as an essential step towards determining annual assessment priorities. One or more initial regional workshops will be convened (including National Marine Fisheries Service (NMFS) scientists and managers, Fishery Management Council (FMC) Scientific and Statistical Committee members, and other fishery experts) to develop a list of stocks for which the prioritization system will be applied, collect and review factor scores for all stocks, and establish initial targets.

Target assessment level (see page 21 for additional details) describes the appropriate level[1] of comprehensiveness of a stock's assessment, and varies according to a variety of factors. Full consideration of target setting for assessment level will be included in the prioritization process after completion of the update to the NMFS Stock Assessment Improvement Plan (SAIP; currently under development).

Target assessment frequency (further description begins on page 25) defines the ideal interval between updates[2] for a stock's assessments, and is a key factor in determining stock assessment priorities. Target frequencies depend strongly on the biology of the stock and its expected scale of fluctuations over time, and also consider the Fishery Importance and Ecosystem Importance scoring categories.

Assessment priorities are then developed through a series of annual workshops:

- Regional fishery experts, to review prioritization factor scores and targets, and update as necessary.
- Regional managers involved in deciding assessment priorities, to assign weights to each applicable factor and use priority scores in selecting stocks for assessment.

A stock's priority for assessment in the coming year is calculated as the weighted sum of the applicable factors (for additional details, see the example provided on page 24). This process shares many characteristics of a Multi-Criteria Decision Analysis (MCDA). MCDA can be used in applications as diverse as deciding where to site a school, to deciding on a portfolio of stocks in which to invest. In an MCDA, there are multiple factors that are scored by experts. For annual assessment priorities, these factors relate to fishery importance, stock status, and other relevant topics for each stock. These same factors are also assigned importance weights by regional managers. The combination of the expert-assigned stock-specific scores for each factor, along with the manager-assigned weights for each factor in their region, results in a list of priority scores for each stock. This list of priority scores across all regional stocks (or relevant groupings of regional stocks) will then be the basis from which regional managers and experts can develop the final list of stocks to be assessed in the coming year.

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[1] Assessment level refers to the comprehensiveness of the assessment used for a given stock and generally reflects the availability of data, as well as value or importance to the fishery. Assessment levels are defined in the 2001 Stock Assessment Improvement Plan (Mace et al. 2001), and will be revised in the update to the SAIP currently being developed by NMFS.

[2] Update here typically refers to a full assessment update.

Prioritization Scoring Factors

Detailed descriptions of scoring for each of the 12 factors utilized for determining annual assessment priorities are included in this section. For a summary of all factors, please see Table 2 on page 18 at the end of this section. All raw scores assigned by experts will be converted into scaled relative scores (process described in detail beginning on page 25). Information on the two Stock Biology factors used to support Target Assessment Frequency follows in that section beginning on page 21.

Fishery Importance

It is not feasible to quantify fishery importance in terms of benefits to the nation, nor would it be politically feasible to create a system that ignored the regional importance to coastal fishing communities. Research to develop holistic indicators of socioeconomic importance are beginning to identify potential methods (Seung and Zhang 2012), but we are not yet ready to apply such methods across all fisheries. Here, we utilize a set of six indicators, described below.

Commercial Fishery Importance: To measure a stock's commercial importance, a non-linear ranking based on the landed value of the catch will be calculated. A non-linear transformation is preferred over raw catch values because otherwise the most valuable stocks would overwhelm the lower value stocks and there would be little ability for other factors to establish a priority for assessment of the lower value stocks, for which there still is a mandated need to prevent overfishing. The progressive commercial fishery importance score transforms the raw catch values to reduce the range while preserving the relative ranking, and then scales against the most valuable regional stock on a scale of 0 to 5. Scores are calculated as

$$\text{Commercial Fishery Importance (stock x)} = \left(\frac{\log_{10}(1 + \text{landed value of stock x})}{\log_{10}(1 + \text{landed value of most valuable regional stock})} \right) * 5$$

Default catch values for each stock will be obtained from the National Marine Fisheries Service's (NMFS) Species Information System (SIS) that records catch and annual catch limits. Species-specific price per unit of catch will be obtained from the Annual Commercial Landings Statistics database[1] and used to convert the catch amount into ex-vessel value. More detailed regional information may be used to calculate stock-specific landed values where available. The distribution of average catch values across all stocks in 2011-13 is displayed in Figure 2. Although there is a general distribution of commercial catch values across both Fish Stock Sustainability Index (FSSI) and non-FSSI stocks, in general higher values are associated with FSSI stocks.

Recreational Fishery Importance: Stocks important to recreational fisheries tend to be at least moderately important to commercial fisheries; however, the most important commercial stocks nationally tend have very low recreational catches. It would take a very complete economic analysis to actually place recreational value on a comparable scale to commercial value, although some studies may provide such information in the future. At this time data are not available to develop quantitative, species-specific scores for recreational fishery importance. Instead, facilitated working groups of recreational fisheries experts will be convened to develop regional rankings of recreational fishery importance. Information on regional marginal values of recreational species will be provided, where available, to these groups as a starting point upon which to base scoring. A range of scores from 0 to 5 is provided. The score of 5 is expected to be assigned to just a few top recreational stocks and the rest of the stocks for which there is non-zero recreational catch should be assigned relative scores between 1 and 4. However, a set of stocks being prioritized

[1] Developed and maintained by NOAA Fisheries (http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index). No login required.

