The SocioEconomic Aspects in Stock Assessments Workshop (SEASAW) Report

Recommendations for Increasing Assessment Accuracy and Improving Management Advice

Andrea N. Chan, Alan C. Haynie, Patrick Lynch, Skyler Sagarese, Kalei Shotwell, Lisa Pfeiffer, Scott Crosson, Melissa Krigbaum, Doug Lipton, Jeffrey Vieser, Aaron Mamula, John Walter, Richard Methot, Kristan Blackhart, Marysia Szymkowiak, Emily Markowitz, Stephanie Oakes, Michael Downs, Howard Townsend, T. Todd Jones, Diana Stram, Matthew McPherson

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Main photo: Theresa Peterson and her family haul in a catch of salmon off Kodiak, Alaska. Photo credit: Charlie Peterson.

Bottom center photo: Dungeness crabs caught by a California fisherman. (Credit: Benjamin Drummond, bdsjs.com)

Bottom right photo: NMFS/SERO IFQ Program. Does not represent NMFS endorsement of the Gulf Wild program.

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Executive Summary

Fisheries are coupled social-ecological systems, and as such, fish population interactions with social systems must be characterized if the system is to be successfully managed. In NOAA Fisheries and beyond, there is a need for better integration between social science and population dynamics research programs in support of fisheries stock assessments – which will require more cross-disciplinary collaboration and stakeholder engagement. NOAA Fisheries has a robust socioeconomic research community that can engage in studies to improve interpretations and considerations of economic, management, and social aspects of the marine environment that relate to the sustainability of different stocks.

Fisheries management measures are designed to sustain population levels of fish stocks while providing optimum yield from fisheries, protecting the marine ecosystem, and achieving other economic and social goals (MSFCMA, 16 U.S.C. §§ 1801 *et seq*). The success of these measures depends on the ability of the managing agency to understand, measure, and predict human behavior. Changes to regulations impact the fishers directly and the fish stocks indirectly, and can complicate development and interpretation of data inputs to stock assessments. To provide the best available science, economics and other social sciences must be included in the management of our living marine resources.

Events such as heat waves, harmful algal blooms, and disease outbreaks are increasing in frequency and intensity. While these disturbances can lead to dramatic changes in physical environments and biological communities, they also directly impact human systems. There are a number of linkages between human and natural resource processes that can influence the sustainability of the social-ecological fisheries system, depending on the direction of changes in external factors over time. Climate change is impacting fish species in a variety of ways including shifting their spatial distributions, which in turn will affect fishers' choices about where and when to fish. With ongoing and increasingly frequent disturbances to fisheries social-ecological systems, fisheries management needs to be more adaptive.

The objectives of the SocioEconomic Aspects in Stock Assessments Workshop (SEASAW) initiative were to gain an understanding of current practices for incorporating socioeconomic information within the stock assessment process, to bring together regional experts to discuss how to better coordinate research and management, and to provide recommendations for future actions. A survey was conducted in advance of the workshop with specific goals to obtain high-level regional information on:

- How economists and other social scientists are involved in the stock assessment process.
- What socioeconomic methods and data are most useful for improving stock assessments and the resulting management advice.
- Relevant socioeconomic data and knowledge gaps.

The specific goals of the workshop were to:

- Foster collaboration between stock assessment scientists, economists, and other social scientists.
- Discuss ways to improve stock assessment accuracy by better utilizing socioeconomic data and methods.

- Develop recommendations for when and how to incorporate socioeconomic information in the fisheries stock assessment and fishery performance evaluation process.

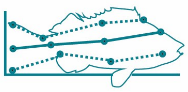
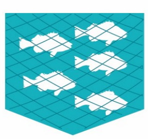
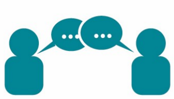
This document provides summaries of responses from the survey of current practices, workshop discussions and presentations, and recommendations for improving the stock assessment process by further utilizing socioeconomic information. The recommendations build upon the important concepts identified from the survey, workshop, and the academic and technical literature.

The SEASAW initiative was motivated by previously published strategic guidance, and supported by different laws and policies. Notably, NOAA Fisheries' strategic plan for stock assessments, Implementing a Next Generation Stock Assessment Enterprise (Lynch et al., 2018) – also known as the Stock Assessment Improvement Plan (SAIP) – provides strategic guidance for NOAA Fisheries' population assessment programs and emphasizes the need to make stock assessments more holistic, in part by incorporating more socioeconomic data and methods. For the purposes of this technical report, we define the stock assessment process to include data collection, data processing, stock assessment models, projections, harvest control rules, and the delivery of scientific advice. Detailed background information on the NOAA Fisheries stock assessment process can be found in the SAIP.

The SEASAW was held in-person prior to COVID-19 restrictions in New Orleans, LA from February 11-13, 2020. The workshop had 36 participants including stock assessment scientists and economists from all NOAA Fisheries science centers and headquarters as well as other (non-economist) social scientists, academics (with expertise in social sciences, economics, and stock assessments), and fishery management council staff. The workshop agenda included presentations on socioeconomic connections in stock assessments and management strategy evaluations, including a broad range of themes and diverse fisheries from across the country. Survey responses were summarized and presented at the workshop. Specific case study presentations from different regions demonstrated novel socioeconomic data and methods integration, and broader discussions between workshop participants facilitated the development of workshop recommendations and future research directions.

In this document, we present recommendations for incorporating socioeconomic data and methods into each step of the stock assessment process. A summary of these recommendations are included in the table below (Table ES1).

Table ES1: *Abbreviated list of recommendations for using socioeconomic information in the stock assessment process, separated by different steps of the process. Note that the process is not linear; see Figure 1. The full text recommendations are in* [*Table 2*](#)*.*

	**Data Collection**	1. Data collection could be augmented by gathering additional socioeconomic data. 1.1 Biologists and social scientists should jointly design and implement interview protocols (e.g., skipper surveys) to obtain local ecological knowledge (LEK). 1.2 More effort should be made to study human behaviors related to misreported catch, discards, and landings in the stock assessment process. 1.3 Cost information should be collected in regions where data are lacking. 1.4 Socioeconomic information should be used to help interpret historical patterns of fishing activity. 1.5 Social science information should be collected at the appropriate frequency and resolution for use in the stock assessment process.
	**Data Processing**	2. Processing stock assessment data inputs can be improved by using more socioeconomic data and methods. 2.1 Social scientists should be more involved in the refinement of fishery-dependent data streams to capture potential impacts of economic, social, and management changes. 2.2 Appropriate socioeconomic information should be collected and used to standardize CPUE time series that are included in stock assessments. 2.3 Economic approaches can be used to combine fisheries dependent data with fisheries independent survey data to enhance spatial and temporal resolution of stock abundance estimates.
	**Stock Assessment Models**	3. Better characterizations of changing fishing practices over time will enable improved parameterization of stock assessment model components. 3.1 Economists and other social scientists can inform the selection of priors for trends in catchability. 3.2 Time-varying selectivity should be integrated in assessment models where appropriate. 3.3 Economic data from catch share programs should be more effectively integrated into stock assessments. 3.4 Coupling stock assessment models with bioeconomic models should be explored further.
	**Projections**	4. Economists and other social scientists can help improve projection accuracy by integrating socioeconomic data and models into stock assessment projections. 4.1 Stock assessment projections can be improved by addressing socioeconomic assumptions. 4.2 Projections should be conducted by interdisciplinary teams of stock assessment modelers, ecosystem modelers, economists, and other social scientists. 4.3 Multispecies projections should be developed that incorporate interactions between species, market demands, and fisher choices. 4.4 Potential socioeconomic impacts of alternative projection scenarios should be provided to support management decision-making.
	**Harvest Control Rules**	5. Socioeconomic information should be included in the evaluation of harvest control rules (HCRs). 5.1 Changing management regulations necessitate revisiting control rule calculations in collaboration with economists and other social scientists. 5.2 When appropriate, socioeconomic metrics should help inform each Council's determination of the acceptable risk of overfishing (P*). 5.3 HCRs for transboundary stocks should be developed with connected nations and economists. 5.4 Socioeconomic triggers for the review of HCRs should be established. 5.5 Socioeconomic information and analyses should be included in Management Strategy Evaluations (MSEs) when evaluating alternative HCRs. 5.6 Allocation reviews should be conducted more frequently, when appropriate. 5.7 Efforts to define and prioritize social objectives should be supported.
	**Communication with Managers and Stakeholders**	6. Stock assessment scientists, economists, and other social scientists should work together to communicate socioeconomic indicator trends. 6.1 Relationships between potential socioeconomic indicators and stock dynamics should be explored. 6.2 Stock assessment scientists, economists, and other social scientists should work with managers to determine the best ways to communicate scientific advice. 6.3 Methodologically sound socioeconomic data and trends should be used to inform interpretations of advice, uncertainties, and risks. 6.4 Interdisciplinary teams should collaborate to create system-level products to improve communication of socioeconomic indicator trends to managers and stakeholders.

By combining results from a survey of the NOAA Fisheries science centers; discussions from a national workshop attended by economists, other social scientists, and biologists from all regions of the United States; and lessons learned from case studies in the literature, this report describes a diversity of socioeconomic methods and data that can be used to improve the stock assessment process. One important recommendation is to better engage with the fishing community with support from economists and other social scientists (Figure ES1). Guided discussions with fishers on a range of topics – including stock biology, data quality, and defining social and economic objectives – could help fill data gaps and improve both assessments and subsequent management advice. This workshop provided a valuable opportunity for stock assessment scientists, economists, and other social scientists to interact and discuss activities in different disciplines and regions. The need for enhanced and ongoing coordination and interaction among disciplines within and across regions was made clear. More effective sharing of knowledge and tools will minimize potential duplicated efforts and substantially increase the pace of progress. Ongoing collaboration can make socioeconomic input more consistent across assessments and help NOAA Fisheries better achieve its mission to provide sound scientific advice in support of an ecosystem-based approach to management.

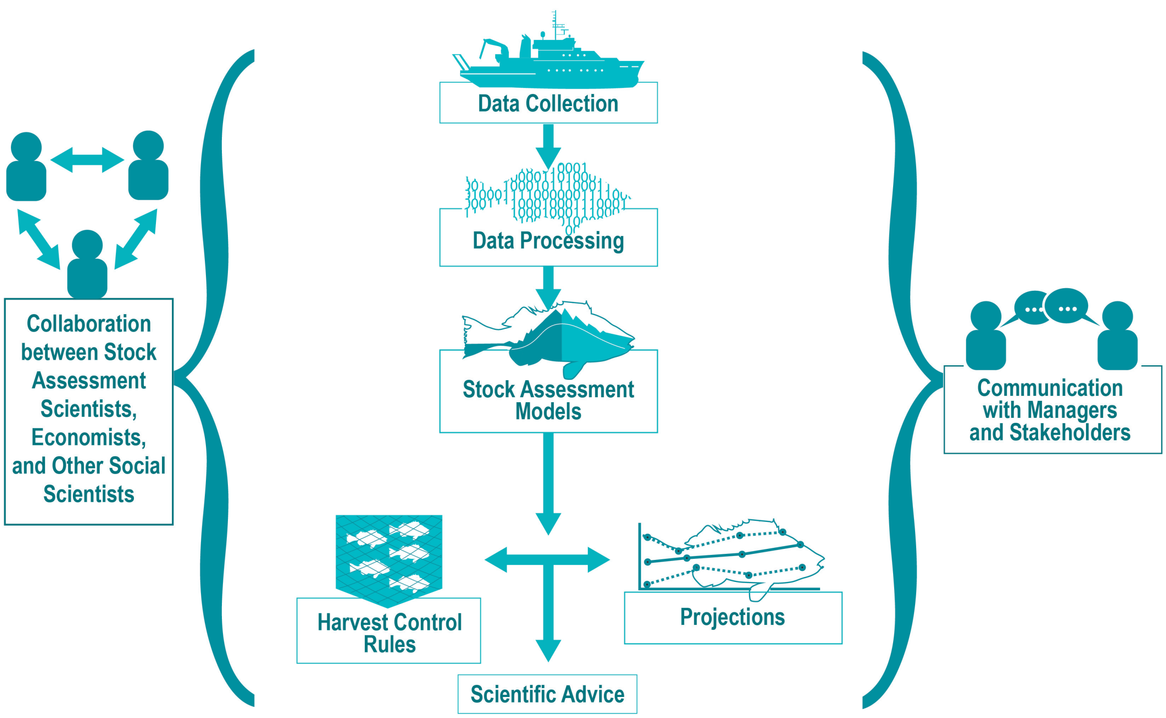


Figure ES1: *The recommended future fisheries stock assessment and fishery evaluation process, with economists and other social scientists fully integrated in each step of the process alongside stock assessment scientists.*

Introduction

Fisheries are coupled social-ecological systems (SES) where humans are the most prominent actors in the ecosystem (Ommer et al., 2011, Leslie et al. 2015), and as such, fish population interactions with social systems must be characterized if the system is to be successfully managed. Improving the stock assessment process (Box 1) by better accounting for linkages between social and ecological systems in both the historic and forecast periods will enhance how assessment programs respond to current and future challenges. In NOAA Fisheries and beyond, there is a need for better integration between social science and population dynamics research programs in support of fisheries stock assessments – which will require more cross-disciplinary collaboration and stakeholder engagement. NOAA Fisheries has a robust socioeconomic research community that can engage in studies to improve interpretations and considerations of economic, management, and social aspects that relate to the sustainability or decline of different stocks. The survey of NOAA Fisheries science centers described in this report provides insight into the diversity of work currently underway and key gaps across regions.

Box 1: The Stock Assessment Process

For the purposes of this technical report, we define the stock assessment process to include data collection, data processing, stock assessment models, projections, harvest control rules (including using Management Strategy Evaluation to choose between alternative control rules), and the delivery of scientific advice (Figure 1). At each of these phases of the process, communication with managers and stakeholders is crucial to successful fisheries management. Detailed background information on the NOAA Fisheries stock assessment process can be found in the SAIP (Lynch et al., 2018), and is briefly summarized here. The data collection portion of the process includes the collection of both fishery-independent data via standardized scientific surveys, the integration of satellite data and other environmental observations and model outputs, and fishery-dependent data which include the levels of catch, effort, and discards as well as additional biological information about the landed and discarded fish. Processing data for input into stock assessment models involves expanding data series to unsampled areas/fleets (e.g., when estimating discards) and calculating indices, such as an abundance index from catch per unit effort (CPUE) data. Different types of stock assessment models can be used to support stock status determinations (for example, whether or not overfishing is occurring) depending on how much data are available for the stock. These models are also used to project future fish stock dynamics in the near-term, including abundance and catch. These model outputs are translated using harvest control rules (HCRs) to determine recommended catch levels, which are communicated to the appropriate management bodies. Delivering scientific advice often involves presenting recommendations and supporting information for catch limits to the Scientific and Statistical Committees (SSCs) of the regional fishery management councils for peer review, and then to the councils themselves for the final catch specifications.

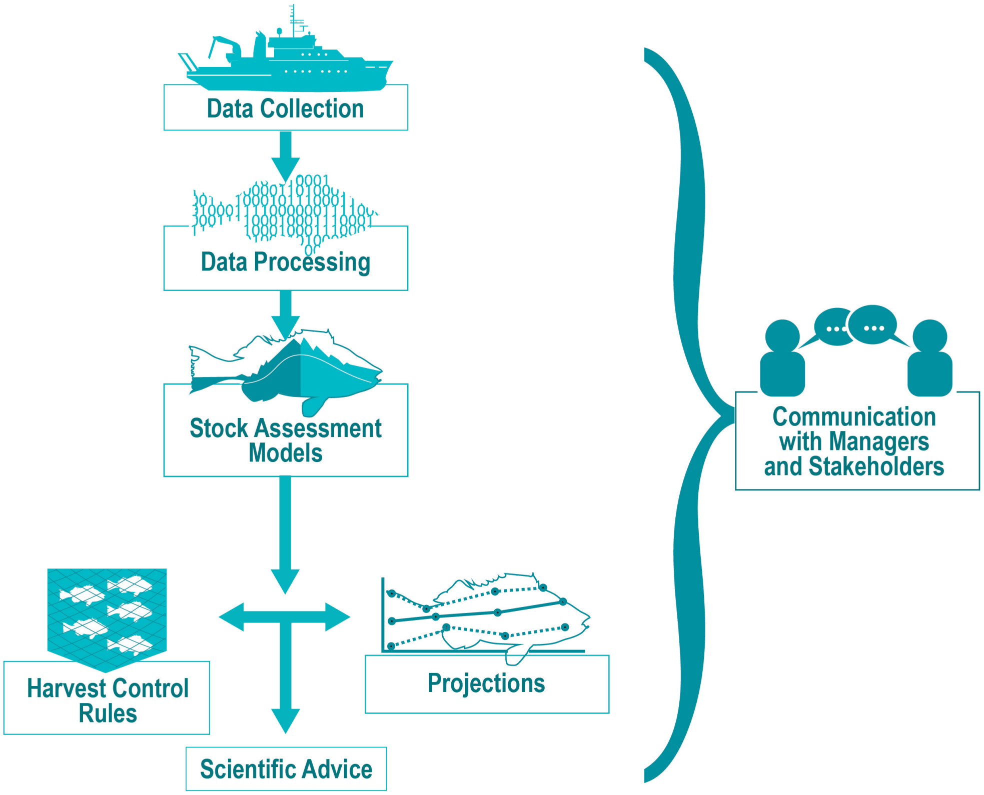


Figure 1: *Overview of the different steps of the fisheries stock assessment process.*

Fisheries management measures are designed to sustain population levels of fish stocks while providing optimum yield from fisheries (Box 2), protecting the marine ecosystem, and achieving other economic and social goals (MSFCMA, 16 U.S.C. §§ 1801 *et seq*). The success of these measures depends on the ability of the managing agency to understand, measure, and predict human behavior. Changes to regulations impact the fishers directly and the fish stocks indirectly, and can complicate development and interpretation of inputs required for stock assessments (e.g., fishery-dependent indices of abundance from catch per unit effort data). Assuming that the functional relationships among fish abundance, prices, costs, and fishing effort are static over space and time occurs frequently and oversimplifies the dynamics of fisheries. As the stock assessment models used in fisheries management move towards incorporating increasingly complex spatial information, the dynamics of fishing location choices of fishers become increasingly relevant for providing information about differences in stock characteristics across space. For this and many reasons discussed in this report, economics and other social sciences must be included to provide the best available science for the management of our living marine resources[1].

[1] NOAA Fisheries has researchers with backgrounds in both economics and other social science disciplines. While they are all social scientists who conduct "human dimensions" research, it has proven at times to be a semantic and identity challenge to speak about the social scientists who are not economists as a group. NOAA will often refer to social scientists as the group that does not include economists, but the language used is not entirely consistent. We try here to be clear whether we are including economists when we refer to social scientists.

Box 2: Description of Different Yield Objectives

In the United States, the Magnuson-Stevens Fishery Conservation and Management Act (MSA) establishes the maximum sustainable yield (MSY) as the limit for optimum yield (OY) from sustainable fisheries (16 U.S.C. §§ 1801 *et seq*.). The MSY is defined as the largest long-term average yield that can be removed from a fish stock, given the current natural and fishery conditions. Economics can enter the MSY calculation through changes in fleet allocation and fishery selectivity, both of which are socioeconomic in nature. While MSY is a long-term average, in practice, a control rule is used to adjust the annual limit to track the fluctuating stocks. The Annual Catch Limit (ACL) has a precautionary buffer to avoid overfishing. Under National Standard 1 (NS1) of the MSA, fisheries should be managed to achieve the OY from each managed fishery, defined as, "…the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor…" (50 CFR §600.310). Management decisions thus impact the OY.

The maximum economic yield (MEY) is the level at which the net economic returns (e.g., profits) are maximized, and is used as a management objective for fisheries in other countries, such as Australia (Commonwealth Fisheries Harvest Strategy Policy, 2018). While MEY provides a valuable framework for a management reference point, it can be challenging to implement (Dichmont et al., 2010), particularly in fisheries with often competing management objectives, such as mixed recreational and commercial fisheries. For example, stakeholder net benefits or utility is particularly hard to measure and define in the context of recreational fisheries and non-consumptive activities (e.g., SCUBA diving). Additional data on costs of fishery operations would be required for implementing MEY in U.S. fisheries, including single-species fisheries. Implementing MEY in Australia has required substantial collaboration and agreement among scientists, economists, managers, and members of industry to collect the needed data series, develop appropriate model specifications, and establish limitations on acceptable outcomes (Dichmont et al., 2010).

We are in a period of rapid global change, where environmental disturbances such as heat waves, harmful algal blooms, and disease outbreaks are increasing in frequency and intensity (e.g., USGCRP 2018, IPCC 2021). While these disturbances can lead to drastic changes in physical environments and biological communities, they also directly impact human systems. The stock assessment process increasingly explores and attempts to account for the dependence of the observed variability in stock abundance on the vulnerability of the species to changing environmental variables. For example, in the stock assessment for Gulf of Alaska Pacific cod, bottom temperature indices were used to delineate periods with increased winter heat wave activity. The natural mortality of the stock was allowed to vary from standard values during these heat wave periods (Barbeaux et al., 2019). However, the impacts of fluctuating environmental conditions are amplified by the interactions between species (Ives et al., 1999), which include biological and economic interactions in SES. These interactions, in turn, contribute to the observed trends in individual stock abundances. For instance, when the available markets for fisheries products change suddenly, fisher incentives to target different species will also change – and understanding the interactions between market forces, fisher incentives, and resulting species-specific catch is crucial.

There are a number of linkages between human and natural resource processes that can influence the sustainability of the fisheries SES, depending on the direction of changes in external factors over time (Haynie & Pfeiffer, 2012). Climate change is already impacting fish species by shifting their spatial distributions, which in turn will affect fishers' choices about where and when to fish (i.e., the spatial distribution of fishing effort). Changes in fisher behavior will subsequently impact the spatiotemporal abundance and distribution of the target species. Another timely example of a changing external factor is the change in markets for higher priced fresh seafood products following restaurant shutdowns during the COVID-19 pandemic (White et al., 2021). In response to this change in demand, fishers may have responded by switching target species, switching fishing gears, and/or reducing their fishing effort. With ongoing and increasingly frequent disturbances to fisheries SES, fisheries management must become more adaptive.

As ongoing global environmental change alters the state of fisheries SES and increases scientific and management uncertainty, stewardship of natural resource populations will be challenged in a variety of ways that will require complex solutions involving multidisciplinary approaches. Alongside better characterizing and incorporating interactions between human and natural systems, stock assessment science can benefit from better promoting collaborative governance through increased stakeholder participation at all steps of the process (Bodin, 2017). The purpose of this document is to provide recommended practices for achieving these goals within the stock assessment enterprise of NOAA Fisheries to improve the social-ecological resilience of our managed fisheries (Ojea et al., 2017).

The objectives of the SocioEconomic Aspects in Stock Assessments Workshop (SEASAW) initiative were to 1) survey the different regions to gain an understanding of current practices for incorporating socioeconomic information within the stock assessment process, 2) bring together regional experts to discuss how to improve current practices, and 3) provide recommendations for future improvements through collaboration between the socioeconomic and stock assessment communities. The specific goals of the survey and national workshop are shown in Figure 2. The purpose of this technical guidance document is to summarize the NOAA Fisheries Science Center responses from the survey of current practices, summarize discussions and provide abstracts from presentations at the SEASAW, and present recommendations for improving the stock assessment process by further utilizing socioeconomic information – building upon the important concepts identified from the survey, workshop, and the academic and technical literature.

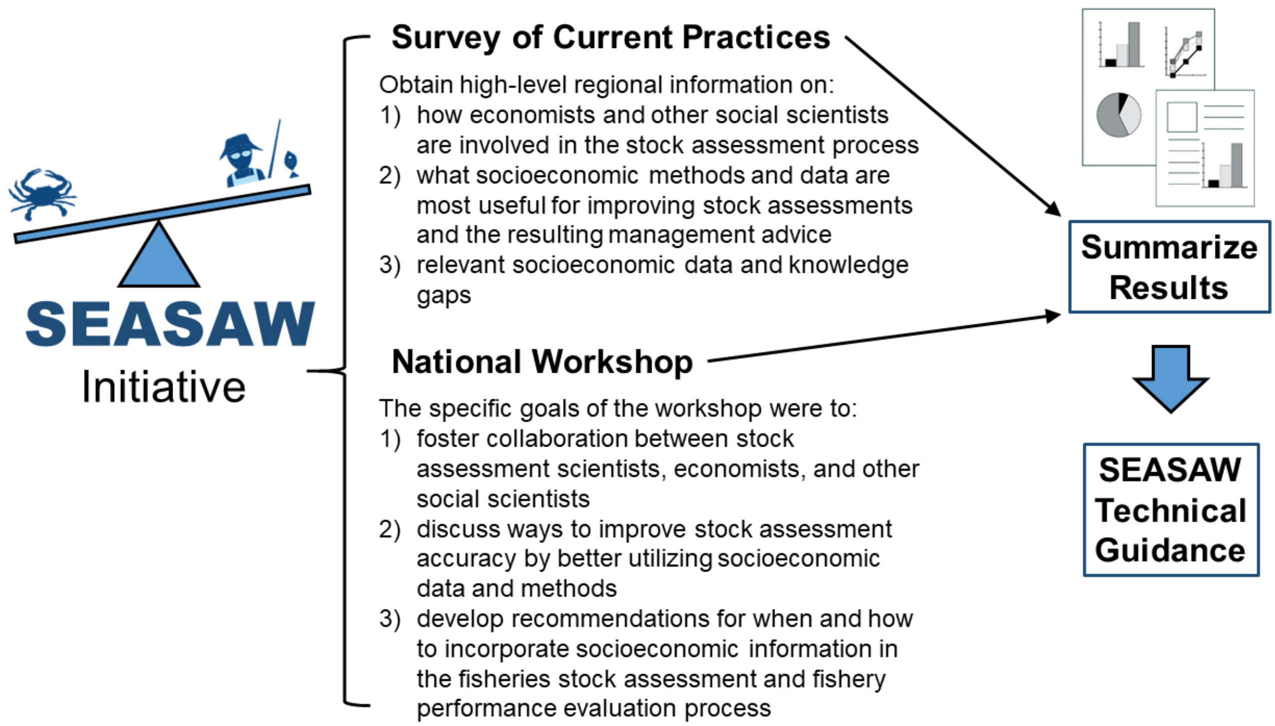


Figure 2: *Summary of activities, goals, and products from the SEASAW initiative.*

This report begins with some background information on applicable laws, policies, strategic guidance documents, programs, previous workshops, and committees. The next section includes a brief description of our approach to forming the workshop steering committee, conducting the NOAA Science Center Survey, and organizing the workshop. In the main portion of this document, recommendations for incorporating socioeconomic data and methods at different steps of the stock assessment process alongside supporting information from case studies are presented, followed by a section on general conclusions. A number of appendices can be found at the end of this document containing the complete survey results, the workshop agenda, abstracts from workshop presentations, summaries of workshop discussions, and a list of steering committee members and workshop participants.

Background Information: Laws, policies, strategic guidance supporting the incorporation of socioeconomic aspects in stock assessments, and relevant programs, workshops, and committees

Incorporating socioeconomic knowledge and data in the stock assessment process will advance the quality of scientific advice provided to fisheries managers. Science-based decision-making is the foundation for sustainable fisheries management in the United States, and with the mandate for decisions to be based on the best scientific information available, the United States has become a global leader in establishing responsible and sustainable fisheries management. The stock assessment process includes quantitative analyses of fish stocks and fisheries to develop catch advice, and this process is fundamental to sustainable fisheries management. Historically, stock assessments have relied primarily on data sources related to stock abundance, stock biology, and fisheries catch and effort over time, but the trends in these data sources are a manifestation of complex dynamics and interactions within changing ecosystems and social systems. Thus, to achieve long-term fisheries sustainability, there is a need to better understand the connections between fish stocks, fisheries, and social system dynamics to facilitate holistic decision-making in considerations of well-informed evaluations of tradeoffs and risks.

Many national environmental laws and policies guide the consideration of socioeconomic processes and impacts in fisheries stock assessments and fisheries management. The Magnuson-Stevens Fishery Conservation and Management Act of 1976 (MSFCMA, also known as the Magnuson-Stevens Act, or MSA) and the National Environmental Policy Act of 1969 (NEPA) guide the considerations of socioeconomic impacts when developing new or changing existing fisheries regulations (e.g., setting the Annual Catch Limits [ACL] for a stock). The MSA includes ten national standards that address different components of sustainable fisheries management, and many of these provide guidance on how social and economic data should be used in fishery management plans. National Standard 1 (NS1), for example, describes the target optimum yield, which is reduced from MSY after considering economic and social factors (50 CFR §600.310). Technical guidance on the carry-over and phase-in provisions of NS1 was recently published, and stressed the importance of enhancing economic performance and minimizing negative social impacts by allowing more flexibility in fishing time and stability in harvest levels from year to year (Holland et al., 2020). In all regions, economic and social science data are collected to analyze the impacts of fisheries management measures on communities to provide for the sustained participation of fishing communities and, to the extent practicable, minimize adverse economic impacts on such communities in accordance with the National Standard 8 guidelines in the MSA. Economics research and data collection programs generally focus effort on assessing socioeconomic impacts more than directly informing stock assessment models.

NEPA requires the preparation of Environmental Impact Statements (EIS) when a proposed federal agency action would significantly affect the environment (40 CFR §1502). The EIS must include a range of reasonable alternatives and discuss the economic and social effects when the agency concludes that the socioeconomic and natural effects are linked (40 CFR §1502.16). For example, an EIS is required when changes are made to the harvest control rule for determining default harvest specifications in a fishery management plan, and those changes are expected to significantly impact the environment (e.g., PFMC and NMFS 2015). Actions for which an EIS is prepared also require an environmental justice analysis under the Executive Order 12898 to analyze the potential for disproportionately high and adverse human health or environmental effects on low-income populations and minority populations, including Federally-recognized tribes.

The ecosystem-based fisheries management (EBFM) approach, guided by the NOAA Fisheries EBFM policy (NMFS 2016a), highlights the importance of understanding links among physical, biological, and social systems, and incorporating knowledge of those connections into fisheries management. The goals of EBFM are to support more sustainable fisheries/ecosystems and economically prosperous communities, which are reflected in the Guiding Principles and core components of the EBFM Road Map (NMFS, 2016b). Community impacts are explicitly included in risk assessments and as measures of resilience (i.e., community well-being). NOAA Fisheries has long recognized the importance of understanding the relationship between fisher behavior and fish stock variability by supporting socioeconomic data collection, bioeconomic research, and model development (e.g., see the 2001 NMFS Strategic Plan for Fisheries Research). This SEASAW technical guidance document was inspired by and initiated in response to NOAA Fisheries' strategic plan for stock assessments: Implementing a Next Generation Stock Assessment Enterprise (Lynch et al., 2018), also known as the Stock Assessment Improvement Plan (SAIP). The SAIP provides strategic guidance for NOAA Fisheries' population assessment programs and emphasizes the need to make stock assessments more holistic, in part by incorporating more socioeconomic science and metrics. While this strategic plan provides a crucial starting point, further interdisciplinary discussions with regional experts are needed to capture the current variability in approaches to connecting stock dynamics, market forces, and community interactions throughout federally managed fisheries.

The NOAA Fisheries Economics and Human Dimensions Research Program currently includes 58 economists and 14 human dimension scientists that specialize in anthropology, sociology, and marine resource management (Human Integrated Ecosystem Based Fishery Management (HI)-EBFM Research Strategy 2021-2025). The majority of these staff are located at the six NOAA science centers: Alaska Fisheries Science Center (AFSC), Northwest Fisheries Science Center (NWFSC), Northeast Fisheries Science Center (NEFSC), Southwest Fisheries Science Center (SWFSC), Southeast Fisheries Science Center (SEFSC), and Pacific Islands Fisheries Science Center (PIFSC). Likewise, each center also has a population dynamics program charged with assessing the stocks in each region. NOAA Fisheries Headquarters staff provide national coordination and support of research activities for both the economics and human dimensions programs and stock assessment programs.

The (HI)-EBFM Research Strategy emphasizes the integration of human dimensions research into EBFM, including the importance of coupling economic research and data with stock assessments. The action plan encompasses national integrated modeling projects, management strategy evaluations, and disentangling institutional and biological drivers of changing fishing behavior ((HI)-EBFM Research Strategy 2021-2025). The recommendations from this SEASAW report align with this national strategic guidance.

An additional motivation for the SEASAW initiative is the need to expand the integration of socioeconomic and ecological indices and analyses in Integrated Ecosystem Assessments (IEAs). IEAs are developed by synthesizing the pertinent physical, biological, and socioeconomic components and interactions in an ecosystem using conceptual models, which facilitate the communication of ecosystem state and risks to stakeholders, resource managers, and policy makers (Levin et al., 2008, Monaco et al., 2021). Conceptual models include environmental drivers, ecological interactions, and human activities identified by interdisciplinary teams of NOAA Fisheries scientists, partners, and stakeholders (NMFS, 2016b). IEAs are useful for communicating risks to regional fisheries management councils, prioritizing management actions, identifying trade-offs among management objectives, and building resilience in social-ecological systems (Spooner et al., 2021). IEAs also provide an avenue through which stakeholders such as fishers, processors, and fishing community members can be directly involved in fisheries management. A key driving principle of IEAs is that promoting sustainable ecosystems requires an understanding of interconnected human and natural factors to develop indicators, assess trends, and project conditions under multiple management scenarios (Levin et al., 2008). Regional IEA teams support the production of Ecosystem Status Reports or State of the Ecosystem Reports that compile suites of indicators that describe and synthesize current climatological, ecological, and socioeconomic trends for an ecosystem. In some regions these are presented to the fishery management council on an annual basis to inform management decisions. In one case, the council adapted the IEA approach to implement a structured decision framework to address species, fleet, habitat, and climate interactions for specific species as part of their Ecosystem Approach to Fisheries Management (Muffley et al. 2021, Gaichas et al. 2016). Historically however, the IEA process has been largely decoupled from direct input to the stock assessment process (defined in the next section) or, in rare cases, has required considerable external resources (SEDAR 2014, SEDAR 2015), and the efforts and guidance described here are part of an effort to improve connections between IEAs and stock assessments to support EBFM.

A number of scientific meetings and standing committees have promoted collaboration between the stock assessment and social science communities, which are summarized in Table 1 below. This table is meant to provide some relevant examples rather than a comprehensive list.