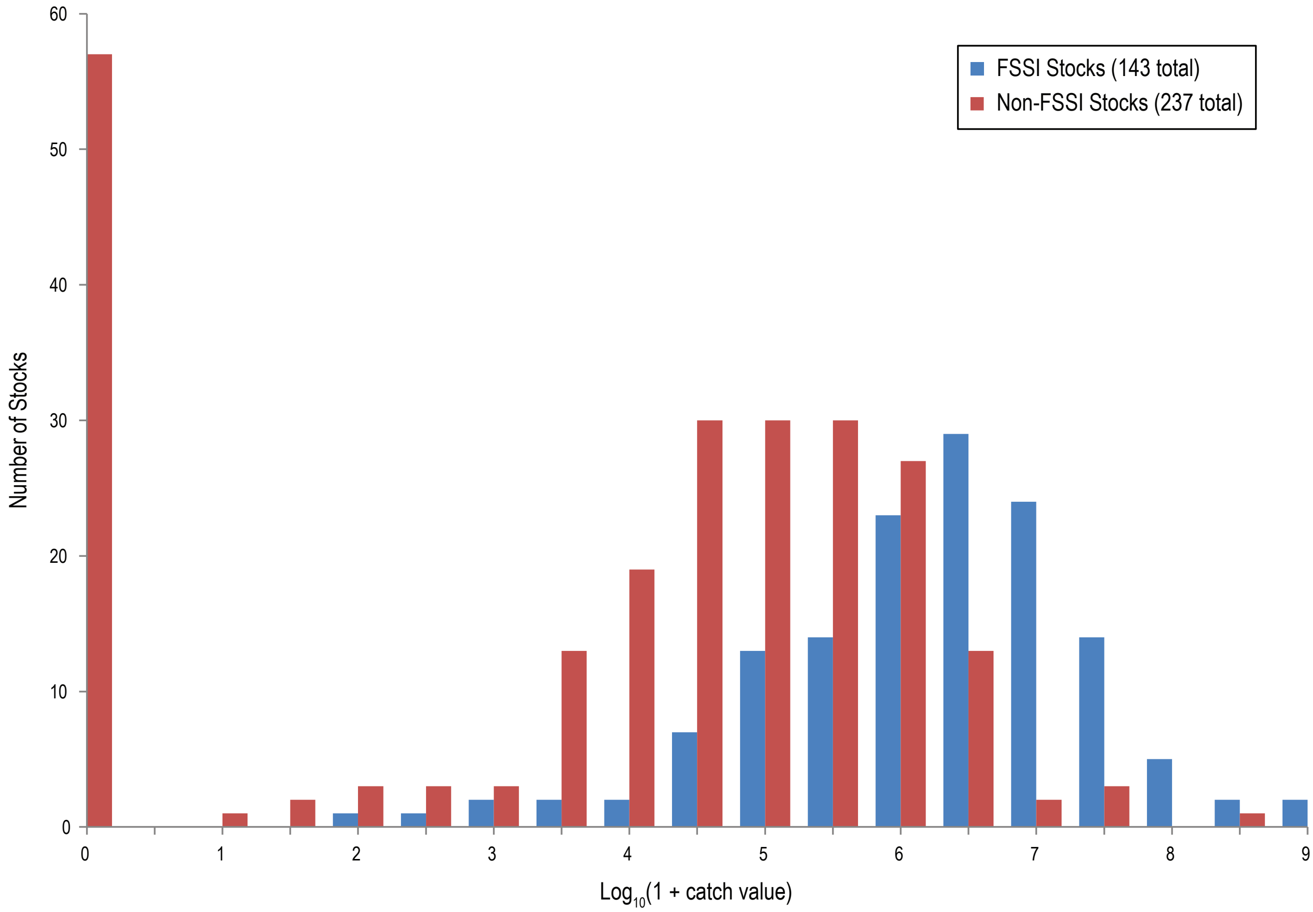

Figure 2. Average ex-vessel commercial value for 2011-13, shown separately for Fish Stock Sustainabiliity Index (FSSI) and non-FSSI stocks. Regional rankings of commercial fishery importance will be calculated from similar information.

could use a lower maximum score if recreational fishing is generally unimportant for the set of stocks being considered. Overall significance of recreational fisheries versus commercial fisheries is addressed with the prioritization weighting scheme assigned by regional managers (more on assigning factor weights on page 25).

Importance to Subsistence: Some stocks make important contributions to subsistence fisheries that are difficult to quantify. These contributions should be acknowledged in the overall fishery importance. An expert regional panel will assign scores ranging between 0 and 5 points for each stock with regard its importance to subsistence fisheries. Note that the full range of scores does not need to be utilized for all categories. For instance, no stocks may receive the top scores in this category if subsistence fisheries are generally unimportant for that set of stocks.

Rebuilding Status: Stocks on rebuilding plans or listed as endangered or threatened under the Endangered Species Act (ESA) experience depressed recent catch levels relative to the long-term potential yield. In addition, a substantial portion of the stock's total catch could occur as discarded bycatch that has no market value. Assessing stocks is important in order to track rebuilding closely and allow for catch to return to optimal levels as soon as possible. A score of 1 is assigned for stocks that are on rebuilding plans or listed under ESA, while a score of 0 is assigned to all other stocks.

Constituent Demand: This category recognizes that some stocks have a particularly high constituent demand for excellence in stock assessment. This might include stocks in catch share programs, choke stocks that limit access to other stocks, stocks with controversy over the existing assessment, stocks with high sociocultural fishery importance to the region, or simply stocks for which regional or national constituents have come to expect high quality, timely stock assessments. Scores are assigned by an expert regional panel ranging between 0 and 5 points for each stock with regard its importance due to constituent demand. As with the Subsistence category, the full range of scores need not be utilized.

Non-Catch Value: Another aspect of a stock's value is not associated with any harvest and is instead based on the relatively undisturbed existence of that stock in its ecosystem. A principal example would be underwater viewing of reef fish, but this category could extend to include other species for which there is a public sentiment for protection and hence a demand for some level of assessment. A recent paper by Sanchirico et al. (2013) identified methods to estimate non-catch value and found that these may be substantial. Points ranging between 0 and 5 for this factor are assigned by regional experts in the same manner as Subsistence and Constituent Demand Categories. The full range of scores need not be utilized.

Stock Status

A stock's status is based on the most recent estimates of the stock's abundance (spawning biomass, *SB*), and fishing mortality rate (*F*), relative to targets and limits set for these quantities (Figure 3). This category assigns scores based on current stock status, providing higher scores for stocks that are in greater need of conservation and management actions (e.g. overfished or experiencing overfishing). For data-limited stocks, two recently developed tools can assist in assigning these stocks to one of the five categories for stock status, or leaving them with stock status scores of "3" to signify their unknown status:

1. Productivity-Susceptibility Analysis (PSA; Patrick et al. 2010) – This procedure looks at simple information regarding the productivity of each stock and its exposure (susceptibility) to the fishery. Together these produce a score that ranks stocks according to their vulnerability to being overfished. Application of this procedure can identify those stocks that are potentially at risk, and thus in need of an assessment to provide a more complete evaluation of the status of the stock.
2. Only Reliable Catch Stocks (ORCS; Berkson et al. 2011) – This tool provides a data-poor approach for setting annual catch limits (ACLs) by looking at available information regarding catch, other species in the fishery, and simple indicators of trends in stock abundance. It evaluates whether recent exploitation rates are light, moderate, or heavy, and then provides advice on an ACL that should prevent overfishing until a more complete assessment can be completed.

Relative Stock Abundance: Scores for this factor are based on most recent spawning biomass (SB_C) information, as well as biomass targets (SB_{MSY} or a suitable proxy such as 40% of $SB_{unfished}$) and limits (Minimum Stock Size Threshold (MSST), or suitable proxy, below which a stock is considered overfished), from stock assessment and management data stored in the SIS database. Scores are assigned as follows:

- 1 point = stock biomass is above target ($SB_C > 1.25*SB_{MSY}$)
- 2 points = stock biomass is near target ($MSST < SB_C \leq 1.25*SB_{MSY}$)
- 3 points = caution - SB_C or MSST is unknown and status cannot be determined
- 4 points = stock is overfished ($SB_C \leq MSST$)
- 5 points = stock is overfished and show signs of decline

Relative Fishing Mortality: Similar to Relative Stock Abundance described above, this factor is based on current fishing mortality rates (F_C) and fishing mortality limits (F_L, above which overfishing is occurring; set at F_{MSY} or a suitable proxy) from stock assessment and management data stored in the SIS database. Scores for this factor are assigned as follows:

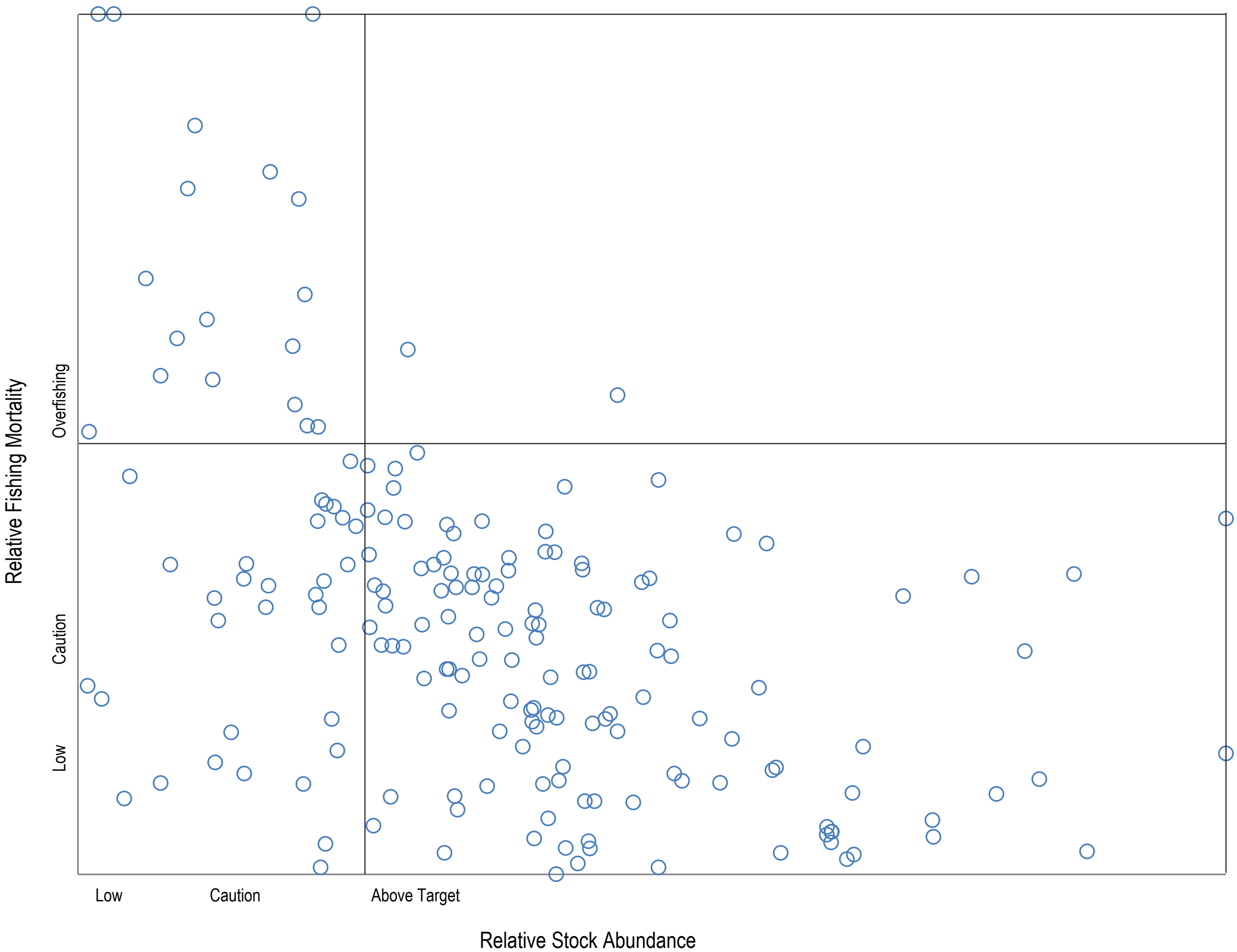

Figure 3. Kobe plot summarizing relative abundance and fishing mortality from the most recent assessment of 180 federally managed stocks with available information. A majority of these stocks are not experiencing overfishing and have a relative biomass near or above target.

- 1 point = low fisheries impact on stock ($F_C \leq 0.25*F_L$)
- 2 points = moderate fisheries impact on stock ($0.25*F_L < F_C \leq 0.9*F_L$)
- 3 points = caution - F_C or F_L is unknown and status cannot be determined
- 4 points = high impact of fisheries on stock ($F_C > 0.9*F_L$)
- 5 points = stock has been determined to be experiencing overfishing

Ecosystem Importance

All species are important to their ecosystems, but their importance increases if:

1. They constitute a major forage species for one or more managed species (particularly an endangered or protected species; i.e. "bottom-up").
2. Their role as a predator or competitor is important for structuring ecosystems, including changing the natural mortality rate of other species (i.e. "top-down").

Although the capability to quantitatively define ecosystem importance is difficult, a mixture of food habits data, basic ecological information and model exploration (when available) can usually identify ecosystem components that have potential or likely substantive impacts on predation mortality rates or community structure.

Key Role in Ecosystem: This factor is developed by scoring both bottom-up and top-down contributions to the ecosystem. Scores for this factor, ranging between 1 and 5 points, are assigned by regional experts as described below. Because scores for one component may cancel out scores from the other component (e.g. high for bottom-up and low for top-down, or vice versa), the maximum of the two components is used as the score for this factor rather than treating the two components separately.

<u>Bottom-Up (Forage or Habitat) Component</u>

- 1 point = stock is only a minor dietary or habitat provider for managed stocks (e.g. Pacific grenadier)
- 2 to 4 points = stock is a moderate dietary or habitat component for one or more managed stocks (e.g. Pacific sardine, corals)
- 5 points = stock is a major dietary or habitat component for a broad range of managed stocks, or critical to an endangered or otherwise protected and vulnerable stock (e.g. skipjack tuna, menhaden, krill, shrimp)

<u>Top-Down (Predator/Ecosystem Interaction) Component</u>

- 1 point = a change in the stock's abundance would likely have minor or unmeasurable impacts on other managed stocks (e.g. splitnose rockfish)
- 2 to 4 points = a change in the stock's abundance would likely have notable changes in predation mortality, recruitment, or other vital rates for one or more managed stocks (e.g. lingcod, marlin)
- 5 points = a change in the stock's abundance would likely result in substantive changes in predation mortality, recruitment, or other vital rates for one or several managed stocks (e.g. Gulf of Alaska arrowtooth flounder)

Assessment Information

Unexpected Changes in Stock Indicators: When the target interval between assessment updates is several years, it may be possible to make a quick evaluation of new information as it becomes available and adjust the stock's priority for assessment up or down based upon how closely the new data match expectations from forecasts from the previous assessment (Figure 4). A "traffic light" approach similar to this is already being used in some regions. While such indicators are intended to provide information on true changes in stock productivity and abundance, all indictors have some degree of measurement noise, so this approach should be applied cautiously. Note that timely assembly of indicators requires data preparation, staff analysis, and report writing that will compete with stock assessment program's capability to complete other assessment activities. Nevertheless, good indicators can focus assessment efforts on stocks that are most in need of updating. Scores for this factor should be assigned as follows, with intermediate scores permissible:

- 0 points = new data are basically as expected from previous assessment forecasts
- 3 points = new data indicate that the stock is moderately deviating from past projections
- 5 points = new data indicate that the stock is strongly deviating from past projections

For data-limited/unassessed stocks, possible indicators of changes in status should be monitored. However, the existence of a relevant indicator means that an assessment is probably possible.