Table 1: *Examples of past and current collaborations between the stock assessment and social science communities.*

Title	Year	Description
National Workshop on Integrating Economic Considerations into Management Strategy Evaluations (MSEs)	2019	This workshop was motivated by the need to improve the consideration of trade-offs between alternative management strategies when attempting to achieve both economic and biological objectives (Stohs et al. in prep).
National Ecosystem Modeling Workshop (NEMoW): Using Ecosystem Models to Evaluate Inevitable Trade-offs	2017	The purpose of this meeting was to address EBFM trade-offs, and workshop attendees recommended increased engagement between social scientists and the ecosystem modeling community (Townsend et al., 2017).
National Stock Assessment Workshop (NSAW): Overfishing? Overfished? Approaches and Challenges Surrounding Stock Status Determination Criteria	2015	An economist from the AFSC (Alan Haynie) delivered a presentation on how NOAA scientists can better integrate socioeconomic information into the stock assessment process. One conclusion from the workshop was that socioeconomic information and stakeholder engagement can help fill in gaps for data-limited stocks (Vieser & Lynch, 2016).
NSAW: Improving Integrated Surveys and Stock Assessments	2008	This was a joint meeting with the National Economic and Social Science Workshop.

NSAW: Quantifying Scientific Advice for Ecosystem-Based Fishery Management	2006	For this NSAW, both economists and stock assessment scientists attended and presented work in an interdisciplinary session.
International Council for the Exploration of the Sea (ICES) Strategic Initiative on the Human Dimension (SIHD)	Ongoing	This group focuses on supporting the integration of social and economic sciences into ICES initiatives. Overlap between socioeconomics and stock assessments is one area of intended focus.
North Pacific Marine Science Organization (PICES) Human Dimensions Committee	Ongoing	This committee supports interdisciplinary research on characterizing interactions between ecosystems, communities, and economies in the North Pacific.

Workshop Approach: Forming the Steering Committee, Conducting the NOAA Science Center Survey, and Organizing SEASAW

In preparation for the SEASAW, we formed a steering committee of economists and stock assessment scientists from each of the six NOAA Fisheries science centers (centers) so that our group represented regions with a broad range of stocks and economic conditions. The committee also included members from NOAA Fisheries Office of Science and Technology (OST) who provided strategic direction and coordination. The steering committee was charged with formulating the questions for the survey of current practices (described below), and identifying key workshop themes. Steering committee members also helped draft a call for abstracts, which yielded 18 presentations, and served as workshop discussion leaders and rapporteurs.

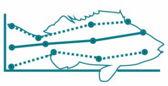
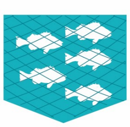
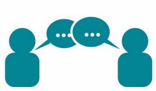
In order to provide recommendations on socioeconomic information usage in the stock assessment process, we needed to understand socioeconomic data availability and how these data are currently being used by NOAA Fisheries. The SEASAW steering committee developed a survey to obtain regional information on collaboration between economists/other social scientists and stock assessment scientists, socioeconomic methods and data that are useful or needed for improving stock assessments, and how socioeconomic data, analyses, and results inform the scientific advisory process. The acting OST director distributed the survey to the six science center directors, economists, other social scientists, and stock assessment scientists from each respective center. Responses were collected between November and December 2019, summarized, and presented at the workshop.

The SEASAW was held in New Orleans, LA from February 11-13, 2020. This workshop had 36 participants, including stock assessment scientists and economists from all centers and NOAA headquarters as well as other social scientists, academics, and fishery management council staff. The workshop included a range of presentations on economic connections in stock assessments and management strategy evaluations, and how projections of stock dynamics could be improved with interdisciplinary research teams. Specific case study presentations from different regions demonstrated novel socioeconomic data and methods integration, and broader discussions among workshop participants facilitated the development of workshop recommendations.

Recommendations for Incorporating Socioeconomic Data and Methods Throughout the Stock Assessment Process

Engaging stakeholders in the decision-making process has been shown to be critical for promoting voluntary compliance with regulations (Viteri & Chávez, 2007). Cooperative research projects between fishers and scientists (including social scientists) have resulted in increased transparency and accountability of the management process, as well as knowledge integration between both participating groups (Hartley & Robertson, 2008, Kaplan & McCay, 2004). NOAA Fisheries scientists should continue to participate in outreach with the fishing community, such as through the Gulf of Maine Research Institute's Marine Resource Education Program workshops. Increasing stakeholder engagement in fisheries management – from data collection to delivering scientific advice to managers – leads to increased trust in the stock assessment results, and can contribute to reduced misreporting, non-cooperation, and non-compliance. This can have positive implications for the accuracy of stock assessments and associated catch recommendations. A number of the examples from the survey of current practices and the literature highlight different ways to ***engage stakeholders throughout the stock assessment process, with input from social scientists***. The complete list of recommendations can be found in Table 2, and these are discussed in more detail in the following sections.

Table 2: *Recommendations for using socioeconomic information in the stock assessment process, separated by different steps of the process. Note that the process is not linear; see Figure 1.*

	**Data Collection**	1. Data collection for some stock assessments could be augmented by gathering additional socioeconomic data at the appropriate resolution, such as illegal catch, cost information, and current-year fishing conditions. 1.1 Collaborative data collection programs should be expanded in each region, where biologists and social scientists jointly design and implement interview protocols (e.g., skipper surveys) to obtain local ecological knowledge (LEK). LEK can be used to understand changes over time, such as those related to fish size compositions, durations of unusual mortality events, fishing effort, and fishing practices. 1.2 More effort should be made to study human behaviors related to misreported catch, unreported discards, and unreported landings in the stock assessment process. 1.3 Cost information should be collected in regions where data are lacking. 1.4 Socioeconomic information should be used to help improve our understanding of historical patterns of fishing activity. 1.5 Social science information should be collected at a sufficient frequency and at the appropriate resolution to be useful during the assessment cycle.
	**Data Processing**	2. The processing of stock assessment data inputs (e.g., abundance indices from catch per unit effort (CPUE) data) can be improved with the application of more socioeconomic data and methods to help interpret observed trends. 2.1 Social scientists should be more involved in either the development or evaluation of fishery-dependent data streams (e.g., landings and effort data) to capture changes that may be the result of economic, social, and management changes. 2.2 Appropriate socioeconomic information should be collected and used to standardize CPUE time series that are included in stock assessments. 2.3 Economic approaches can be used to combine fisheries dependent data with fisheries independent survey data to enhance spatial and temporal resolution of stock abundance estimates.
	**Stock Assessment Models**	3. Better characterizations of changing fishing practices over time will enable improved parameterization of stock assessment model components, such as catchability and selectivity. 3.1 Economists and other social scientists can inform the selection of priors for trends in catchability. 3.2 Time-varying selectivity based on size-based targeting and changing fleet fishing behavior should be integrated in assessment models where appropriate. 3.3 Cost and other economic data collected from catch share programs should be more effectively integrated into stock assessments. 3.4 Coupling stock assessment models with bioeconomic models should be explored further, particularly where there is significant overlap between fleets and species.
	**Projections**	4. Integrating socioeconomic data and models into stock assessment projections – in collaboration with economists and other social scientists – can inform assumptions about future fishing behavior, improve the accuracy of projected abundance and catch, and evaluate socioeconomic impacts. 4.1 Stock assessment projections can be improved by addressing assumptions about socioeconomic influences, e.g., future fishing practices assumptions. 4.2 Projections should be conducted by interdisciplinary teams of stock assessment modelers, ecosystem modelers, economists, and other social scientists to provide catch advice for multiple, interconnected stocks simultaneously. 4.3 Multispecies projections should be developed that incorporate interactions between species, market demands, and fisher choices. 4.4 Potential socioeconomic impacts of alternative projection scenarios should be provided to support management decision-making, e.g., when Councils are determining the acceptable risk of overfishing.
	**Harvest Control Rules**	5. Socioeconomic information should be included in the development of harvest control rules (HCRs), the process for choosing between alternative HCRs, and the review of existing HCRs. 5.1 Changing management regulations, such as size limits that influence discarding behavior, necessitate revisiting control rule calculations and scientific advice with collaboration between economists, other social scientists, stock assessment scientists, and managers. 5.2 When appropriate, socioeconomic metrics should help inform each Council's determination of the acceptable risk of overfishing (P*). 5.3 HCRs for transboundary stocks should be developed in collaboration with connected nations, and include input from economists. 5.4 Socioeconomic triggers for the review of HCRs should be established. Rules should be reassessed and updated when they are no longer meeting management objectives, or when objectives change. 5.5 Socioeconomic information and analyses should be included in Management Strategy Evaluations (MSEs) when alternative HCRs are being evaluated to help managers choose between alternative rules. 5.6 Allocation reviews should be conducted more frequently, when appropriate, to assess community impacts and evaluate whether management measures achieve stated objectives. 5.7 Efforts to define and prioritize social objectives should be supported.
	**Communication with Managers and Stakeholders**	6. Stock assessment scientists, economists, and other social scientists should work together to communicate socioeconomic indicator trends important for interpreting scientific advice from stock assessments to managers and stakeholders. 6.1 Relationships between potential socioeconomic indicators and stock dynamics should continue to be explored. 6.2 Stock assessment scientists, economists, and other social scientists should work with managers to determine the most efficient and effective ways to communicate scientific advice. 6.3 Methodologically sound socioeconomic data and trends should be used to inform interpretations of advice, uncertainties, and risks, and to provide both systematic and anecdotal context. 6.4 More interdisciplinary teams should collaborate in all regions to create system-level communication products such as ESPs and conceptual models to improve and standardize communication of socioeconomic indicator trends to managers and stakeholders.

1. Data Collection:

Data collection for some stock assessments could be augmented by gathering additional socioeconomic data at the appropriate resolution, such as illegal catch, cost information, and current-year fishing conditions.

In the survey of current practices at the NOAA Fisheries science centers, respondents were presented with a list of possible socioeconomic data types, and were asked to select whether the data type is currently used in the stock assessment process, whether the data type is available but not used, or whether the data are unavailable. More data types were available but not used compared to the number of data types that were being used in the stock assessment process by at least one center. This indicates that there are multiple opportunities to explore the benefits of using more socioeconomic data streams in stock assessments. However, the existence of a data stream does not mean that it was collected at the appropriate frequency or resolution for inclusion in the assessment cycle. Using the results of this survey, we were able to match centers with available socioeconomic data types that are not currently used in their respective assessment cycles with centers that use the same data types during some portion of their assessment process. Recommendations on the use of socioeconomic data inputs in the stock assessment process are provided below.

1.1 Collaborative data collection programs should be expanded in each region, where biologists and social scientists jointly design and implement interview protocols (e.g., skipper surveys) to obtain local ecological knowledge (LEK). LEK can be used to understand changes over time, such as those related to fish size compositions, durations of unusual mortality events, fishing effort, and fishing practices. LEK is the knowledge gained by a group of individuals over their lifetimes about their local ecosystems (Olsson & Folke, 2001). LEK should be considered during the stock assessment review process as an additional source of information, and can be used to contextualize stock assessment models or serve to inform assessment authors of potential changes in stock or associated ecosystem health. LEK, such as fisher observations, can be used to highlight uncertainties in an assessment related to an unusual mortality event. An example presented at SEASAW involved the 2018 red tide event (Sagarese, AB8). Oral history interviews of fishers were jointly conducted by a fishery biologist and a social scientist. These oral history interviews were used to extract LEK such as observations of fish size composition of red tide-induced mortality, severity and duration of the red tide event (and historical events), and grouper species mortality (Karnauskas et al., 2019). Oral history interviews can also reveal how the fishers are responding and changing their fleet distribution in response to an unusual mortality event. For these efforts to be successful, analysts need to utilize scientifically rigorous survey methods which in some cases may require more social scientists, or more cooperative research with academic or private sector partners.

Although it was not specifically discussed at the workshop, traditional ecological knowledge (TEK) also serves an important role in understanding marine ecosystems and changing ecological conditions. Additional collaborative data collection programs could also be used to collect TEK, which has been defined as an accumulation of knowledge about the interactions between living beings (including people) with each other and with their environment, passed down through generations of shared culture (Berkes 1999). For example, in the North Pacific, there are growing targeted efforts at eliciting and including TEK in the fisheries management process directly (e.g., see recent work from the North Pacific Fishery Management Council's Local Knowledge, Traditional Knowledge, and Subsistence Taskforce).

1.2 More effort should be made to study human behaviors related to misreported catch, unreported discards, and unreported landings in the stock assessment process. The PIFSC survey response showed that illegal catch estimates are used as data inputs to stock assessment models and in the development of stock projections. Estimates of unreported fishery catch were incorporated into the Bayesian surplus production model for Deep 7 bottomfish (Brodziak et al., 2011). The specific data available were time series of ratios of unreported to reported catch by species of Deep 7 bottomfish. The unreported catch ratios were based on previously published data and analyses, including fisher surveys (Courtney & Brodziak, 2011). Estimates of unreported catch were calculated based on these ratios, and the total catch is the combination of reported and unreported catch. An estimate of total catch was included in the surplus production model, and was calculated similarly based on assumed reported catch to forward project catch from 2018-2022 (Langseth et al., 2018).

The methods used by the PIFSC to include an estimate of illegal catch in stock assessments can serve as a potential guide to other regions. A recent publicized example of mislabeling catch occurred in the Northeast multispecies groundfish fishery, when Carlos Rafael (the "Codfather") falsely reported over 700,000 pounds of fish to avoid strict quotas (Department of Justice, 2017). Because the Atlantic cod stock is overfished (NEFSC, 2017), accounting for this type of illegal catch is crucial for increasing the accuracy of assessments and projections.

1.3 Cost information should be collected in regions where data are lacking. Data on costs are essential for calculating the profitability of fishing activity, and are therefore important for understanding fisher behavior in response to the costs and revenues of fishing (Girardin et al., 2017). Understanding the costs experienced by fishers can elucidate the incentives to participate in different types of fishing activities, such as traveling to farther fishing grounds (Haynie & Layton, 2010) or switching fishing gear type (Krigbaum & Anderson, 2021). For example, data on costs could be used when evaluating alternative harvest control rules (HCRs) as part of the stock assessment process by providing information on how fishing costs are expected to change under different future scenarios (Kritzer et al., 2019). Both the NWFSC and NEFSC described the methods they use to collect data on costs in the survey of current practices. The NWFSC obtains information on the West Coast Groundfish Trawl Catch Share Fishery from Economic Data Collection (EDC) forms. All participants in the fishery are required to complete these forms annually (50 CFR 660.114). Data are also collected via the voluntary limited entry fixed gear survey and the open access groundfish, crab, shrimp, and salmon survey. The NEFSC noted the importance of the observer program for collecting trip cost data, and fishing vessel and crew surveys for collecting data on annual fixed costs, crew remuneration, job satisfaction, and demographics. The fishing vessel and crew surveys are conducted approximately every three years.

The NWFSC also reported in the survey responses that socioeconomic data has improved scientific advice in terms of setting risk levels, assessing tradeoffs for rebuilding species, and in projecting catch by fleet/area/gear and apportioning the ACLs. Because all participants in the catch share program are required to report economic data for the fisheries they engage in, including non-catch share fisheries, there has been a substantial increase in available economic data since 2009. The communication of economic trends is facilitated by an interactive tool for exploring, analyzing and downloading data (Fisheries Economics Explorer (FISHEyE)). With this tool, managers, analysts, and stakeholders can compare revenue, costs, and net revenue of catcher vessels. Revenue and cost data collected via EDC forms are used to provide the PFMC with measures of efficiency in the West Coast groundfish trawl catch share program (PFMC and NMFS, 2017).

1.4 Socioeconomic information should be used to help improve our understanding of historical patterns of fishing activity. For many fish stocks, historical data on fishing activity are not consistently available from traditional sources (e.g., logbook forms have changed over time). In many regions, detailed fishing data and some economic data are poorly or incompletely integrated. Additionally, historical data may be available, but may not be reported in units that can be used by stock assessment scientists. Nontraditional socioeconomic data sources can be used to produce historical constructions of biomass. Interviews of fishing vessel captains that were active during the historical period of interest were used to map spatial changes in the relative abundances of different stocks (Ames & Lichter, 2013). Fishers can also be interviewed to estimate the magnitude of undocumented historical landings. For the Gulf of Mexico red grouper assessment, individuals with knowledge of the Cuban fleet were interviewed to collect information on historical catch, effort, and fishing fleet characteristics (Saul, 2014). Ultimately, the landings data were used in sensitivity runs, but not the base assessment model (SEDAR 2015).

The South Atlantic Fishery Management Council (SAFMC) FISHstory Citizen Science Pilot Project may provide useful data for stock assessments, and serve as a model for similar projects in other regions. Volunteers for this citizen science project identified and counted fish in historic photographs from the 1940s to the 1970s. For some species such as King mackerel, fish lengths were also collected. Notably, the historic photos for this pilot project were provided by a retired Florida fisher serving on the Council's Snapper Grouper and Mackerel Cobia Advisory Panels. Because dedicated catch monitoring did not begin until the 1970s, these historic photographs will help provide a more complete time series of catch data and improve understanding of fish stock health. Additional assessments without historic conditions should be expanded using any available data, including socioeconomic information. Socioeconomic information used to support assessments should be submitted to and peer reviewed during stock assessment data workshops.

1.5 Social science information should be collected at a sufficient frequency and at the appropriate resolution to be useful during the assessment cycle. Robust time series are needed to understand connections between socioeconomics and fish population dynamics. Routine monitoring is essential to collect time series of social science information. National Standard 8 of the MSFCMA states that conservation and management measures need to use the best economic and social science information available to account for the dependence of fishing communities on fishery resources (50 CFR § 600.345). This national standard also specifies that necessary data should be identified and collected. Additional socioeconomic information should be included in the stock assessment and fishery evaluation (SAFE) report, but without the appropriate data resolution (e.g., the data are not collected at the same frequency as annual catch information), it is difficult to make potential connections between socioeconomic and stock assessment trends. In other words, even if a mechanistic link between a socioeconomic variable and a stock assessment parameter is plausible, the strength of the relationship cannot be tested without more complete data on the socioeconomic variable. For example, a recent study showed how fishers will change their behavior (e.g., fishing deeper waters) in order to avoid catching small sablefish in Alaska (Szymkowiak & Rhodes-Reese, 2020). The authors conducted semi-structured interviews for this study to obtain information on the adaptive strategies of the fishing fleet. With increasing warm water conditions being favorable to sablefish recruitment, sustained collection of data on fleet adaptive strategies could be beneficial for understanding and predicting changes in fishery selectivity over time.

Challenges with including more socioeconomic data inputs in stock assessments

SEASAW participants also identified associated challenges with including more socioeconomic data inputs in the stock assessment process. Many stock assessments use longer time series than the available economic and other social science data series. Achieving the timely availability of socioeconomic data is an ongoing challenge, which requires trained social scientists to process data, and subsequent communication to stock assessment authors. The time period for collecting economic data is also not aligned with stock assessments; the data may not be able to be collected early enough to be incorporated (i.e., economists must wait until the end of the fiscal and/or tax year). Maintaining centralized repositories for socioeconomic data streams could facilitate improved data-sharing, with appropriate protections in place to maintain data confidentiality. However, socioeconomic data still need to be collected at the appropriate spatiotemporal resolution (i.e., the socioeconomic data can be related to the dynamics of individual stocks) for use in stock assessments. Making sufficient time available for economists and social scientists to be involved in the stock assessment process continues to be a challenge for some regions.

2. Data Processing:

The processing of stock assessment data inputs (e.g., abundance indices from catch per unit effort (CPUE) data) can be improved with the application of more socioeconomic data and methods to help interpret observed trends.

2.1 Social scientists should be more involved in either the development or evaluation of fishery-dependent data streams (e.g., landings and effort data) to capture changes that may be the result of economic, social, and management changes. The way fishing effort is defined in some stock assessments may not be appropriate for capturing the variability in actual effort over space and time. Biases in input data can significantly impact stock assessment results. Social scientists can help stock assessment scientists become aware of how these factors are impacting fish stocks and how stock assessment scientists can incorporate this information in models. For example, collaborating with economists can help improve the way fishing effort is defined and measured. Using a proxy variable (e.g., days) to measure changes in effort over time can lead to biased and inconsistent estimates. A useful alternative could be to define effort as a composite index using an effort aggregator function (Squires, 1987).

A relevant example for this recommendation was identified from the survey of current practices at the NOAA science centers. A number of issues with the commercial fishery data for the Deep 7 bottomfish species in the Pacific Islands were identified, making it complicated or misleading to use these data in stock assessments. Data workshops including commercial fishers were held to resolve many of these issues (Yau, 2018). Importantly, a data field to record the number of hours fished was only added to the reporting form in 2002. Therefore, different metrics for commercial fishing effort needed to be applied and agreed on for the time periods before and after 2002. Through data workshops including commercial fishers, many of these issues were resolved with guidance and support from social scientists. The interdisciplinary group agreed the solution for this data issue was to use a “single-reporting day” as an effort metric prior to 2002, and to use the number of hours fished as an effort metric post-2002 (Yau, 2018). Information in the older records needed to be filtered to account for multi-day trips that were recorded as single-reporting days. The fishers in attendance provided valuable insight on the possible maximum pounds of fish that could be caught in a day (which is impacted by market demand and price), and the maximum distance traveled during a trip. By including the fishing community and social scientists in the commercial data filtering discussions, stock assessment scientists were able to make a number of improvements to specifying the fishing effort time series and CPUE standardization processes for subsequent Deep 7 bottomfish stock assessments.

2.2 Appropriate socioeconomic information should be collected and used to standardize CPUE time series that are included in stock assessments. When CPUE data are used to infer relative abundance in stock assessments, selection biases may result from fisher targeting behavior and bycatch avoidance, which impacts the generalizability of the data to the entire assessed stock. In other words, catch rates can vary over time for reasons other than changes in the abundance of the stock (Maunder & Punt, 2004). Stock abundance trends may be derived from CPUE data after standardizing with explanatory socioeconomic variables; appropriate statistical methods should be used to determine whether to include an explanatory variable (Maunder & Punt, 2004). These explanatory socioeconomic variables may change over time and, for example, may include an individual vessel effect (Matsumoto et al., 2019). The composition of fleets can influence CPUE since factors such as the engine power of a vessel influence CPUE. Competition between fleets may also impact standardization in areas of hyper depletion, where CPUE decreases faster than the true abundance of the stock (Hilborn & Walters, 1992). High resolution spatial data are required to characterize fisher targeting behavior by considering the spatial distribution of the fleet relative to the fish stock, and to determine whether variation in fisher targeting behavior significantly affects CPUE (Quirijns et al., 2008). Variable fisher responses to different management actions (e.g., implementing an individual quota system) as well as improvements in fishing over time (e.g., increased gear efficiency due to improved skills of the crew) can impact CPUE (Rodríguez-Marín et al., 2003; Salthaug, 2001). Separate CPUE time series may be specified when fisher behavior is changing in response to management actions. Vessels with low catch values or short tenures in the fishery may need to be excluded to remove some of these effects from the standardization process.

The survey of current practices revealed that the PIFSC and SWFSC use ex-vessel price information (the price at first point of sale of landed fish) in the processing of stock assessment data inputs, and the SWFSC also uses these data to structure stock assessment models. Ex-vessel value can help refine the appropriate fleet selectivity structure in developing stock assessment models, particularly for species that are sorted by size according to price (e.g., sablefish and dover sole). However, price or value information is not directly used to inform fishery selectivities in assessments at the SWFSC. A recent international stock assessment for swordfish conducted by the PIFSC explores relationships between ex-vessel prices and CPUE in a qualitative framework. In this assessment, a decreasing trend for ex-vessel price of Hawai`i swordfish indicated a weakened market for swordfish. Fishers thus had a reduced incentive to re-engage in the swordfish fishery. Hawai`i longline vessels change target species between swordfish or tuna, so increased effort was devoted to tuna while swordfish fishing trended downward. CPUE decreased before stabilizing in recent years (PI Pelagic FEP SAFE Report 2018). Future assessments may further explore the relationship between ex-vessel prices and CPUE.

2.3 Economic approaches can be used to combine fisheries-dependent data with fisheries-independent survey data to enhance spatial and temporal resolution of stock abundance estimates. Further research is needed regarding the feasibility of augmenting stock information (i.e., abundance and distribution) obtained from fishery-independent surveys with spatially explicit catch data (Bell et al., 2021). Holzer and Lipton (2013)[2] demonstrate a methodology to estimate monthly blue crab abundance and distribution by utilizing the spatial and temporal overlap of a fishery-independent Chesapeake Bay winter dredge blue crab survey with the commencement of the crab fishing season. The authors calibrate a profit model of crab fishing location tied to spatially explicit abundance during the remainder of the season when no fishery-independent survey was operating (Lipton, AB1). They solve for the most likely stock abundance and distribution that results in the observed fleet performance. Application of the approach to other fisheries requires dealing with the multiproduct nature of most fishery-independent surveys and the multiproduct fishing fleet. Greater use of commercial vessel and individual angler data (with appropriate bias corrections) to fill in the gaps (areas and times) that are costly to obtain from fishery-independent surveys are another step towards becoming more efficient in conducting stock assessments.

[2] Holzer, J. and D. Lipton. 2013. Inferring blue crab spatial distribution. Presentation at Biennial North American Association of Fishery Economists. St. Petersburg, FL.

3. Stock Assessment Models:

Better characterizations of changing fishing practices over time will enable improved parameterization of stock assessment model components, such as catchability and selectivity.

3.1 Economists and other social scientists can inform the selection of priors for trends in catchability. Survey and fishery catchability are important quantities in fish stock assessment models, and can be thought of as the probability of any individual fish being captured. Catchability is influenced by complicated interactions between fish and fishers (Walters & Martell, 2004), and is the proportion of a fish stock that is caught by a standardized unit of fishing effort, ranging from 0 to 1 (Ricker, 1975). While there are a number of biological factors that influence catchability, we will focus on the socioeconomic factors here, including technological factors. Some examples of these factors include the physical characteristics of the fishing gear, the placement of the gear (including position in the water column, duration of a set, and handling), and the experience of the fishing crew.

Studies including time-varying catchability in stock assessment models have been reviewed previously, and the authors recommended that catchability should generally be assumed to vary over time (Wilberg et al., 2009). One common way to account for time-varying fishery catchability is by standardizing CPUE data (see previous section), yet standardization of abundance indices can only be used to account for known factors with adequate data that impact catchability. Explicitly modeling catchability as a function of time can account for more variables influencing catchability for which specific data are not collected or available. However, time-varying fishery catchability does not include temporal changes in investment in physical capital (e.g., sensors, echosounders) and subsequent knowledge spillover effects, because the effort measure typically used is not at the resolution of the vessel (Squires & Vestergaard, 2015). Still, stock assessment models which allow for time-varying fishery catchability can provide higher resolution information on changing fishing practices/technology, fisher responses to new regulations, the retention/loss of skilled fishers, and fisher learning and adaptation.

Informative priors for trends in fishery catchability can be constructed from fisheries that are subject to similar changes in relative price, which could drive comparable changes in fisher targeting and effort (Wilberg et al., 2009). Social scientists can also conduct fisher interviews and develop priors for time-varying catchability and other model parameters (e.g., time-varying selectivity) in Bayesian stock assessments (Medley et al., 2005). Insights from fishery bycatch encounter rates can also be used to ground-truth fishery-independent survey catchability parameters, which occurred recently for the West Coast spiny dogfish survey.

3.2 Time-varying selectivity based on size-based targeting and changing fleet fishing behavior should be integrated in assessment models where appropriate. Changes in fishing practices (which are responsive to market demand, changing management regulations, protected species bycatch, etc.) contribute to changing fishery selectivity over space and time. Young and old fish are not coincident in space, and so the unit of fishing effort is not uniformly applied across all ages. Over time, fishery selectivity may transition from asymptotic where there is higher mortality of larger (older) fish to dome-shaped when fishers increase economic efficiency by targeting younger fish (Methot, AB2). Multiple socioeconomic processes can each contribute to temporal variation in the fishery-selected proportion of a fish stock length/age composition. Spatial patterns in fishing effort can vary over time due to changes in the marketability of different sized fish, changing management regulations like minimum size restrictions or quota restrictions, and shifts in the mixture of fishing gear types (Sampson & Scott, 2012). The economics of fishing activities (e.g., market demand) also drive changing patterns in fishery selectivity over time.

Allowing fishery selectivity to change over time may result in improvements to the overall stock assessment model. Including an estimate of time-varying selectivity in age-structured stock assessment models can produce more accurate estimates of spawning biomass, fishing mortality, and management reference points (Stewart & Monnahan, 2017; Xu et al., 2019). Notably, underestimating the temporal variability in selectivity can result in larger errors in spawning biomass (Stewart & Monnahan, 2017), and it is therefore recommended that information is collected on any directional changes in factors influencing selectivity (e.g., fishing behavior) to allow for proper model specification. In the Pacific hake stock assessment, fishery selectivity is allowed to vary over time based on previous simulation analyses that showed how including time-varying selectivity yielded multiple benefits, such as higher average catch, lower risk of falling below 10 percent unfished biomass, reduced probability of fishery closures, and lower variability in catch (Grandin et al., 2020). The variation in selectivity over time is at least partially a result of changes in fishing effort in response to variable cohort sizes, since Pacific hake recruitment can vary drastically from year to year (Pacific hake status and MSE, 2014).

3.3 Cost and other economic data collected from catch share programs should be more effectively integrated into stock assessments. Catch share programs have now been implemented in 19 fisheries in the U.S., and generally involve assigning a share or quota of fish to individual fishers, fishery cooperatives, or fishing communities. The collection of multiple socioeconomic data types has increased in conjunction with these programs in order to assess the economic and social effects on the fishers, markets, and associated communities (NMFS, 2017). For example, the West Coast Groundfish Trawl Catch Share Program has yielded increased profitability, particularly for Pacific whiting harvesters (Errend et al., 2018). After the implementation of the Northeast Multispecies (groundfish) Catch Share Program, revenue from all groundfish and non-groundfish landings increased and groundfish vessel economic performance was enhanced (Clay et al., 2014). These programs allow fishers greater flexibility to choose when to fish, which can help them increase profits by fishing when prices are higher. While the increased collection of economic data has provided some information relative to whether the catch share programs are fulfilling management objectives, more work is needed to improve the utilization of these data in the stock assessment process.

One example of how economists can help improve stock assessment methods using catch share program economic data is by providing insight into the fishers' selection process that resulted in the fishery-dependent data. Ongoing research demonstrates how explicitly modeling the profit-maximizing behavior of fishers can correct the fishery selectivity by accounting for fisher incentives (Chen & Haynie, NAAFE 2019). In this simulation analysis, the authors demonstrate how using corrected fishery-dependent data can improve the performance of multiple assessments.

3.4 Coupling stock assessment models with bioeconomic models should be explored further, particularly where there is significant overlap between fleets and species. One promising area of research is the coupling of existing stock assessment models (particularly for commercial fisheries) with existing or yet-to-be-developed bioeconomic models. The MSA establishes the management limit for U.S. fisheries to be based on MSY rather than MEY (Box 2). The focus on MSY has led to less emphasis on the development of fully coupled bioeconomic models, but additional work can provide more information for decision makers to set the optimum yield (OY). Bioeconomic models are regularly used directly in fisheries management in Australia, largely driven by the choice of MEY as a management target (Pascoe et al., 2016). Bioeconomic models can be very useful for incorporating interactions between biological and human systems to allow for more accurate determinations of the impacts of these feedbacks on management targets, even when MEY is not the explicit management objective. Bioeconomic models are used to support management efforts in multispecies individual transferable quota (ITQ) fisheries with multiple interacting target fish species and fishing fleets, as in the Australian Southern and Eastern Scalefish and Shark Fishery (Pascoe et al., 2016). While in Australia MEY estimates are typically only calculated for a subset of key species in the fishery (ignoring many complex interactions), a model including more of these technical interactions demonstrated substantial deviations in the estimated economic target reference biomass levels (Pascoe et al., 2015). Similarly complicated multispecies fisheries in the United States could benefit from the application of bioeconomic models for management purposes using the economic data collected as part of catch share programs.

Because MEY is not currently used in U.S. fisheries management, there has been less effort devoted to building applicable bioeconomic models. The development and use of coupled social-ecological models to support EBFM in U.S. fisheries has been reviewed recently (Kasperski et al., 2021), and the authors provide guidance on choosing when, how, and why to couple SES models. They conclude that bioeconomic models are particularly useful for providing strategic advice for solving long-term resource management problems. Examples of fully coupled bioeconomic models with well-developed stock assessment and economic components exist (Punt et al., 2014; 2016), and have been used to estimate the long-term maximum MEY in addition to other reference points. These interdisciplinary modeling efforts were possible because of the availability of economic data such as fuel costs from Economic Data Reports. However, these models are only partially used by management, and need to be developed further to provide action-specific advice (Kasperski et al., 2021). Bioeconomic models constructed by economists often have simplified biological models to the point where they are useful only for strategic (general and/or long-term) advice. Bioeconomic models that incorporate biological model components and assumptions about uncertainty consistent with assessment models are more likely to be useful for supporting tactical decisions (e.g., setting ACLs). In order to determine whether MEY should be estimated more broadly in the United States, additional regional case study applications of fully coupled bioeconomic models should be supported. Multispecies assessments should also be explored further, where reference points take into account additional factors other than biology alone (Methot, AB2).

Future modeling research directions related to stock assessments

Future research directions identified at the workshop included improving models of fleet dynamics that can be integrated into assessments, and improving models of price elasticity. There is a need for stock assessment models that can incorporate adaptive fisher behavior, such as fishing deeper and switching gear types to avoid small sablefish and whale depredation (which can have implications for size selectivity) and unobserved discarding that has increased over time. In Alaska, this type of information is now included outside of assessment models in the risk table under the fishery performance category, or in an appendix document like ESPs and Economic Performance Reports (EPRs) (see further details below). Additional efforts should be made to directly integrate the results of spatial fisher behavioral models into the stock assessment process.

4. Projections:

Integrating socioeconomic data and models into stock assessment projections – in collaboration with economists and other social scientists – can inform assumptions about future fishing behavior, improve the accuracy of projected abundance and catch, and evaluate socioeconomic impacts.

In the survey of current practices, centers were asked to generally describe the assumptions made related to socioeconomic factors in assessments, recognizing that assumptions will differ depending on the stock in question. For projections by the NWFSC, it is often assumed that relative catch by fleet/gear is constant. When developing projections, NWFSC analysts rely on both recent catches by fleet, which can be well below catch limits, and information from the PFMC Groundfish Management Team on expected catches by fleet based on developing fisheries, competing opportunities, etc. For example, the Groundfish Management Team reported expected decreases in fishing effort due to COVID-19 and the resulting Executive Order 20-12 (Groundfish Management Team, 2020). Additional science center responses on this topic are summarized in the appendix.