New Type of Information: Another type of new information is of a more fundamental nature (e.g. a new type of survey or new biological research result such as a change in estimate of natural mortality). Such new information may help resolve uncertainties or issues identified in previous assessment efforts or to upgrade a stock's assessment towards its target level. For previously unassessed stocks, this means that data are now available for a first time assessment. Scores for this factor range between 0 and 5, with any

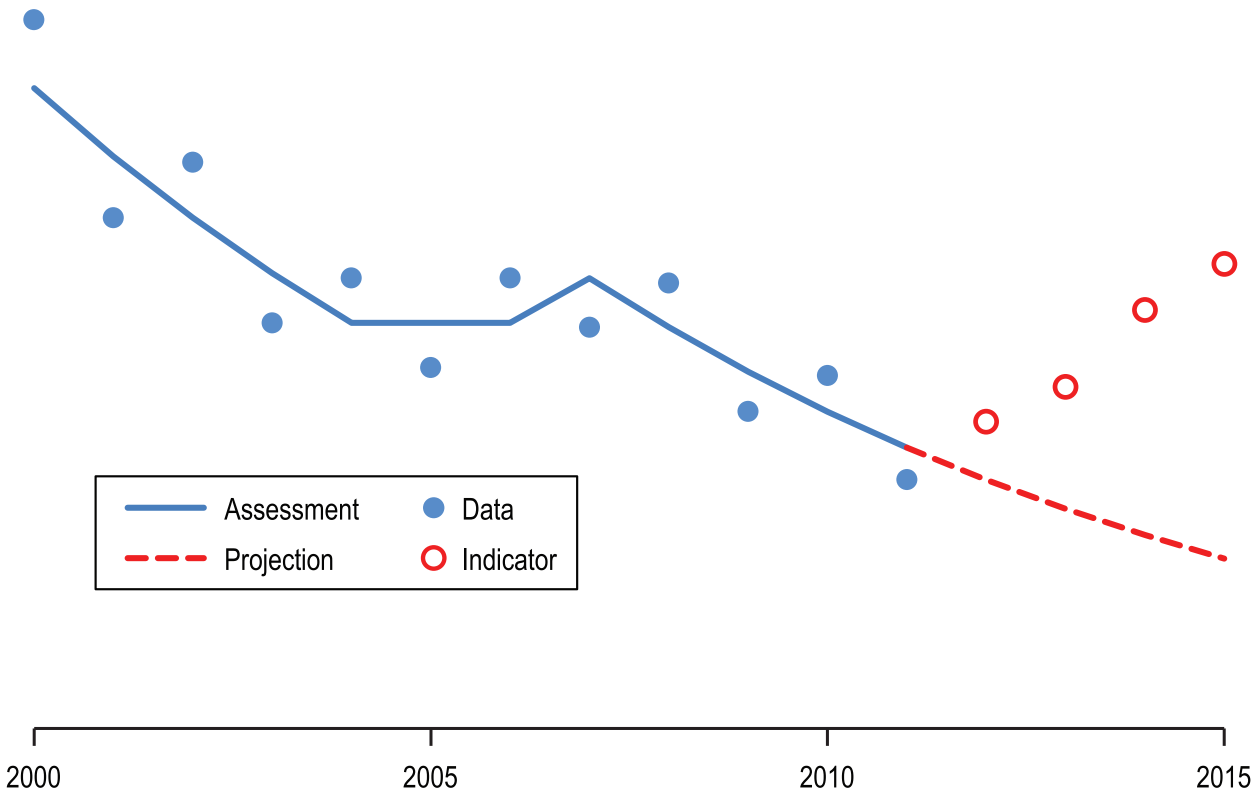

Figure 4. Example of an unexpected change in indicator data from assessment projections. Such a deviation could highlight an increased need for an updated stock assessment.

intermediate score judged appropriate by regional experts acceptable.

- 0 points = no significant new types of information are available
- 3 points = new information is available that could have a modest impact on the assessment
- 5 points = newly available information is expected to have a major impact on the assessment

When new information is available, a benchmark effort can be recommended to account for it in the assessment. However, regional experts should be cautious about assigning scores of “5” too liberally. All assessments have some number of factors, such as natural mortality and form of the fishery selectivity, for which the information has uncertainty that is not easily resolved. It is not useful to simply redo the assessment to re-examine these issues again unless it is expected ahead of time that the new information will help resolve the issue. Otherwise, the assessment effort is better directed to other stocks.

Most data-limited stocks will start with a score of “0” for this factor because data is not available to support an assessment. As data to conduct a first-time assessment does become available for stocks, scores for those stocks will increase for this factor.

Years Assessment Overdue: This factor measures how many years (if any) an assessment of a stock is overdue relative to the stock’s target assessment frequency (once established). Scores are based on the date of last assessment data entered in SIS and regionally-developed target assessment frequencies (additional details on page 21). For previously unassessed stocks, the number of years an assessment is overdue should be set at a moderate level (e.g. “5”) initially upon implementation of prioritization. This number will then increase incrementally on an annual basis until some level of assessment is completed for the stock, allowing less important stocks to cycle into the upper tier of priority.

Table 2. Summary of the 14 factors included in the stock assessment prioritization process, including scoring range, how scores are assigned, and use in prioritization activities. It is not necessary for the full scoring range to be used for each factor. Details on the final two factors listed here (Mean Age, Stock Variability) are provided in the section on Target Assessment Frequency on page 21.

Factor	Scoring Range	Scoring Based On	Target Assessment Frequency	Determine Annual Priorities
Commercial Fishery Importance	0 to 5	National catch and value databases; calculated as $\log_{10}(1 + \text{landed catch value})$	X	X
Recreational Fishery Importance	0 to 5	Regional recreational fisheries expert opinion	X	X
Importance to Subsistence	0 to 5	Regional fisheries expert opinion	X	X
Rebuilding Status	0 or 1	National stock status database	X	X
Constituent Demand	0 to 5	Regional fisheries expert opinion	X	X
Non-Catch Value	0 to 5	Regional fisheries expert opinion	X	X
Relative Stock Abundance	1 to 5	Most recent spawning biomass and target/threshold levels, as available from SIS database		X
Relative Fishing Mortality	1 to 5	Most recent fishing mortality estimates and limit levels, as available from SIS database		X
Key Role in Ecosystem	1 to 5	Maximum of bottom-up and top-down components; assigned by regional fisheries expert opinion	X	X
Unexpected Changes in Stock Indicators	0 to 5	Regional fisheries expert opinion, where indicators are available		X
New Type of Information	0 to 5	Regional fisheries expert opinion		X
Years Assessment Overdue	0 to 10	Calculated as: year for setting priorities - year of last assessment - target assessment frequency + 1 year		X
Mean Age in Catch	value	Recent average of mean age; direct measurement or assessment estimates	X	
Stock Variability	-1 to +1	Coefficient of variation (CV) for recruitment from assessment estimates	X	

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Target Assessment Level

Additional types of input data allow for improved assessment calibration and improved understanding of the factors affecting stock changes. Establishing target assessment levels serves two important purposes:

1) As new data become available to move a stock up to its target level for a data type, priority for upgrading that stock's assessment to use these new data increases.
2) Investment decisions can be guided by the gap between current data availability and the data needed for a stock's target assessment level.