In their response to this question, the NWFSC also highlighted a catch projection model produced by the West Coast Regional Office for the quota-based groundfish fishery. Using the results from the stock assessment process, this model can be used to project catch and landings by fleet and individual vessel (Matson et al., 2017). Fleet size and the distribution of fleet allocations between vessels are assumed to match the most recent year of available data. However, correction factors can be applied if data from a different time period (e.g., based on market conditions) more closely approximates the future conditions of the projection (Matson et al., 2017). The model parameters can be adjusted to reflect expected changes in the fishery, such as changes in demand for certain groundfish species. The flexibility of this projection model helped produce highly accurate projections that were used for groundfish fishery management.

4.1 Stock assessment projections can be improved by addressing assumptions about socioeconomic influences, e.g., future fishing practices assumptions. Many assumptions of stationarity are not accurate, and assessments can better represent reality by using socioeconomic data and analyses. Predictive power could improve with more realistic representations of changes in socioeconomic variables over time. One SEASAW presentation described a case study in the Atlantic sea scallop fishery, where management is area-specific (Hart, AB13). The assumption that fishing mortality is uniform is not valid due to spatial differences in fishing effort. When projecting where fishers will fish, stock assessment scientists need to predict human behavior. A spatially explicit projection model is in development that will have a much finer geographic scale (GeoSAMS). Explanatory variables include landings per unit effort (LPUE), distance offshore (steam time to fishing ground), and vessel size. Economists who attended the workshop noted that modeling individual fisher choices is more accurate. Aggregating data takes away the scale at which operational decisions are made.

More communication between economists, other social scientists, and stock assessment scientists is needed to address assumptions made during the development of projections (see next section). Generally, there is substantially less peer review of the projections compared to the assessment models. Assessment authors have to make assumptions that are highly influential. When appropriate, economists and other social scientists should inform assumptions about factors like the proportion of the ACL that will be caught in the future based on projected fisher behavior (Pfeiffer, AB9). Input from economists and other social scientists could also be used to incorporate more uncertainty into projections (i.e., different projection scenarios), or the additional uncertainty could be illustrated using decision tables.

4.2 Projections should be conducted by interdisciplinary teams of stock assessment modelers, ecosystem modelers, economists, and other social scientists to provide catch advice for multiple, interconnected stocks simultaneously (Lynch, AB19). Operational projecting tools need to be developed that link human behavior (i.e., fishing practices, management regulations) to multiple target species dynamics. These tools will not only produce more accurate projections in a changing world, but will also evaluate possible impacts of different projected scenarios on the economy, fishing industry, and affected communities (Lynch, AB19). These tools could produce projections of total catches in an ecosystem, and maximize system-level production of interacting target species by accounting for trade-offs. Where system dynamics are less understood (e.g., data-poor fisheries), non-mechanistic modeling approaches could be applied (Ye et al., 2015).

A germane example of an interdisciplinary modeling effort is the Alaska Climate Integrated Modeling (ACLIM) project, which provides a common analytical framework for climate, biological, and socioeconomic models in the eastern Bering Sea (Hollowed et al., 2020). The ACLIM team includes stock assessment scientists, fisheries biologists, economists, ecosystem modelers, and oceanographers. This integrated modeling approach ensures that responses and feedback mechanisms in the social-ecological fisheries system are accounted for when projecting stock dynamics. Notably, this multi-model approach includes exploring linked spatial economic and biological models to project fisher behavior with regards to fishing time and location. The multidisciplinary team ensures that the best available biological, ecosystem, and socioeconomic science is included in fisheries management in the eastern Bering Sea. Similar efforts are now also underway in the Gulf of Alaska (Gulf of Alaska Climate Integrated Modeling Project), the California Current (Future Seas), and the Northeast United States (Northeast Climate Integrated Modeling [NCLIM]).

4.3 Multispecies projections should be developed that incorporate interactions between species, market demands, and fisher choices. Projections are typically for single species, but those species are part of multispecies assemblages. Single species projections do not account for feedback between market demands for co-caught species, or fishers' incentives to participate in different fisheries. Gear- and fleet-switching behavior should be included in forward projections for multispecies fisheries (e.g., West Coast Groundfish). Incorporating interactions between human and fisheries systems can help explain changes in fishing mortality among correlated fleets and/or species. For instance, rockfish bycatch increases in the Alaska Sablefish Fishery due to fishers avoiding small sablefish and fishing deeper. There is a need to better understand which species and/or stocks are caught together and which trade off in catch. In another example, Dover sole is generally co-caught with West Coast sablefish (Hicks & Wetzel, 2011), and therefore Dover sole catches are dependent on the results of the sablefish TAC. The projected catch of dover sole should take the more restrictive sablefish ACL into account rather than assuming future dover sole landings will be similar to recent years (Hicks and Wetzel 2011).

A case study presented at the workshop focused on a bioeconomic model of recreational angling that was developed to account for multispecies interactions (Steinback, AB17). In the Northeast United States Groundfish fishery, changing regulations for Gulf of Maine cod could affect haddock mortality. The economic sub-model estimates the probability that a prospective angler trip will happen, i.e., the demand for recreational fishing trips (M.-Y. Lee et al., 2017). The bioeconomic model is used to simulate angler behavior under different projected stock structures and regulations. A choice experiment survey provides information on future fishing effort, and is the foundation of the recreational behavioral model. In a comparison of the age-structured stock assessment projections (without economics) to the bioeconomic stock projections, the authors showed that the bioeconomic model can capture how the regulations affect the recreational selectivities for cod and haddock. In this two-species example, this model can address these multispecies interactions.

Managing fish on a population-by-population basis can lead to sequential overfishing and resulting economic losses (Link & Watson, 2019). Sequential overfishing has been a problem in multiple U.S. fisheries, including for red snapper in the Southeast (Schirripa & Legault, 1999). The portfolio effect can be used to understand changes in fishing mortality among correlated fleets/species/stocks, and how coordinated management approaches could lead to increased stability of fisheries yields. If different fleets, species, or stocks respond in synchronous ways to stressors, the buffering effects of diversity are reduced (Schindler et al., 2010). Likewise, if fishers change their behavior over time to target fewer stocks, the corresponding fishing industry will be more vulnerable to fluctuations in the abundance levels of those stocks.

Limited time and resources are challenges to better integrating multispecies analyses for management use. However, the lost precision in not fully utilizing this information in projections can necessitate larger buffers between target and limit reference points, resulting in potential foregone profits. Stocks will need to be prioritized for inclusion in multispecies modeling efforts by balancing the resources required with potential benefits to fishing communities and ecosystems.

4.4 Potential socioeconomic impacts of alternative projection scenarios should be provided to support management decision-making, e.g., when councils are determining the acceptable risk of overfishing. Expected differences in revenues and fishing costs, based on projected catch alternatives, should be regularly provided so that the councils have enough information on the possible socioeconomic impacts of different scenarios. When comparing projected alternatives, analysts need to understand stakeholder preferences by conducting regular interviews. This additional information should be provided to the councils alongside projections to support management decisions. In the Southeast, a decision support tool was developed for use by non-experts, allowing managers and stakeholders to update projections with fleet-specific allocation proportions, expected discard mortality rates, and population targets. NOAA Fisheries regional office staff can run the stock assessment projection under alternative regulations to support management decisions, particularly when there is a multi-year delay between update assessments. Currently, the projections are limited in terms of including feedback mechanisms between biological and socioeconomic variables, and the tool was designed for assessments conducted using Stock Synthesis 3.24. Future work is planned to update compatibility of the tool with Stock Synthesis 3.3 and to incorporate environmental and management uncertainty into projections. Additional efforts should determine whether the decision support tool should be updated to incorporate anticipated changes in fisher behavior in response to alternative allocation scenarios.

Testing and expanding stock assessment projections

When projections provide incomplete management advice and assessment models do not capture underlying processes that are important for estimating fisheries management parameters, then more complex representations of future socioeconomic dynamics in projection models may be necessary. Stock assessment projections do not currently project what will happen with the fishery, such as future changes in fisher behavior and the expected differences in revenues. Projections that account for interactions in fisheries SES are an expanded product that will require more resources, but may provide better advice for managing fish stocks. Sensitivity analyses should be conducted to test projection output variability in response to socioeconomic assumptions to assess whether more complex models may be beneficial. Different projection scenarios (i.e., assumptions) can be run and results can be shown as a decision table to highlight the major uncertainties. Ideally, the projections should incorporate uncertainty from different assumptions (e.g., how fishery selectivity will change based on projected fisher behavior) into the projected catch advice. However, assessment scientists should take care to not embed their own value choices or risk preferences in the alternatives presented to councils. The performance of projections should be evaluated once new data are collected. There should be greater use of retrospective out-of-sample prediction (leaving out some new data) to learn about system drivers and evaluate the prediction skill of projections.

5. Harvest Control Rules:

Socioeconomic information should be included in the development of harvest control rules (HCRs), the process for choosing between alternative HCRs, and the review of existing HCRs.

Stock assessment models are used to estimate the target and limit reference points for the target stock, which are typically used as inputs to the HCR (Punt, 2010). Because the HCR in combination with the resulting stock status from the assessment model determines the catch advice provided to management bodies, we are including recommendations for HCRs as a section in this document. Importantly, socioeconomic data and models can be particularly useful when developing and selecting HCRs since the best HCR depends on the management objectives for the stock and the data available (Punt, 2010), as demonstrated by the examples below.

5.1 Changing management regulations, such as size limits that influence discarding behavior, necessitate revisiting control rule calculations and scientific advice with collaboration between economists, other social scientists, stock assessment scientists, and managers. When regulations such as minimum size limits change, discarding practices are altered, and the MSY for that stock changes. This information needs to be provided when surveying fisher preferences for alternative management regulations. The corresponding changes in fishing effort and expected fisher compliance with regulations should also be incorporated into ABC calculations.

In the results for the survey of current practices, only the SEFSC indicated using socioeconomic information in the development of ABC through SSC ABC decision tools. Specifically, the South Atlantic Fishery Management Council (SAFMC) incorporates productivity-susceptibility analyses into the ABC control rule that determines the acceptable risk of overfishing (SAFMC, 2011). The "susceptibility" portion of these analyses are partially determined by the desirability of the stock, which includes market desirability (commercial catch value of the fishery in dollars per pound) and historical importance of the stock (MRAG, 2009). A revision to the amendment for the ABC control rule is in progress, which includes an alternative that would remove the stock productivity and susceptibility analysis from the uncertainty determination. Instead, the SAFMC would choose a risk of overfishing (P*) that would be added to the SSC uncertainty adjustment (SAFMC, 2019), similar to other fishery management councils. The SAFMC's proposed approach for determining the acceptable P* still includes human dimensions attributes to help determine the size of the buffer between the Overfishing Limit (OFL) and the ABC. For example, one attribute considers the importance of a species to the total annual revenue of all the species in the fishery management plan (FMP), calculated as the percentage of total annual revenue (see the story map on the Comprehensive ABC Control Rule for more information).

5.2 When appropriate, socioeconomic metrics should help inform each council's determination of the acceptable risk of overfishing (P*). In some regions (e.g., Pacific Council), the council selects a P* based on the anticipated yield produced. Both the NWFSC and the SWFSC work with the PFMC to manage fisheries on the West Coast of the United

States. In the development of ABCs, socioeconomic information may affect the PFMC's choice of the level of acceptable risk (P*), which, along with scientific uncertainty (σ), determines the buffer between the OFL and the ABC (Prager & Shertzer, 2010). A description of how the PFMC implements its P* ABC Control Rule can be found in Amendment 23 to the Pacific Coast Groundfish Fishery Management Plan. Briefly, the SSC characterizes the scientific uncertainty of the OFL estimate, which is related to a range of P* values. The buffer between the OFL and the ABC that would result from each P* value in the range is calculated, and then based on this information, the Council selects a preferred P* value (PFMC, 2010). A more complex analysis that includes additional stock-specific information to help the Council determine P* (e.g., information about the relative amount of annual revenue generated by the stock) could be more useful for achieving the Council's management objectives. Other councils select the most appropriate P* based on scores for different criteria such as data limitations or increased susceptibility of the stock to fishing pressure (SAFMC, 2011). Documenting the criteria scores that are used to select the P* also increases transparency, and could facilitate stakeholder engagement and support for the resulting harvest specifications.

5.3 HCRs for transboundary stocks should be developed in collaboration with connected nations, and include input from economists. Stock growth and mortality in one jurisdiction can influence the amount of fish available in an adjacent jurisdiction, depending on the level of connectivity. Different fisheries policies and a lack of cooperative management agreements hinder the sustainable and efficient management of transboundary stocks. Fishers can be constrained by where their operations are located, which determines what portion of the catch they can access. The United States and Canada are collaborating to develop a coastwide model for Alaska sablefish. The Alaska and coastwide models will then be compared to determine which model performs the best. In addition, there are ongoing efforts to better integrate stock assessments among Alaska, the West Coast, and Canada. There is a treaty for Pacific hake with established allocation percentages for Canada and the United States (Agreement with Canada on Pacific Hake/Whiting, 2003). Recent work has shown that warmer water temperatures are associated with higher biomass of older fish in Canada (Malick et al., 2020), which may lead to possible changes in the total allowable catch (TAC) percentages for the United States. and Canada. Developing harvest guidelines for transboundary stocks is also an issue for halibut in the North Pacific and for coastal pelagic species along the west coast of North America.

The economics literature can help inform joint harvest agreements and management of transboundary resources, including highly migratory species. The economics of the management of transboundary fishery resources have been reviewed previously (Miller & Munro, 2002), and the authors demonstrate how a combination of economic models of the transboundary fishery and game theory can be used to predict the consequences of non-cooperation. The authors concluded that, with very limited exceptions, cooperative agreements with adequate flexibility to respond to environmental shocks are essential for successful management of the common property resource (e.g., producing profits for the connected nations while avoiding overexploitation). More recent work supports these conclusions (Palacios-Abrantes et al., 2020; Sumaila et al., 2020), and shows how intensifying impacts of climate change could destabilize current joint management agreements between nations. The effects of climate change on fish stocks (e.g., shifting population distributions) will exacerbate the difficulties of managing transboundary stocks (Karp et al., 2019), making international cooperation more valuable and necessitating more frequent revisions to joint harvest agreements in many cases.

5.4 Socioeconomic triggers for the review of HCRs should be established. Rules should be reassessed and updated when they are no longer meeting management objectives, or when objectives change. The SES may shift outside of the bounds considered during the analysis when the HCR was developed, and stakeholder preferences for acceptable ranges of economic performance metrics may shift. A possible application of this recommendation pertains to the red tide case study presented at the workshop (Sagarese, AB8; Sagarese et al., 2021). The possibly increasing frequency of severe red tide events needs to be accounted for in the management plan for red grouper and other affected species. One way this could be accomplished is by including a red tide-related trigger in the HCR to reduce the allowable catch when red tide-induced mortality is expected to be high, and stakeholders are reporting low stock abundance. Results from a simulation study of different HCRs for Gulf red grouper under uncertain natural mortality events (i.e., red tides) demonstrated that precautionary catch limits that account for uncertainty from unknown impacts of red tides could improve management of the stock (Harford et al., 2018). An alternative approach of employing reactive decision-making (where the occurrence of a severe red tide triggers a new stock assessment) was also supported by the simulation results. Additional socioeconomic data streams that can be used to trigger adjustments to catch limits when warranted by changes to the SES should be explored further.

Future research directions in this area should develop improved economic analyses that take into account the short- and long-term impacts of different HCRs. The selection of uncertainty buffers in rebuilding timelines can be improved, possibly by incorporating more socioeconomic considerations. Control rules that incorporate socioeconomic information directly in the rules themselves should be explored. Phase-in changes for control rules may be optimal in some scenarios, and methods should be developed to analyze the phase in of changes.

5.5 Socioeconomic information and analyses should be included in Management Strategy Evaluations (MSEs) when alternative HCRs are being evaluated to help managers choose between alternative rules. Model-based methods such as MSEs are increasingly being used to assess the multifaceted costs and benefits of potential management actions. Because fisheries are managed to produce biological, economic, and social benefits, more mathematical models that include economic and social components should be used. For example, bioeconomic MSEs can be conducted using the simulation model FLBEIA (Bio-Economic Impact Assessment using the Fisheries Library in R (FLR)), which can incorporate interactions between multiple stocks and multiple fishing fleets (Garcia et al., 2017). Integrated ecological-economic fisheries models (IEEFMs, a synonym for bioeconomic models) have been reviewed in detail, and the factors that improved implementation included involving stakeholders directly in the development and use of IEEFMs (Nielsen et al., 2018). Increased communication among modelers, managers, and stakeholders can yield both improved models and more effective implementation of scientific advice.

Risk analyses for alternative control rules should be conducted to ensure that all important variables with available data are included in the MSE. More interdisciplinary MSEs should be implemented to balance different stakeholder objectives and inform allocation discussions. The socioeconomic considerations of alternative harvest guidelines should then be provided to councils. The Atlantis ecosystem model provides a potentially promising framework for incorporating complex interactions and economic processes, including quota trading (Fulton et al., 2007), in assessments of alternative management strategies. For example, the Atlantis model developed for the Gulf of Mexico was used to evaluate the performance of a blanket, two-point threshold harvest control rule to manage several reef fish species (Masi et al., 2018). The exploitation submodel included spatial fishing fleet dynamics to account for the ways fleets co-catch reef fishes, which contributed to the final realized fishing mortality (Masi et al., 2018). A more thorough discussion of possible economic contributions to MSEs may be found in the MSE Economics workshop report (Stohs et al., in prep). While almost all science centers reported in the survey of current practices for SEASAW that they use socioeconomic information in MSEs, there remain many opportunities for improvement and research to explore alternative approaches.

An example presented and discussed at the workshop was the West Coast sablefish economic MSE that is currently being developed (Krigbaum, AB6). The complex vessel dynamics in this fishery need to be included in the model to appropriately estimate selectivity and the fishery behavior. Sablefish are targeted by different fisheries, permits, and gear types, and there is a gear switching provision that allows fishers with trawl quota to catch sablefish using longline or pot gear. While sablefish caught using longline or pot gear fetch higher prices, other marketable species are caught alongside sablefish using trawls so that the interaction of different prices and fishing conditions leads to the actual gear-specific balance of the fishery in a given year. Quota trading between vessels with any of the three legal gear types allows the allocation of fishing effort by gear type to be partially determined by these market forces. Krigbaum and Anderson (CJFAS, 2021) have developed a methodology that incorporates the gear-specific prices and size composition of catch to construct expectations about revenue from gear-specific sablefish removals given the current state of the sablefish market. Extending their work to include probabilistic expectations about the state of future sablefish markets could allow MSE teams to form expectations on the future allocation of effort between gear types. In this fishery, different gear types have a strong influence on size composition of catch, with pot and line gears landing more large fish on average, so understanding the sablefish market would allow researchers to predict gear-specific effort and improve stock assessments by conditioning on the resulting behavioral dynamics. Including these dynamics in the MSE model can also help managers understand which communities are more impacted by changes in regulations, markets, and stock conditions.

Social science data were used in the Atlantic herring MSE to assess alternative harvest control rules. Public meetings were held to engage stakeholders directly in the MSE process and communicate trade-offs of alternative control rules to stakeholders using different graphical representations (Feeney et al., 2019). Attendees helped identify acceptable ranges for performance metrics that informed the MSE models. For example, stakeholders expressed interest in the stability of net revenues as a performance metric. Feedback from stakeholders was used to build the closed-loop simulation portion of the MSE (Deroba et al., 2019). Notably, the MSE also included an economic submodel, enabling economic performance metrics such as median revenues to be included in the evaluation of alternative HCRs. The inclusion of social science in this process helps to more effectively capture the diversity of preferences stakeholders have about management trade-offs, allowing MSEs to explore the most relevant trade-offs.

MSEs often focus on economic outcomes, but a more holistic and representative approach would include the many dimensions of well-being that other social scientists have found people derive from fisheries participation and use (Szymkowiak & Kasperski, 2021). Avenues for including additional social science information (other than economic data alone) and linkages in MSEs, such as indicators of community well-being with connections to fishery participation, should be developed where appropriate. Other important social linkages may include the ability to enforce new regulations, and accounting for unregulated fishing. Further, the efficacy of hard closures or hard caps should be tested with MSEs to see if other regulatory options would work better to meet management objectives.

Socioeconomic data are also needed to evaluate trade-offs in rebuilding plan objectives for overfished stocks, such as reducing year-to-year changes in catch, increasing spawning stock biomass by a percentage per year, altering the length of time until the stock is above the biomass reference point, etc. Average long-term catch or effort and the resulting harvest rate needs to be balanced with the stock rebuilding time to a target level (Davies et al., 2008). Notably, it is difficult to evaluate the lost benefits associated with catch variability directly. Industry has stated that variable catches lead to lost markets, but it is rarely possible to quantify this effect. There are also many different ways to measure variability, including the variance of catch or revenue over time, the frequency of significant changes in catch, whether there are fish available for harvest through the season, or the frequency of falling below some critical level. Working with stakeholders to define and track measures of variability and related objectives would be valuable.

The social and economic analyses of rebuilding plan alternatives have been reviewed thoroughly, and the resulting report shows that a lack of socioeconomic data and analyses to provide the appropriate socioeconomic context can result in increased tensions between managers, fishers, and other stakeholders (National Research Council, 2014). If the overfished stock is part of a multispecies fishery, then economic data and analyses will be crucial for quantifying the foregone profits from the stocks that are not overfished. Data on fisher incentives and behavior should be included to understand changes in fishing effort resulting from regulations – and how this will impact the time required to rebuild.

5.6 Allocation reviews should be conducted more frequently, when appropriate, to assess community impacts and evaluate whether management measures achieve stated objectives *(e.g., by looking at engagement and dependency relative to revenues)*. Allocation reviews are conducted every five years for limited access privilege programs to evaluate whether actions are meeting council objectives (16 U.S.C. 1853a MSA § 303A), but these trends may need to be assessed more frequently. Climate change will impact fish abundance and distributions (Karp et al., 2019), as well as human populations in coastal areas (Hauer 2017), which may lead to changes in demand for catch over time. These changes to fisheries SES may not align well with a static allocation review period for some fisheries. Stakeholder feedback on the frequency of allocation reviews should be collected (Lapointe, 2012), since the ideal frequency may vary across different fisheries and communities.

Biologists and social scientists (including economists) should work together to provide advice on how different fleet allocation scenarios and resulting changes in fishery selectivity will impact population projections, and how socioeconomic information can help identify the optimal allocation that maximizes societal value. Further research is needed to determine how to best use socioeconomic analyses of impacts (e.g., Impact Analysis for Planning (IMPLAN) modeling, Leonard and Watson, 2011) and value to inform allocation discussions. In Alaska, economists have estimated the economic impact from particular fisheries, with the most effort focused on the economic impacts of pollock (Seung & Ianelli, 2016; Seung & Waters, 2009) and the Amendment 80 fishery (Waters et al., 2014). Researchers in Alaska have also used state data sources to better understand how fishing income benefits communities of different sizes (Watson et al., 2021). Research efforts such as these should continue to be supported to better inform allocation reviews in all regions.

5.7 Efforts to define and prioritize social objectives should be supported. Robust social science data are needed to define social objectives (in addition to economic objectives), and measure the social benefits of different management alternatives, e.g., allowing increased catch and/or season length. Identifying social objectives and methods to evaluate the social benefits of alternative management measures (such as harvest control rules) will facilitate fisheries management that produces positive social outcomes. Extensive work on this subject has been conducted, and the objectives identified at a workshop with managers from different Australian jurisdictions provide a useful starting point (Pascoe et al., 2014). However, the prioritization of social objectives alongside sustainability objectives in different regions requires considerable discussion between the managers, policy makers, and stakeholders within the relevant management area. A relatively new ICES working group, WGBESEO, is developing approaches to balancing economic, social, and ecological objectives. The methodology developed by this working group can be used to identify and classify these objectives in different governance and geographic contexts. Interdisciplinary groups working to adapt this methodology to their region in the United States may benefit from collaborating with regional IEA teams.

There are many challenges associated with quantifying and measuring conservation values and socioeconomic values. For example, established methods are needed to measure the benefit of leaving more fish to sea lions to help this protected species recover vs. allowing fishers to catch more fish. If there is harm to a protected species, then this often outweighs economic objectives. Additional guidance is also needed to measure and balance different objectives for recreational and commercial fishers, and to properly address trade-offs, including trade-offs with yield.

6. Communication with Managers and Stakeholders:

Stock assessment scientists, economists, and other social scientists should work together to communicate socioeconomic indicator trends important for interpreting scientific advice from stock assessments to managers and stakeholders.

It is important to develop useful socioeconomic indicators corresponding to the fishery management objectives for individual stocks. There are three key issues: finding the right indicator, weighting multiple indicators appropriately over time, and then communicating trends clearly, with appropriate caveats. A number of socioeconomic indicators have been developed and explored by academic and agency scientists. For example, in response to the need to assess management system performance with respect to community, economic, and ecological objectives, 68 metrics were chosen to evaluate individual fisheries systems (Anderson et al., 2015). The authors applied these fishery performance indicators to 61 case studies (including both developed and developing countries) to measure the benefits created in fishing communities. In Anderson et al. (2015), the community and economic indicators are scored at the fishery level, which may be partitioned by fleet, market, or jurisdiction rather than by the individual fish stock level that is used for stock assessments. Additionally, NOAA Fisheries scientists have developed social indicators of fishing community well-being, including measures of fishing engagement and reliance (Jepson & Colburn, 2013). These different examples and applications of socioeconomic indicators provide a useful starting point for identifying potential indicators that can be used to improve the interpretation and communication of assessment results for individual stocks.

6.1 Relationships between potential socioeconomic indicators and stock dynamics should continue to be explored. Finding the right indicator involves determining the strength of the link between the socioeconomic indicator and the stock parameter, and evaluating the consistency of this relationship over time. For example, the own-price elasticity of open access supply (which relates the change in quantity of product supplied to a change in price) can be used as an indicator of resource abundance. Previous work has demonstrated how in some cases the own-price elasticity of open access supply can provide the magnitude and direction of expected long-run equilibrium stock abundance levels (Rudders & Ward, 2015). Changes in industry investment strategies could also signal fishery changes. Other potential socioeconomic indicators include observing changes in days-at-sea to catch the same amount of fish, measures of the social connectivity of the fleet, difficulty recruiting crew, and decreasing revenues alongside a prolonged fishing season. The directionality of some socioeconomic indicators remains difficult to interpret, or the linkage between the indicator and stock biology may be stock-specific. Is a decrease in employment the result of new investments to increase fishing power in response to optimism about a stock, or a decline in the economic benefits coming from a stock? More collaborative research between stock assessment scientists, economists, and other social scientists is needed to identify and understand linkages between socioeconomic indicators and stock dynamics. This work is increasingly valuable in a dynamic environment in which these signals may be observed in years when biological surveys are not conducted.

A consistent process for identifying potential socioeconomic indicators, narrowing the list of indicators to those with demonstrated linkages to stock dynamics, and communicating these socioeconomic indicator trends to councils is needed. An example of such a process that may be applied to other regions is the Ecosystem and Socioeconomic Profile (ESP), which is a standardized framework developed for North Pacific fisheries to facilitate the integration of ecosystem and socioeconomic considerations in the stock assessment process. The ESP process involves a metric assessment of quantitative stock-specific measures that connect socioeconomic processes to stock vulnerability or resilience. This is followed by an indicator assessment where time-series plots are made of the indicators that are useful for informing the stock assessment (e.g., the data are regularly updated and the relationship over time is consistent). Appropriate statistical tests are applied to the group of indicators depending on the level of data available. Finally, results and recommendations are shared in an appendix document to the stock assessment report (see examples in the reports for sablefish, walleye pollock, and Saint Matthew Island blue king crab). Following completion of the ESP or other regional process, additional research projects should be conducted to explore how the socioeconomic data trends may be included in the assessment model or used to help configure an assessment model.

6.2 Stock assessment scientists, economists, and other social scientists should work with managers to determine the most efficient and effective ways to communicate scientific advice. Science center staff and council staff should collaborate to communicate socioeconomic risks to councils. There is a need to standardize how stock-specific socioeconomic indicator trends are communicated to managers and how connections between socioeconomic trends and biological trends are presented. This will reduce the reliance on anecdotal information that is not representative of the broader fishery participants or fishing community.

In Alaska, risk tables are presented to the North Pacific Fishery Management Council (NPFMC) to categorize information not included in the main stock assessment model by different levels of concern along four categories: model performance, population dynamics, ecosystem information, and fishery performance (Stram, AB16; Dorn & Zador, 2020). Based on this information, the SSC or Plan Team may reduce the ABC from the ABC_{max} and the Council may set the TAC below the ABC. The cause of any disconnect between the provision of socioeconomic information and the timeline for management decisions should be identified in each region, if applicable. Automating the data reporting process for stock assessments and economic performance metrics could facilitate more timely and efficient communication.

During workshop discussions, economists described different processes for communicating stock-specific socioeconomic indicator trends to their respective councils. There is a Socioeconomic Panel for the South Atlantic Fishery Management Council SSC that provides scientific advice on the social and economic impacts of fishery management measures. Economists consult with this subcommittee before presenting information to the Council. To help facilitate communication, economists may develop analogies to help explain economic concepts to policymakers. One economist in attendance had served on the Highly Migratory Species Management Team of the Pacific Council, which does not have a standardized framework for communicating/receiving socioeconomic information as part of the assessment cycle. This economist started the discussion about socioeconomic risks in the Management Team meeting and eventually discussed these issues in the Council meeting. While established communication processes exist for some councils, others would benefit from increased coordination between stock assessment scientists, economists, and other social scientists.

6.3 Methodologically sound socioeconomic data and trends should be used to inform interpretations of advice, uncertainties, and risks, and to provide both systematic and anecdotal context. During workshop discussions, attendees drew attention to the issue of using anecdotal social science information vs. peer-reviewed and statistically rigorous social science data streams. The reality is that in the absence of methodologically sound information, anecdotal information often influences SSC recommendations. There have been cases when larger buffers have been recommended based on a single fisher's testimony. With this in mind, it is important to collect the social science data needed to demonstrate broader spatiotemporal trends in addition to individual fisher accounts.

The AFSC includes trends in employment/jobs, ex-vessel prices, size-specific price information (for sablefish only), and revenue in supplemental documents to the stock assessment report. Social scientists also provide information on social conditions affecting fishing communities and fishers to the Council that may be considered during the TAC setting process. Four different documents submitted with the stock assessment report contain this economic and social science information: the Ecosystem Status Reports, Economic Status Reports, Economic Performance Reports, and ESPs. Ecosystem Status Reports (Slater et al., 2017) support EBFM in part by describing large-scale trends in physical, biological, economic, and social factors (e.g., trends in fish prices, unemployment rates, and school enrollments). Economic Status Reports provide summary statistics on multiple economic factors (e.g., ex-vessel prices, revenue, and first wholesale production volume) to describe economic activity and output. While Economic Status Reports include all fisheries and sectors within larger management groupings (e.g., all groundfish fisheries), Economic Performance Reports are completed for individual stocks and are usually included as appendices to stock assessments (e.g., Fissel, 2020). Lastly, ESPs are also provided as appendices to certain stock assessments, but serve to identify specific socioeconomic indicators that could be integrated in the stock assessment process (Shotwell, 2018, Shotwell & Downs, AB15). By collating time series of economic and social factors, documents such as these can help regional scientists and managers identify data collection priorities to better support council decisions.

6.4 More interdisciplinary teams should collaborate in all regions to create system-level communication products such as ESPs and conceptual models to improve and standardize communication of socioeconomic indicator trends to managers and stakeholders. In the workshop survey, the AFSC reported that socioeconomic data types considered in ESPs include employment/jobs, ex-vessel price, size-specific price information, revenue, and exports. The NPFMC uses this and related information in various spatial and sectoral allocation decisions for managed species. For example, an MSE is being conducted for sablefish to evaluate apportionment options to be presented to the Council for area apportionment of Alaska-wide TAC based on biological ABC limits and fleet value, capacity, and community-related information. Socioeconomic data provide fishery managers with information on the relative value of catching certain stocks over others, the degree to which certain fleets or communities are dependent on those stocks, and who will reap the economic benefits. The existence of the 2 million metric ton OY or ecosystem limit on the aggregate TAC in the entire Bering Sea and Aleutian Islands system necessitates difficult Council trade-offs regarding the total amount of economic value that can be created by different TAC allocations, as well as the parties to whom that value flows.

Parallel efforts in the Northeast and Southeast involve the development of species-specific conceptual models as scoping tools for identifying important linkages between stock biology, the physical environment, and human systems (e.g., commercial profits, fleet dynamics). The summer flounder conceptual model was developed by an interdisciplinary working group of stock assessment and fisheries biologists, social scientists, and natural resource managers in response to a request from the Mid-Atlantic Fishery Management Council. The conceptual model and associated interactive visualization tool helped managers prioritize data collection needs and potential management actions, which will be tested using an MSE approach. Pilot conceptual models for the Gulf and South Atlantic stocks of scamp grouper were constructed to include physical, biological, socioeconomic, and regulatory drivers (McPherson & Karnauskas, 2021). These conceptual models can be used to identify socioeconomic linkages that could be considered for incorporation in the assessment model. Additional system-level communication products that show direct relationships with important socioeconomic indicators should be developed for priority stocks.

Socioeconomic indicator challenges

Concerns regarding interpreting the directionality of socioeconomic indicators were expressed during the workshop. For example, what do changes in prices mean for the health of the stock? How do we draw conclusions about socioeconomic indicator trends related to stock dynamics if different indicators are providing contrasting information?

At the workshop, participants expressed the need for the continued development of social science measures of fleet resilience to better couple these indicators with stock-specific information in the stock assessment process. Many social and economic indicators are available at the national or regional level, while fewer are available at the fishing community level for use in fisheries social impact assessments (Jepson & Colburn, 2013). Increasing indicator resolution further to the fleet level will be needed to understand linkages between fish stocks, fishing fleet dynamics, and the community economic impacts of policies such as catch shares and different allocations and policies related to spatial management (e.g., where wind energy facilities are sited).

As always, expanding the development of socioeconomic indicators to inform the stock assessment process takes time and resources. Opportunities should be provided for stock assessment scientists, economists, and other social scientists to collaboratively develop and investigate socioeconomic indicators with potential linkages to stock dynamics. Where possible, these efforts should be coordinated with regional IEA teams. More work is also needed to evaluate social (non-economic) indicators and how both stock assessment scientists and managers are interpreting them.