Some assessments simply use a sufficiently long time series of a fishery-dependent stock abundance indicator and catch data to calculate the degree to which changing levels of catch cause changes in the stock indicator. A more important stock may warrant requesting a more expensive fishery-independent stock abundance indicator, rather than a fishery-dependent indicator, to have more confidence in the standardization of the indicator over long time periods. For even more important stocks, age-based assessments can provide more direct indicators of the level of fishing mortality and an ability to account for natural fluctuations in stock productivity (recruitment). These assessments require addition of size and/or age data, which requires biological sampling of the fisheries and surveys, followed by laboratory processing to determine the ages of the sampled fish. Where time series are short and not informative about the impact of the fishery on the stock, addition of data collected using advanced sampling technologies can provide a directly calibrated measure of fish abundance. Where changes in fish stocks over time cannot be explained by fishery effects alone, addition of information about changing ecosystem/environmental/habitat factors may help resolve the impact of fisheries relative to other factors.

Advancements in data collection and modeled factors represent higher level assessments and should be reserved for specific situations. These include:

- Stocks with high ecosystem importance, to protect against harm to the ecosystem. Assessments backed by fishery-independent surveys and age-composition data are better able to investigate ecosystem interactions and work towards taking these interactions into account in the assessment.
- Stocks with high fishery importance, to more closely track abundance fluctuations. Models that use age data are more responsive to changing conditions and can have improved forecasts of upcoming changes in abundance and potential yield.
- Stocks that are sensitive to ecosystem/habitat/climate factors that create a high level of natural fluctuations, because age-structured assessments can better track and forecast such fluctuations. Higher-level assessments are also able to better incorporate available information from investigations into the causes of these fluctuations. Note that a stock's sensitivity to ecosystem factors is different from the Ecosystem Importance referenced in the above section on page 14.

Stocks with only moderate importance or that are less prone to fluctuations in abundance may not warrant the extra expense required to develop the targeted fishery-independent surveys and extensive biological sampling required to support higher level assessments. Additionally, stocks that are less common are more difficult (and thus more costly) to survey because they are less frequently encountered in samples and additional sampling stations may be required to attain adequate precision. Fortunately, many fishery-independent surveys are able to simultaneously collect data on a wide range of species regardless of their importance.

The assessment levels defined in the Stock Assessment Improvement Plan (SAIP; Mace et al. 2001) were described in terms of the type of model used. Separate factors were used to score the quality of the fishery-dependent biological data and the fishery-independent survey data. Since that time, evolution of assessment software has blurred these assessment model levels such that it now seems more important to focus on the types of data available than the model itself. For the purposes of prioritization, a system that relates directly to possible investment decisions is more pertinent. Higher levels of assessment modeling require more types of data and it is the acquisition of these data on an ongoing basis that constitutes much of the cost of more comprehensive and more completely calibrated assessments. The SAIP is currently being updated to include a revision of the categorization used to describe the level of data available for each stock. Once complete, this prioritization process will adapt to use these new data input level descriptions. While the SAIP is intended to be descriptive of the current state of data availability, the prioritization process will add consideration of whether this state is satisfactory or if improvements are needed.

Target Assessment Frequency

The Target Assessment Frequency defines the expected interval between updates to the stock's assessment. The interval between assessments specifies how closely an assessment is able to track fluctuations in stock abundance and forecast corresponding changes in the stock's annual catch limit (ACL). More frequent assessment updates require more frequent updates to the data that supports assessments, in some cases requiring data to be collected and processed rapidly to enable a quick turnaround from data collection to management advice. Stock biology (mean age and stock variability) is important for determining the target assessment frequency because it sets the scale for how much the stock abundance, and hence its ACL, is expected to change between assessments. Fast changing stocks need more frequent assessments, while those stock that are more stable over time may require less frequent updates (for example, see Figure 5). Target assessment frequencies are bounded by 1 year on the lower end for annual assessments, and by a proposed cap of 10 years on the upper end.

Four components are used in calculating the Target Assessment Frequency:

1. Mean Age in Catch (or proxy) – The age structure of a stock means that total stock abundance tends to average out recruitment fluctuations and thus provides inertia to change. When adult mortality is high, the occurrence of older age groups is diminished, lessening this inertia to change. The mean age of fish in the catch is a measure of the inertia. It should be measured as an average over several years to smooth out the effect of recruitment fluctuations. In cases where it is not directly measured, it can be calculated in the assessment model from total mortality (*Z*) and selectivity. Where mean age in the catch is not directly measured or estimated by the assessment model, it can be approximated as ***1/Z + 0.5 + (3 - 2*Z).*** This preliminary equation is based on an approximate calibration for 25 stocks from the Northeast and Mid-Atlantic (Figure 6); the formula will be updated as data becomes available for additional stocks, and regional- or even fishery-specific formulas may be required. Here, the term *(3 - 2*Z)* is an adjustment for selectivity based on the premise that high *Z* stocks tend to get selected at a younger age. In some cases, a further approximation may need to use *2*M* (natural mortality) as a proxy for *Z*. Mean age in the catch is not required for data-limited/unassessed stocks until after estimates are available from a first-time assessment.

2. Stock Variability – This factor accounts for phenomenon that cause changes in ACLs relative to previous ACL forecasts. These changes are principally due to variability in the annual recruitment of young fish, but can also result from changes in growth, natural mortality, and fishing mortality (if last year's catch deviated much from last year's expected catch). In some cases these factors may not be readily measurable, but variability is expected because of known fluctuations in ocean conditions that influence such changes. Annual fluctuations in recruitment of young fish into a stock are an important driver of changes in stock abundance, but forecasting these fluctuations is infeasible in most situations. This "recruitment variability" has a coefficient of variation (CV) often near 60%, and can be greater than 100% for some stocks. Stocks will also fluctuate over time when there are changes in adult natural mortality and/or growth. Estimates of recruitment variability are not required for data-limited/unassessed stocks until after they are available from a first-time assessment. Scores for recruitment variability should be assigned as follows: +1

Calculating Target Assessment Frequency

- Begin with **Mean Age in Catch** (or proxy)
- Multiply by regional scaling factor (default = 0.5)
- Adjust for **Recruitment Variability**:
  - -1 year: Recruitment CV > 0.9
  - +1 year: Recruitment CV < 0.3
- Adjust for **Fishery Importance**
  - -1 year: Stock in top 33% of regional Fishery Importance
  - +1 year: Stock in bottom 33% of regional Fishery Importance
- Adjust for **Ecosystem Importance**
  - -1 year: Stock in top 33% of Ecosystem Importance
  - +1 year: Stock in bottom 33% of Ecosystem Importance
- Results will be between 1 and a maximum of 10 years

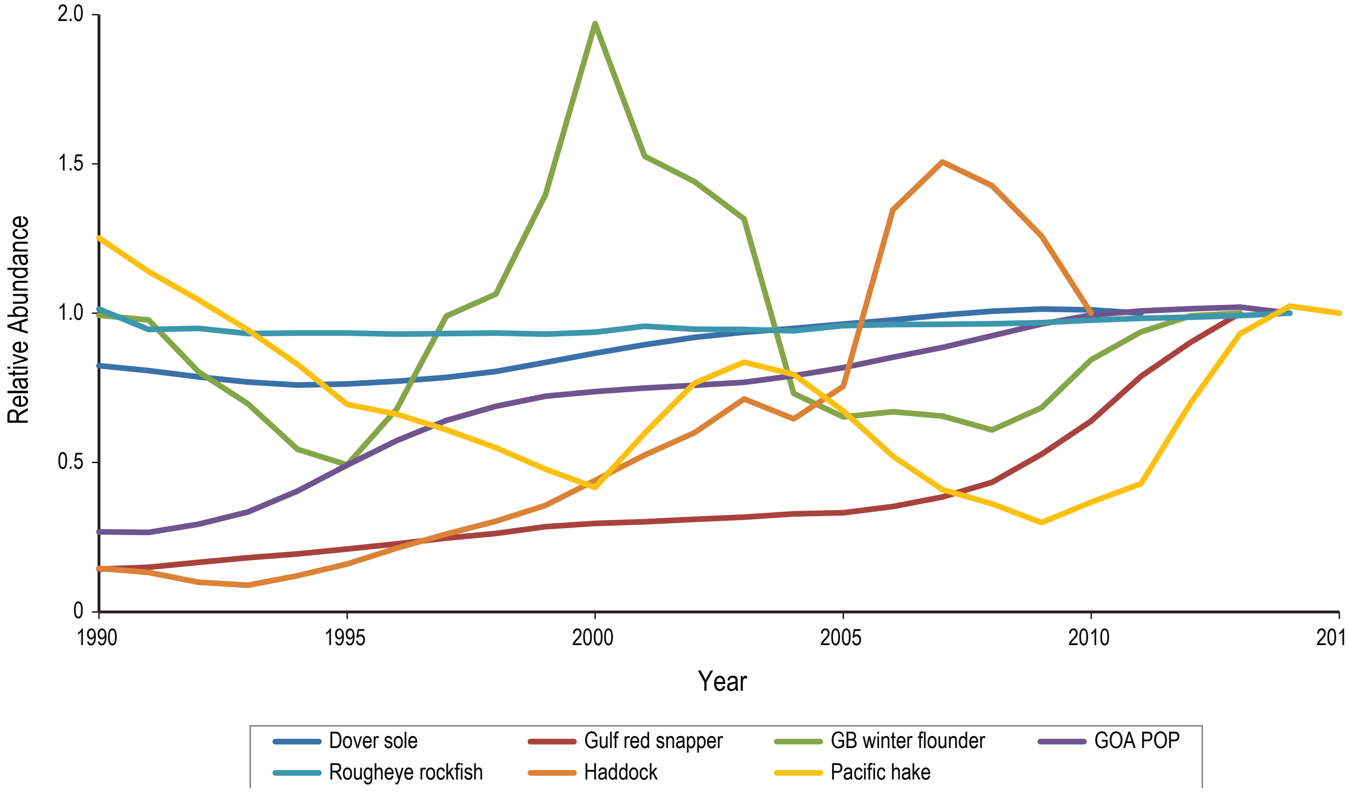

Figure 5. Relative stock abundance of selected representative stocks over the past 25 years, showing the range in variation over time exhibited by managed U.S. stocks.

point for low recruitment variability (CV < 0.3; do assessments less frequently); 0 points for moderate recruitment variability (0.3 < CV < 0.9); -1 point for high recruitment variability (CV > 0.9; do assessments more often).

3. Fishery Importance category – The weighted sum of all six of the factors included in the Fishery Importance category (e.g. Commercial Fishery Importance, Recreational Fishery Importance, Importance to Subsistence, Rebuilding Status, Constituent Demand, and Non-Catch Value) is included in the calculation of target assessment frequency so more important stocks are assessed more frequently. Subtract 1 from mean age for stocks in the top third of regional fishery importance (i.e. do assessments more frequently) and add 1 (i.e. do assessments less frequently) for stocks in the bottom third.

4. Key Role in Ecosystem – This factor is treated similarly to the Fishery Importance category so that the upper third of stocks important to the ecosystem are assessed more frequently, and the lower third less frequently.

To calculate the Target Assessment Frequency, the Mean Age in Catch is first multiplied by a regional scaling factor (e.g. 0.5). This scalar acts as a region-specific "dial" to allow each National Marine Fisheries Service (NMFS) Science Center to work with its management partners to adjust target frequencies to within a reasonable range of currently available regional assessment capacity.

It may seem logical to consider stock status in determining target assessment frequency because stocks approaching an overfished or overfishing condition need to be evaluated more frequently to enable ACL adjustments to prevent negative stock impacts. However, target assessment frequency is expected to be stable over time and stocks that are approaching status limits tend to be those that also have high fishery importance. It therefore is preferable to use fishery importance factors in setting the target assessment frequency. Stock

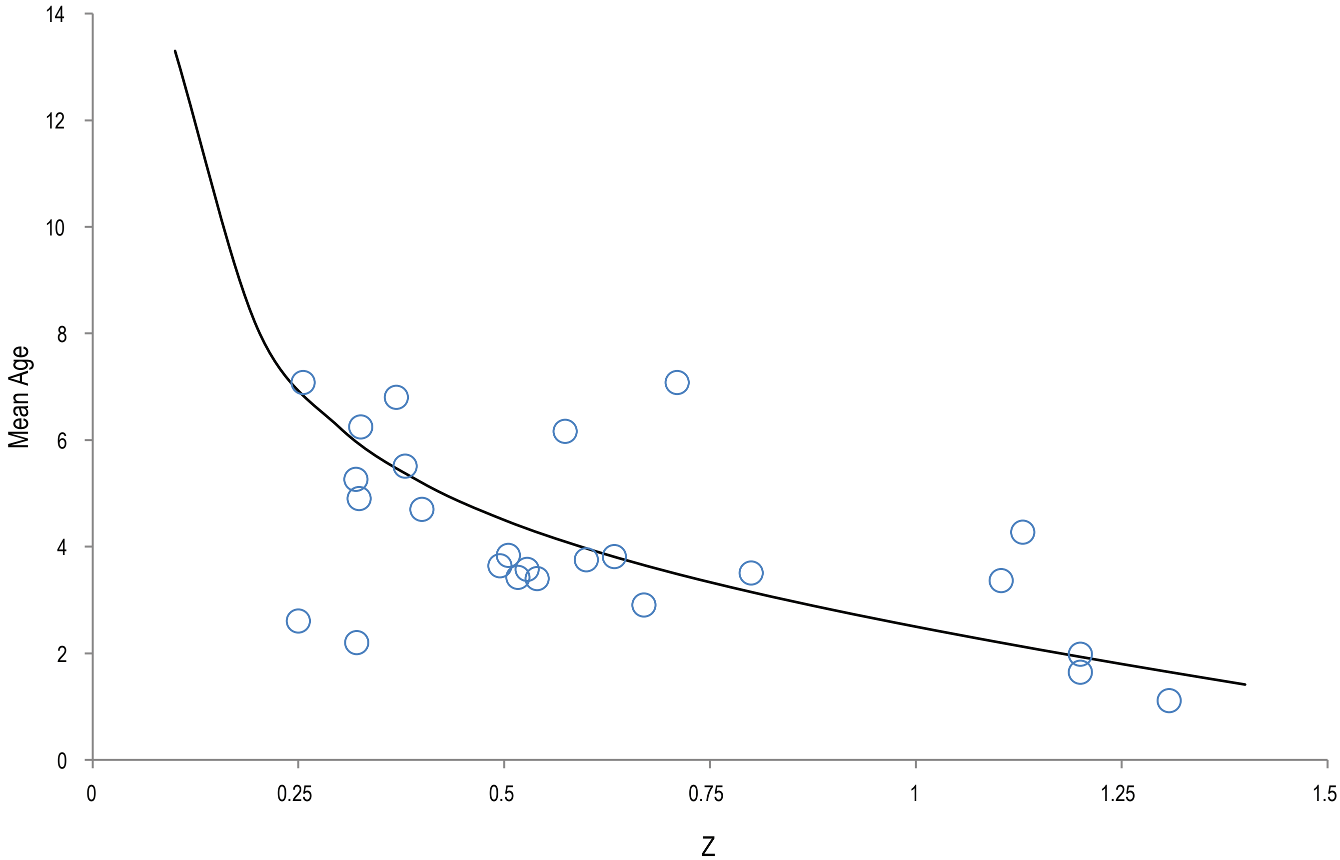

Figure 6. Preliminary calibration of the mean age formula based on data for 25 stocks from the Northeast and Mid-Atlantic in 2015.

status factors are included in determining the annual assessment priorities relative to the target assessment frequencies (more details on page 25).