Conclusion

The SocioEconomic Aspects in Stock Assessments Workshop (SEASAW) was a national workshop attended by economists, other social scientists, and biologists from all regions of the United States. By combining results from a survey of the NOAA science centers and lessons learned from additional case studies in the literature, this report describes a diversity of socioeconomic methods and data that can be used to improve the stock assessment process. Implementing the recommendations from this report will require top-down support of new collaborations and strengthening existing collaborations between economists, biologists, and other social scientists, as well as support for additional socioeconomic data collection. Because fisheries are coupled SES, assessing fish stocks should involve more collaboration between economists, other social scientists, and stock assessment scientists at each step of the stock assessment process (Figure 3). Increased collaboration between disciplines can result in multiple improvements to the science used to support stock assessments, including better data on fishing practices (Recommendation #1.1), more accurate processing of CPUE time series (Recommendation #2.2), enhanced stock assessment models (Recommendation #3.1, 3.2), and biomass projections informed by more realistic assumptions about future fishing behavior (Recommendation #4.1).

Increasingly complex modeling efforts also require additional time devoted to the development and maintenance of modeling tools. Designated resources will be required to support integrated modeling efforts for stock assessments. Some recommended changes may result in efficiencies, such as standardized communication products for socioeconomic indicator trends and automated reporting mechanisms. However, this would not increase communication efficiency if leadership then expects more stock assessments or the same level of work with fewer staff members.

Before additional stock assessments are expanded to include more socioeconomic data and/or methods, pilot projects should be supported to develop good practices that can be shared across regions. There is an existing process to prioritize stock assessments in each region which includes upgrading assessments to incorporate new data types and methods (Lynch et al., 2018; Methot, 2015). This prioritization process provides an excellent starting point for determining which stocks would most benefit from expanded socioeconomic considerations. Some of the factors used to prioritize stocks are socioeconomic in nature and relate to the economic and cultural importance of the fishery. In addition, the stock assessment prioritization process is used to develop target assessment frequencies. Economics can also help determine the optimal frequency for updating assessments (Hutniczak et al., 2019). Thus, better socioeconomic data can help improve the stock assessment process and the prioritization of stock assessments in multiple ways. Science needs to guide management, and help managers understand the impacts of their choices for each fishery and fishing community.

As more socioeconomic information is included in the fisheries stock assessment process, care must be taken to maintain clear lines between assessment and policy advice. Stock assessment research teams should ensure that socioeconomic assumptions (e.g., risk preferences) embedded in assessments are transparent. Only objective information should be provided for use during the stock assessment process, and careful documentation of the justification for decisions made regarding data processing and analysis should be provided in the stock assessment report (or accompanying appendices).That said, fisheries are coupled SES and an accurate understanding of these systems requires socioeconomic as well as biological information.

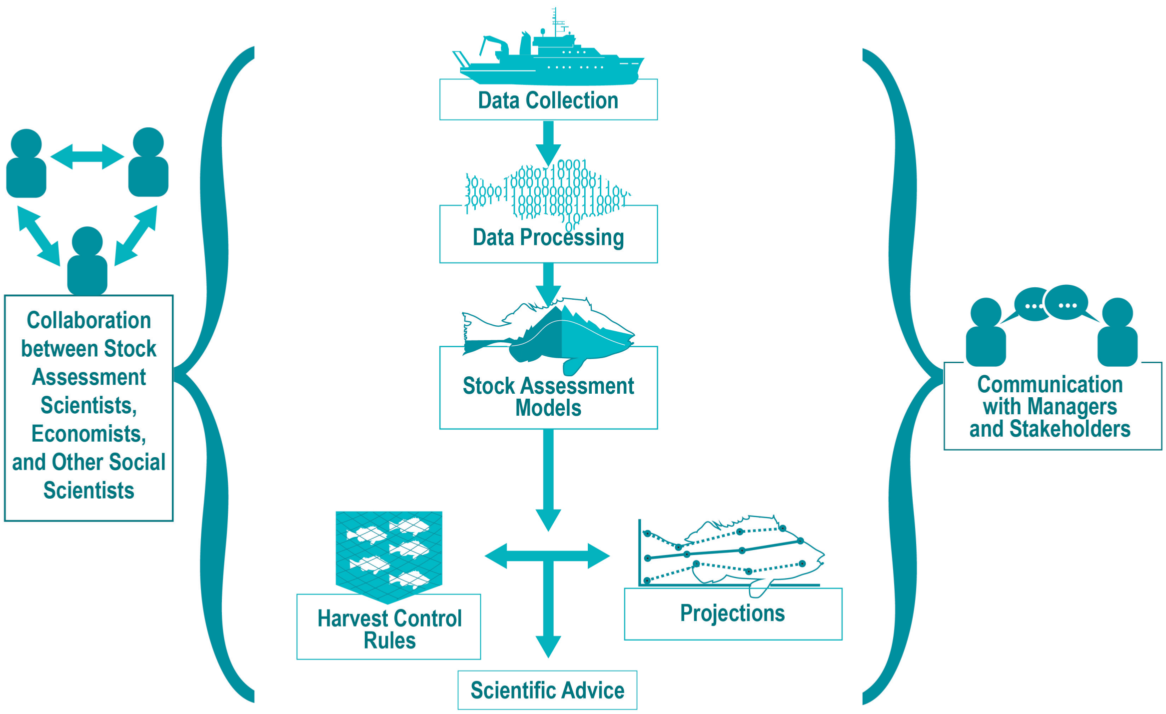


Figure 3: *The recommended future fisheries stock assessment and fishery evaluation process, with economists and other social scientists fully integrated in each step of the process alongside stock assessment scientists.*

SEASAW considered commercial, recreational, and subsistence fisheries. Additional work is needed across all regions to consider the relationships among all of these fishing sectors, stock conditions, and the benefits derived from fishing opportunities. Future integration of biological and socioeconomic research will be advanced both by going deeper in existing interdisciplinary research areas and by considering new directions.

This workshop provided a valuable opportunity for stock assessment and ecosystem scientists to interact with economists and other social scientists. Like stock assessment models, ecosystem models make assumptions about the species caught by different fishing sectors. More work connecting fishery behavior to fish stocks will also be particularly useful for improving ecosystem models across regions.

Ongoing global environmental change is elevating the need for better integration between socioeconomics and biology in the fish stock assessment process. During the first year of the COVID-19 pandemic, many NOAA Fisheries research surveys were canceled. In addition, fisheries observers were prevented from deploying on vessels for months in some regions due to safety concerns and travel restrictions. Increasing water temperatures, rising sea levels, ocean acidification, and the loss of sea ice are all influencing the distribution and abundance of species, and ecosystem functions. The scale of these changes will likely necessitate enhanced observations of natural resource systems to detect critical differences as soon as possible. When traditional fishery-independent and fishery-dependent data sources for stock assessments are unavailable, socioeconomic data streams (e.g., skipper surveys) could provide crucial information for timely management decisions. In order to utilize socioeconomic data sources as part of a resilient stock assessment process, socioeconomic surveys and research need to be supported and, in some cases, expanded. Accomplishing this will require more cross-disciplinary collaboration and stakeholder engagement.

As this report indicates, there is a wide diversity of applied research occurring across management areas. There is a need to promote consistent interaction between disciplines within and across regions. More effective sharing of knowledge and tools will minimize potential duplicated efforts and substantially increase the pace of progress. Ongoing collaboration can make socioeconomic input more consistent across assessments and help NOAA Fisheries better achieve its mission to provide sound scientific advice in support of an ecosystem-based approach to management.

Acknowledgements

We thank all of the members of the SEASAW steering committee and SEASAW attendees for their contributions to this Technical Memorandum. The complete list of contributors can be found in Appendix Table A1. Camille Jones provided critical support for the in-person workshop, including negotiating a contract for the meeting space, room block, and equipment rental. Dan Holland served as the technical reviewer for this Technical Memorandum, and his suggestions significantly improved the document. This project was funded by NOAA Fisheries Office of Science and Technology. The views expressed herein are the authors' and do not necessarily reflect the views of NOAA or any of its sub-agencies.

Appendix 1: Survey Results: Review of Current Practices for Incorporating Socioeconomics in the Stock Assessment Process at the NOAA Science Centers

Specific data call objectives included gathering information on:

A) The involvement of economists and other social scientists in the stock assessment process
B) Useful socioeconomic methods and data for improving stock assessments
C) Quantitative and qualitative use of socioeconomic data in the stock assessment process
D) Sources for socioeconomic data
E) Assumptions about socioeconomic influences in stock assessments and projections
F) Considerations of socioeconomic data, analyses, and results during the scientific advisory process
G) Requests from managers and stakeholders to incorporate socioeconomic considerations in the stock assessment process
H) Any existing plans to use socioeconomic data more frequently in future stock assessments
I) Protocols for prioritizing or determining which stock assessments are expanded to use socioeconomic data
J) Barriers to incorporating socioeconomic information in the stock assessment process.

A. Regional differences in where and how economists and other social scientists are involved in the stock assessment process

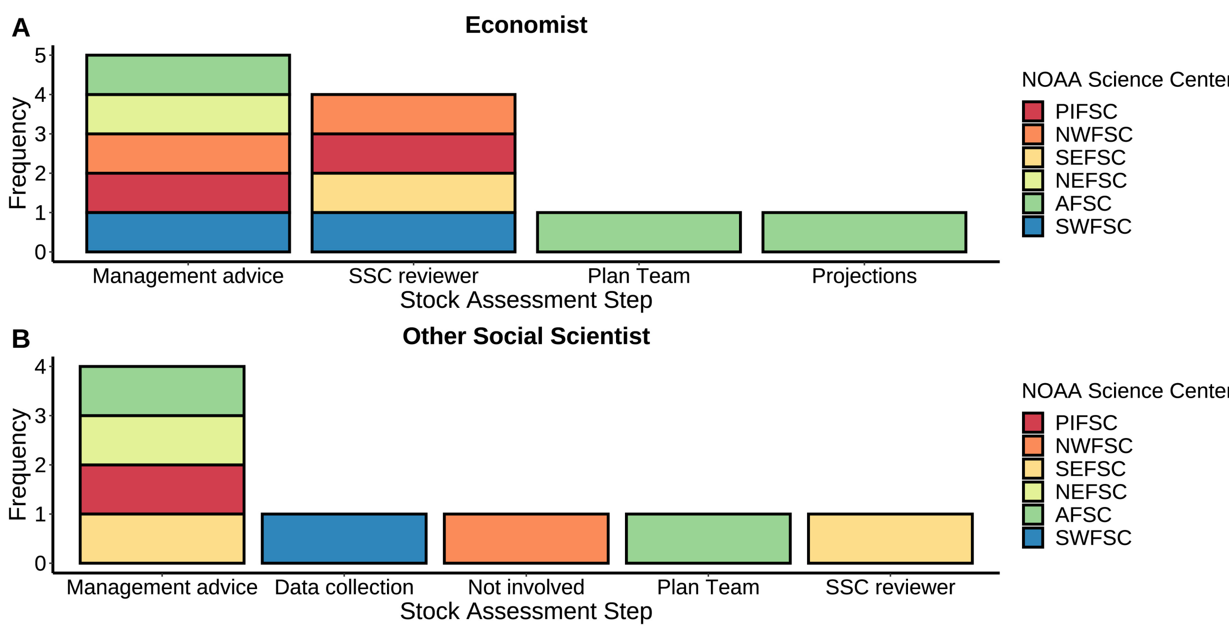


Figure A1: *Economists' and other social scientists' involvement in different steps of the stock assessment process, with colors corresponding to the six NOAA Fisheries science centers.*

The survey contained multiple questions related to the involvement of economists and other social scientists in the stock assessment process. Although a brief document was provided with examples of the types of responses we were looking for, the degree of involvement of different social scientist staff members in stock assessments was still up to the interpretation of survey respondents.

Results show that the step of the stock assessment process with the most economist and other social scientist participation is ‘management advice.’ Economists from five centers and other social scientists from three centers are involved in providing socioeconomic information to managers that is relevant to stock assessments.

At the PIFSC, one way economists and other social scientists contribute to management advice related to stock assessments is through the Western Pacific Regional Fishery Management Council (WPRFMC) Social, Economic, Ecological and Management Uncertainty (SEEM) working group that informs ACL/annual catch target (ACT) recommendations (see below section on communicating advice to managers). The SEEM working groups are formed by the Council staff on an ad hoc basis, and include fishers in the technical process of specifying ACLs. The first SEEM group was formed in 2011, and there have been four SEEM groups since 2015 (approximately seven SEEM groups in total). One economist has participated in a SEEM working group previously. Two SEEM working groups were formed in the past year, and one had a non-economist social scientist (a Guam Advisory Panel member).

At the AFSC, an economist has sat on each of the stock assessment review panels – the “Plan Teams” that are operated by the NPFMC – and more recently economists and other social scientists are actively involved in the development of ESPs as well as EPRs (see below section on communicating advice to managers). Economists are also involved in projections at the AFSC by providing projections of prices. For example, economists may extend the model to forward project both biological and economic time series. Other social scientists are not involved in developing stock assessment projections.

In the NEFSC, the primary way economists are connected to stock assessments is through analyzing the impacts of ACLs (based on stock assessments) set by councils. Other social scientists at the NEFSC also provide analyses of social impacts to councils from setting ACLs that are based on stock assessments. However, economists and other social scientists are not involved in the stock assessments themselves at the NEFSC.

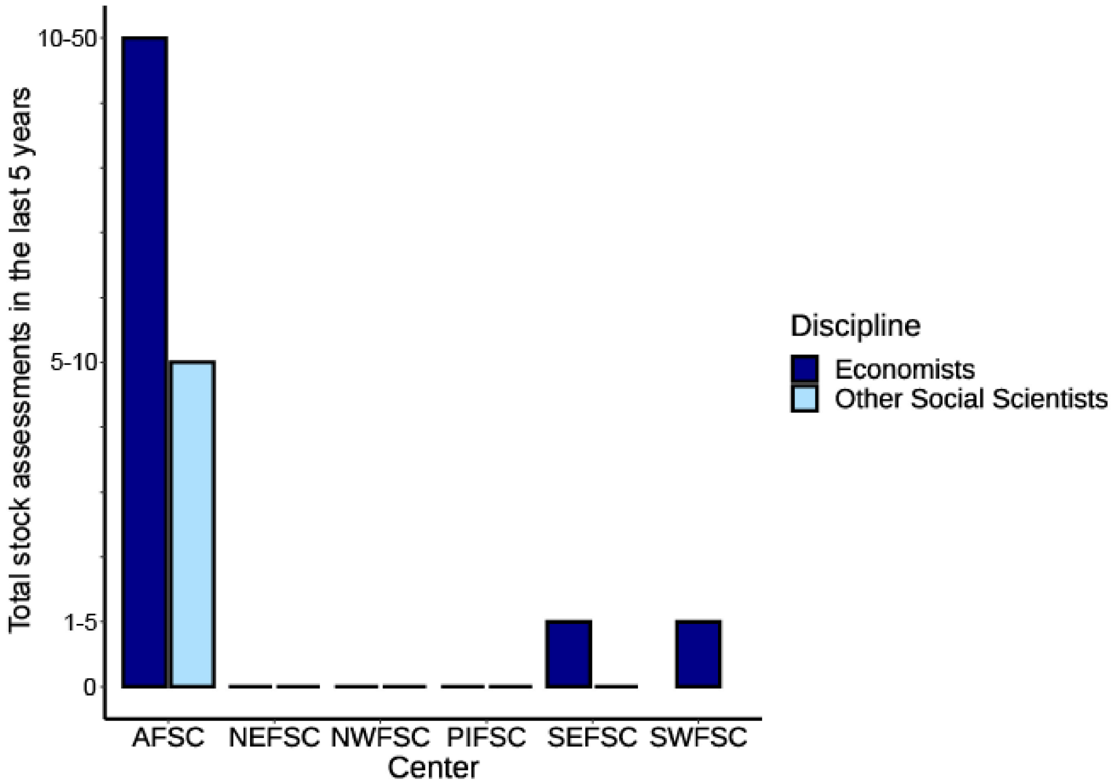


Figure A2: *The total number of stock assessments (completed in the last five years) within specified ranges in which either economists and/or other social scientists were involved.*

Centers were asked to estimate the total number of stock assessments completed in the last five years in which either economists and/or other social scientists were involved. Of the three centers that gave non-zero answers, economists were involved in more stock assessments than other social scientists. Only the AFSC reported the direct involvement of other social scientists, and had the highest estimates of involvement by both economists and other social scientists in the stock assessment process.