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Determine Annual Priorities

Annual assessment priority ranks are based on how long an assessment for the stock is overdue, along with information on Fisheries Importance, Stock Status, Ecosystem Importance, and Assessment Information (Figure 7). Once target assessment frequencies are established, the goal is to keep as close to this schedule as possible given available resources. Conducting assessments more frequently is an inefficient use of assessment expertise and burdens the regulatory system with too frequent and unnecessary changes. Waiting too long to conduct updates means that management is based on increasingly stale information. With each passing year, there is a greater chance that the stock has drifted off the previous forecast and the fishery is being overly or insufficiently restricted. Thus, stocks increase in priority the longer they become overdue relative to their target frequency.

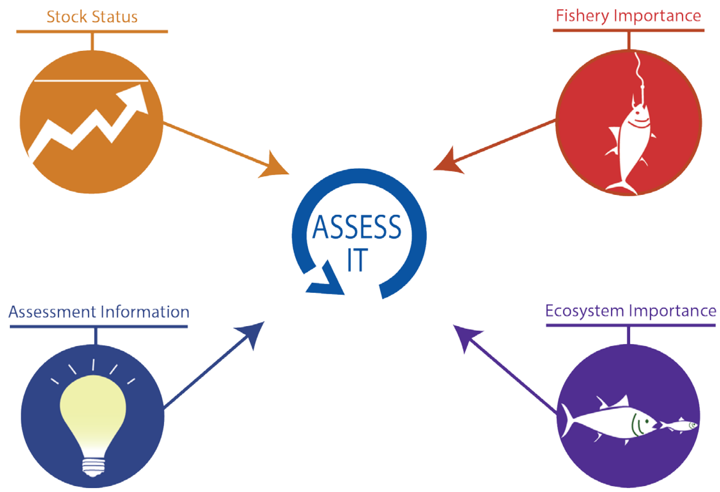

Figure 7. Factors contributing to annual assessment priorities.

In addition to the factor scores provided by regional fisheries experts, weights across each factor are used to calculate annual assessment priorities. Weights for individual factors are to be provided by a regional steering committee made up of managers involved in developing assessment priorities. The 12 factors used for determining annual priorities and an initial range of weights are listed in Table 3.

Regional weights provided by managers must sum to a total of 100%. The weight ranges included in Table 3 is preliminary; adjustments may be necessary after experience is gained. The default weights provided in Table 3 can be used as a starting point for managers to develop regional weights.

Table 3. The 12 factors used for determining annual assessment priorities, along with weight ranges and example weights for each factor. Factor weights will be provided by a steering committee of managers within each region. Note that the total for Commercial and Recreational combined is a maximum of 40, apportioned as applicable to regional fisheries.

Factor	Weight Range	Example Weights
Commercial Fishery Importance	0-40	15
Recreational Fishery Importance	0-40	15
Importance to Subsistence	0-20	4
Rebuilding Status	0-20	3
Constituent Demand	5-25	10
Non-Catch Value	0-20	3
Relative Stock Abundance	5-25	10
Relative Fishing Mortality	5-25	10
Key Role in Ecosystem	0-20	5
Unexpected Changes in Stock Indicators	5-25	5
New Type of Information	5-25	5
Years Assessment Overdue	10-30	15
TOTAL		*100*

To determine annual assessment priorities, each stock's score for each factor is divided by the maximum possible score for that factor. This produces relative factor scores, with a maximum possible value of 1.0 for each factor (note that the full scoring range does not need to be used for each factor, so some factors may not have any regional stocks scoring 1.0). Each relative factor score is then multiplied by the weighting factor provided by regional managers. Stock priorities are the sum across all 12 factors of the product of relative expert factor scores and manager weights. An example of these calculations is provided in Table 4.

Within this process, weights for the Commercial Fishery Importance and Recreational Fishery Importance factors deserve particular attention. Within each region, the maximum Commercial Fishery Importance score will be 5 and the assigned largest Recreational Fishery Importance score may not be at the maximum possible score of 5. The maximum scores for these two factors should be compared before assigning relative weights to the Commercial Fishery Importance and Recreational Fishery Importance factors.

Table 4. Example calculation of annual assessment priorities for five hypothetical stocks. Steps include 1) raw factor scores are provided by regional experts; 2) relative scores are developed by scaling to the maximum possible score for each factor; 3) average factor importance weights are developed with a steering committee of regional managers; and 4) priorities are calculated as the product of relative scores and average manager weights.

Step 1: Regional experts provide raw factor scores

Factor	Stock 1	Stock 2	Stock 3	Stock 4	Stock 5	Maximum Possible
Commercial Fishery Importance	2.2	0.1	0.1	1.5	0.5	5
Recreational Fishery Importance	0	4	0.1	3	1	5
Importance to Subsistence	0	0	2.5	0	0	5
Rebuilding Status	0	0	0	1	0	1
Constituent Demand	2	2	0	3	5	5
Non-Catch Value	0	0	2.5	0	0	5
Relative Stock Abundance	2	2	3	4	5	5
Relative Fishing Mortality	2	2	3	5	4	5
Key Role in Ecosystem	3.5	3	1.5	3	4	5
Unexpected Change in Stock Indicators	5	3	0	0	3	5
New Type of Data	0	0	3	5	2	5
Years Assessment Overdue	0	4	10	0	0	10

Step 2: Raw scores are converted to relative scores by dividing by the maximum possible score for each factor

Factor	Stock 1	Stock 2	Stock 3	Stock 4	Stock 5
Commercial Fishery Importance	0.4	0	0	0.3	0.1
Recreational Fishery Importance	0	0.8	0	0.6	0.2
Importance to Subsistence	0	0	0.5	0	0
Rebuilding Status	0	0	0	1	0
Constituent Demand	0.4	0.4	0	0.6	1
Non-Catch Value	0	0	0.5	0	0
Relative Stock Abundance	0.4	0.4	0.6	0.8	1
Relative Fishing Mortality	0.4	0.4	0.6	1	0.8
Key Role in Ecosystem	0.7	0.6	0.3	0.6	0.8
Unexpected Change in Stock Indicators	1	0.6	0	0	0.6
New Type of Data	0	0	0.6	1	0.4
Years Assessment Overdue	0	0.4	1	0	0

Table 4, continued.

Step 3: Develop average factor importance weights from regional manager input

Factor	Mgr 1	Mgr 2	Mgr 3	Mgr 4	Mgr 5	Average Mgr Weight
Commercial Fishery Importance	20	10	18	10	10	13.6
Recreational Fishery Importance	20	2	15	9	10	11.2
Importance to Subsistence	1	1	3	1	1	1.4
Rebuilding Status	1	0	5	8	2	3.2
Constituent Demand	10	5	15	8	10	9.6
Non-Catch Value	1	5	2	9	5	4.4
Relative Stock Abundance	12	20	10	9	7	11.6
Relative Fishing Mortality	12	20	10	9	7	11.6
Key Role in Ecosystem	3	10	2	9	1	5.0
Unexpected Change in Stock Indicators	5	5	5	9	19	8.6
New Type of Data	5	5	5	9	18	8.4
Years Assessment Overdue	10	17	10	10	10	11.4
Total Weight	***100***	***100***	***100***	***100***	***100***	

Step 4: Annual priorities calculated by summing the product of relative scores and average manager weights

Factor	Stock 1	Stock 2	Stock 3	Stock 4	Stock 5
Commercial Fishery Importance	6	0.1	0.1	4.1	1.4
Recreational Fishery Importance	0	9	0.2	6.7	2.2
Importance to Subsistence	0	0	0.7	0	0
Rebuilding Status	0	0	0	3.2	0
Constituent Demand	3.8	3.8	0	5.8	9.6
Non-Catch Value	0	0	2.2	0	0
Relative Stock Abundance	4.6	4.6	7	9.3	11.6
Relative Fishing Mortality	4.6	4.6	7	11.6	9.3
Key Role in Ecosystem	3.5	3	1.5	3	4
Unexpected Change in Stock Indicators	8.6	5.2	0	0	5.2
New Type of Data	0	0	5	8.4	3.4
Years Assessment Overdue	0	4.6	11.4	0	0
Assessment Priority	***31.2***	***34.9***	***35.1***	***52.0***	***46.6***

The prioritization factor that will change the most over time will be the Years Assessment Overdue factor, which increases by 1 year annually except for stocks that are assessed (which get reset to 0 years overdue). Unexpected Changes in Stock Indicators, if available, may also change from year to year but will require effort by assessment programs to keep updated for all stocks. Stock Status factors are also expected to change over time in response to the assessment updates. Additionally, Constituent Demand should be examined annually by regional experts to ensure priorities align with emerging regional needs.

The resulting set of assessment priorities is not the final step in determining which stocks are most in need of near-term assessment. Managers may first look to see if there is a cluster of higher priority assessments that all can be accomplished and then look to see which in a middle tier might be added. Even in the high priority group they may find some stocks for which data are not yet available, so assessment must be delayed. Managers may also want to look at alignment with the annual or multi-year cycle of management actions so that delivery of assessment results can align as well as possible. Another step could be to consider bundling assessments of stocks within multi-species fisheries to better align their management actions. Overall, the prioritization process will help drive short-to-medium term decisions, while immediate scheduling of assessments will still need wise attention from regional managers.

Challenges and Future Directions

This prioritization system is a first attempt at a comprehensive approach. The described framework will need adjustments as implementation moves forward, working with regional staff and partners to identify appropriate modifications. Nonetheless, the compilation and presentation of information as described in this document can immediately improve the basis upon which priorities for stock assessment are set.

One challenge will be to ward against a lopsided application of the system. The goal is somewhere in between a situation in which all stocks are perceived to need equally good assessments, and a situation in which only the most important stocks get assessed. All stocks need some level of baseline assessment and the most important and vulnerable stocks need better assessments. The prioritization system described here is designed to help achieve such a balance, but adjustments may be needed after a few years of implementation.

Some aspects of this prioritization approach may seem somewhat ad hoc, even though based on expert judgement. The International Council for Exploration of the Sea (ICES) investigation of factors affecting assessment frequency clearly indicated that only through a management strategy evaluation (MSE) can one ascertain the expected improved performance from better data and shorter time lags. This same situation is true for assessments and fishery management in the United States, and ideally MSEs will be conducted to determine the degree to which uncertainty in assessments increases as the interval between assessments increases. It is recommended that such evaluations occur on some example stocks in each region as part of implementation of this prioritization process.

One major area we will be working to improve upon is better incorporation of economic principles in the overall prioritization approach. Ideally, we would use maximizing net economic value to the nation as the determinant of priorities, including commercial, recreational, and other ecosystem service values. As a first step, we can incorporate economic values in MSEs to help inform the priority setting process, as well as develop a set of economic indicators that can serve as proxies when direct calculation of changes in net economic value is not obtainable due to data or other limitations.

Once we get a better understanding of the target frequency for assessments, the same logic can be extended to the best time frame for updating annual catch limits and other reference points. A good opportunity to introduce such changes could arise in the next few years if current proposed changes to the National Standard 1 Guidelines result in more flexible opportunities for specifying multi-year approaches to making overfishing determinations and to phasing-in new assessment results. The complete science-management system has more elements than the assessments themselves. There are potential bottlenecks associated with timing of peer reviews, time needed to develop management responses to updated assessments, alignment of assessments with start dates of fishing years, etc. These additional steps in the overall process also warrant consideration as overall improvements in throughput are sought.

The degree to which this prioritization system addresses the need for inclusion of ecosystem factors is preliminary. The National Marine Fisheries Service (NMFS) clearly recognizes the need for further ecosystem research to support more comprehensive stock assessments, but the focus here is on getting basic assessments done. Ongoing work on an update of the 2001 Stock Assessment Improvement Plan (SAIP) will provide additional guidance on how to determine which stocks are most in need of a broader ecosystem consideration. Future evolution of a prioritization process can include these more comprehensive, ecosystem-linked assessments as part of the balanced portfolio. All assessments should recognize that every fish stock exists within a regional ecosystem and the effect of ecosystem changes on the stock should always be considered to the extent feasible.

It is important to note that the prioritization system does not explicitly identify specific research or survey needs to support assessment. However, research needs are driven by assessment level, a closely-linked concept currently being further developed in the SAIP. The prioritization process will help to elucidate information gaps and research needs for individual stocks, and planned database enhancements to support the process will provide a repository to log such information. Through implementation of a nationally-standardized process, we will be able to better identify cross-cutting issues within and across regions to improve the overall assessment enterprise.

Application of this prioritization system may not get more assessments done each year. Prioritization does however give us a way to identify the needs that are beyond our current program capacity and identify efficiencies that may improve throughput. The overall goal is to be more objective about which assessments get done under existing resource constraints. It is likely that some stocks will be identified as needing better assessments than present data allow, and some stocks for which more frequent assessments are needed. We also expect to see situations in which assessments and management adjustments are occurring more frequently than is necessary, and situations in which there has been over-reliance on extensive benchmark assessments that require great resources to conduct but may only provide limited benefits unless there is fundamentally new information or methods to introduce. Slowing down on both of these fronts will free up assessment resources to conduct more comprehensive assessments and to update more assessments where needed.

The prioritization process can clearly highlight gaps, and being able to communicate needs identified through a transparent, data-based process may be useful as an argument to gain resources. Ultimately though, filling these needs will require an expanded assessment program and increased resources.

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