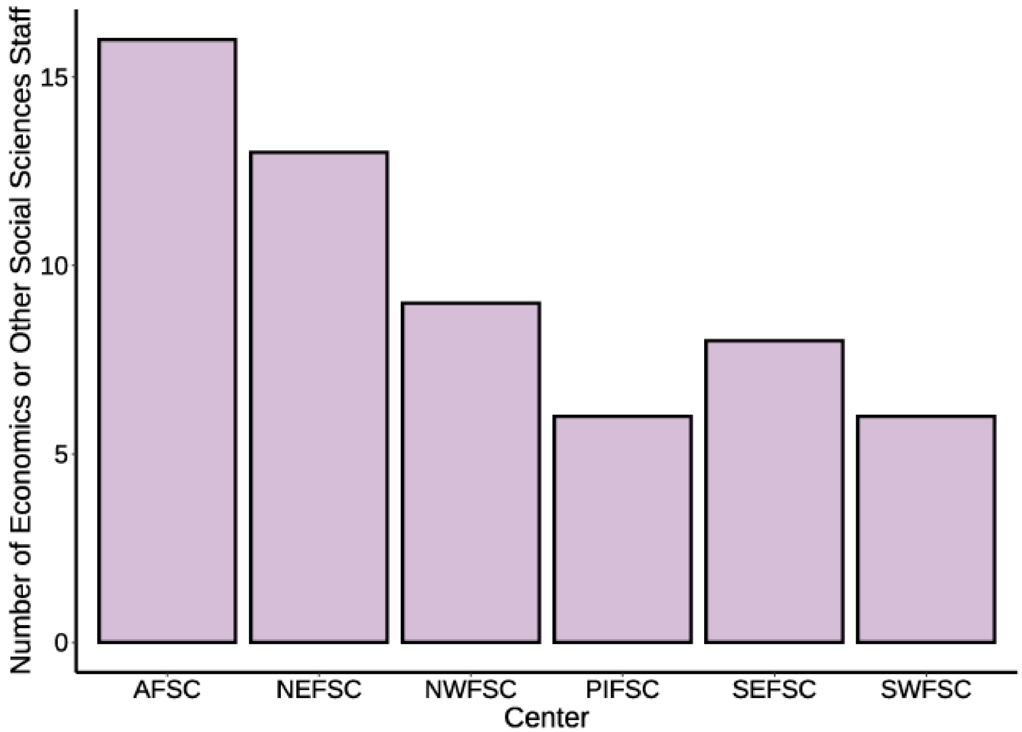


Figure A3: *The number of permanent economists or other social scientists at each of the NOAA Fisheries science centers.*

The number of staff focused on economics or other social science topics related to assessed and managed finfish and invertebrate species also varied by center. The availability of staff time contributes to the amount of integration between socioeconomics and stock assessments, and was noted as a barrier to further collaboration (see section below).

B. What socioeconomic methods and data are most useful for improving stock assessments, and under what circumstances are these factors currently included in assessments?

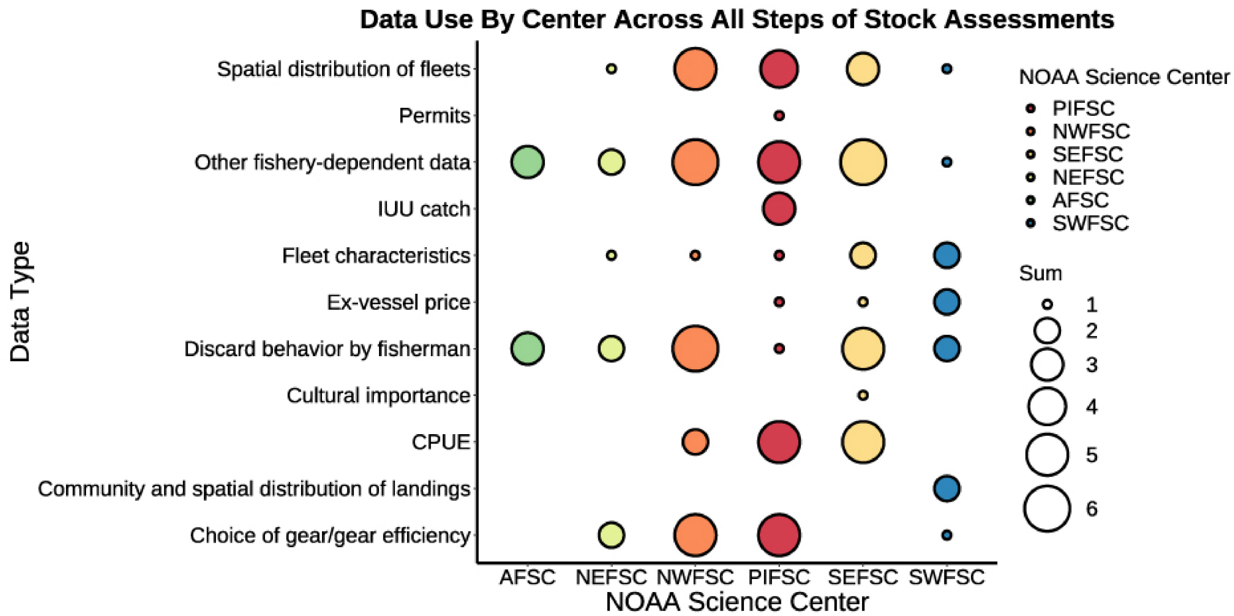


Figure A4: *The use of specific socioeconomic data types (y-axis) in the stock assessment process by each NOAA Fisheries science center (x-axis and symbol color). The symbol size shows the number of steps of the stock assessment process in which the data type is used at each center.*

For the purposes of this survey, we are interpreting "most useful data" as data that is used by the most centers at the most steps of the stock assessment process. "Other fishery-dependent data" was used the most across all steps of the stock assessment process. Examples of other fishery-dependent data include catch statistics, fish size composition, and catch location. All centers used other fishery-dependent data and discard information in at least one step of the stock assessment process. The spatial distribution of fleets was also used in multiple stock assessment steps at most centers.

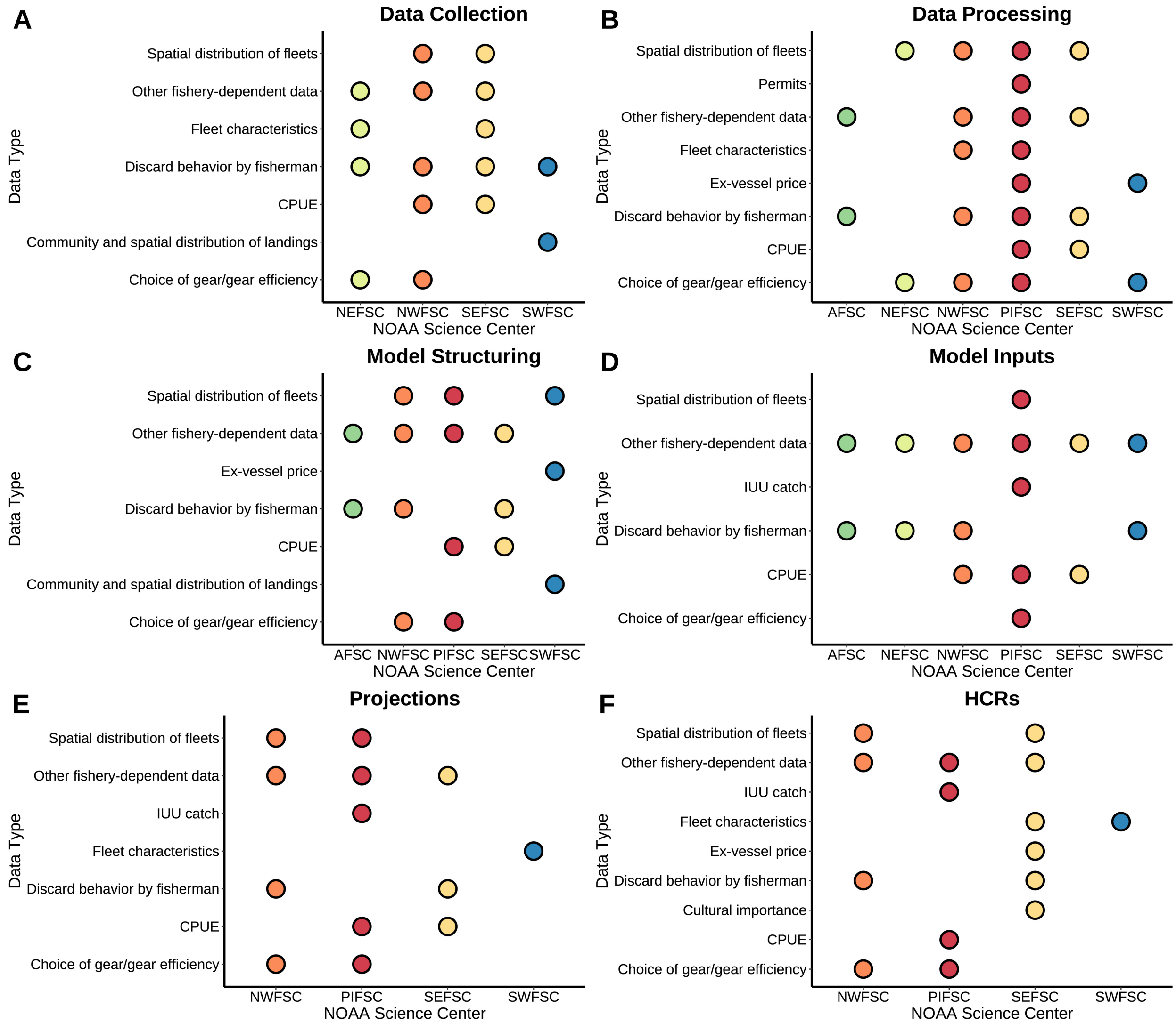


Figure A5: *The use of specific socioeconomic data types (y-axis) in the stock assessment process by each NOAA Fisheries science center (x-axis) disaggregated by stock assessment step, including data collection (**A**), data processing (**B**), structuring stock assessment models (**C**), direct inputs to stock assessment models (**D**), model projections (**E**), and harvest control rules (HCRs; **F**).*

When separating responses out by the different stock assessment steps, additional patterns emerge. Three data types (discard behavior by fishers, spatial distribution of fleets, and choice of gear/gear efficiency) were used by just as many centers as other fishery-dependent data in the processing of stock assessment data inputs. All six centers use other fishery-dependent data as direct inputs to stock assessment models.

With this survey, we also aimed to increase our understanding of the different processes through which socioeconomic information is incorporated into stock assessments in each region. As shown in Figure A5, both “discard behavior by fishers” and the “spatial distribution of fleets” are data types that are used in all stock assessment steps. Multiple centers use these data types in the design/implementation of stock assessment data collection programs, in the processing of stock assessment data inputs, in the structuring of stock assessment models, and even directly as data inputs to stock assessment models. These data types are also used in the development of stock projections and harvest control rules.

Discard behavior is included in stock assessment models at the SWFSC, NWFSC, NEFSC, and AFSC, and in projections at the NWFSC and SEFSC. An example of the use of discard behavior at the NWFSC can be found in the recent Big Skate Assessment Report (2019). Discard rates are estimated by the West Coast Groundfish Observer Program (100 percent coverage of trawl fishery post-2011). Discard rates were modeled for different time blocks using this data and historic reconstructions. Discard data also informs the retention function. Likewise in the northeast groundfish assessments, commercial discards are estimated for different gear types using standardized methods from both observer data and dealer landings.

The spatial distribution of fleets is included in stock assessment models at the PIFSC and in projections at the PIFSC and NWFSC. PIFSC staff are involved in some international assessments where the spatial distribution of fleets is included in an implicit way. For example, Japan divides up their fleets by area and quarter based on the distribution of fishing effort. In the 2018 stock assessment for Pacific Bluefin tuna, an areas-as-fleets approach was determined to be the best model for implicitly accounting for spatial effects (ISC 18 Annex 14 2018). The areas-as-fleets approach accounts for processes like fish movement and spatially-varying fishing behavior in a non-spatial model by incorporating different selectivity coefficients for fleets fishing in different geographic regions (Waterhouse et al., 2014). While the simulation study revealed that the spatially explicit Pacific bluefin tuna model performed the best, the absence of data on annual movement rates hindered the use of this approach in the actual assessment (Lee et al., 2017).

In some stock assessments from the NWFSC, the fleets in different areas were modeled separately. Fleets were defined by state (California, Oregon, or Washington), gear type, and sector (e.g., recreational, foreign) in the 2015 Canary rockfish assessment (Thorson & Wetzel, 2016). However, selectivities for corresponding fleets were specified to be the same in all three states. Employing a spatial model that accounts for differences in exploitation history between the states achieved a better fit to the data. Similarly, in the 2017 Lingcod stock assessment, northern and southern fleets were modeled separately (Haltuch et al., 2018).

A number of socioeconomic data types were noted as available but not used in stock assessments (Figure A6). The results of this survey were shared at the workshop and centers with these available data types were connected to centers that use this data in some part of their stock assessment process, facilitating collaboration and knowledge transfer between regions (Table A1).

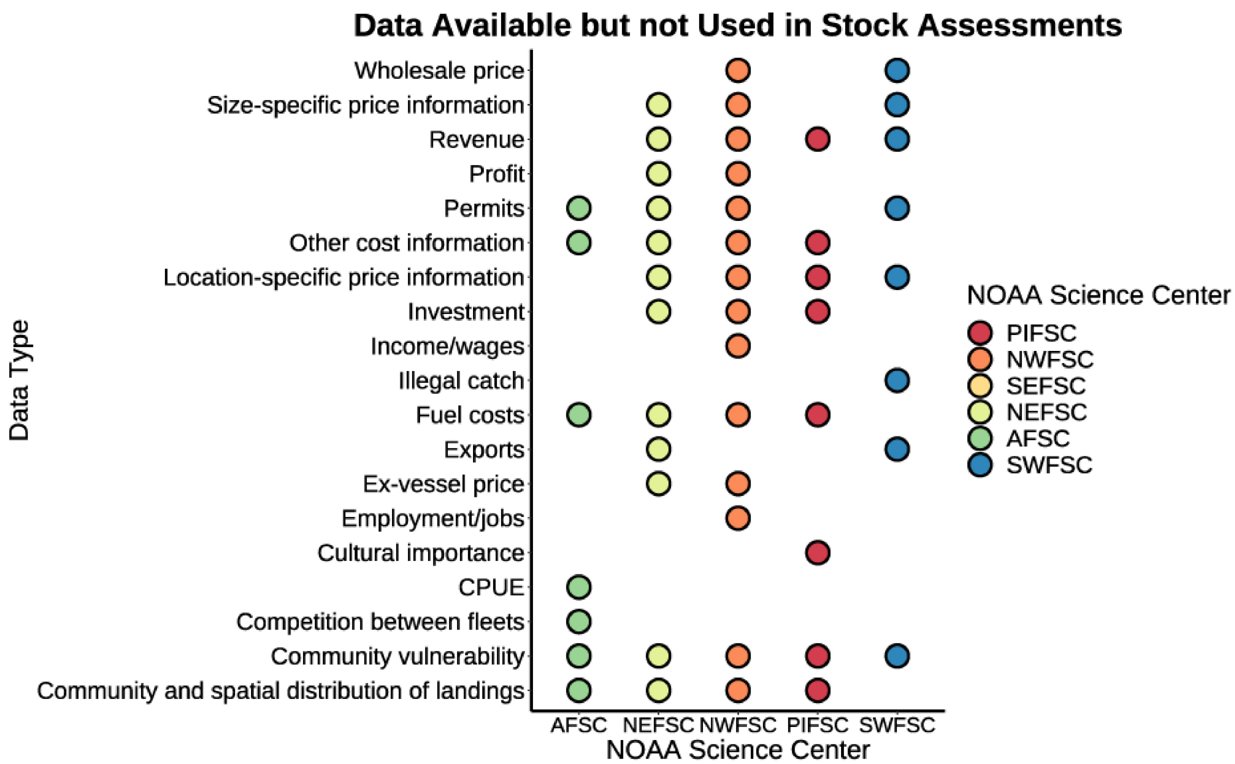


Figure A6: *Specific socioeconomic data types (y-axis) that are available but not currently used in any step of the stock assessment process at each NOAA Fisheries science center.*

Table A1: *Socioeconomic data types included in the survey that were both noted as available but not used by at least one center (left column) and were used by other center(s) in at least one step of the stock assessment process (right column) unless otherwise specified. Data types bolded in blue are discussed further in the text.*

Data Type Available but Not Used by Some Centers	Stock Assessments Steps Where this Data Type is Used in Other Centers
CPUE	Data collection, data processing, model structuring, model inputs, projections, ESP, HCRs
Employment/jobs	ESP
Ex-vessel price	Data processing, model structuring, ESP, HCRs
Size-specific price information	ESP
Revenue	ESP
Permits	Data processing, HCRs
Cultural importance	HCRs
Community and spatial distribution of landings	Data collection, model structuring, HCRs

Location-specific price information	*Not used*
Other cost information	*Not used*
Wholesale price	*Not used*
Exports	ESP
Competition between fleets	*Not used*
Illegal catch	Model inputs, projections, HCRs

Permit data is available but not used in the stock assessment process at the NWFSC, NEFSC, AFSC, and SWFSC. The PIFSC uses permit data in the processing of stock assessment data inputs by standardizing CPUE metrics by individual fishers (see Hawai`i stock assessment models for more details). Individual fishing effort and landings were associated with commercial license numbers (i.e., individual fishers) back through time to create a historical dataset of standardized CPUE. This was a monumental effort because before 1994, individuals were assigned different license numbers every year and fisher names were not systematically recorded (Yau, 2018). Changes in licensing trends as a metric of participation in the fishery can also be used to establish an ACT below the ACL (Hospital et al., 2019).

Ex-vessel price (i.e., the price at first point of sale of landed fish) data is available but not used by the NWFSC and NEFSC. The PIFSC and SWFSC use ex-vessel price information in the processing of stock assessment data inputs, and the SWFSC also uses this data to structure stock assessment models. The PIFSC highlighted a recent international stock assessment for swordfish, which explored relationships between ex-vessel prices and CPUE in a qualitative framework. A decreasing trend for ex-vessel price of Hawai`i swordfish indicated a weakened market for swordfish. Hawai`i fishers thus had little incentive to re-engage in the swordfish fishery due to decreased swordfish demand. Hawai`i longline vessels may easily change target species between swordfish or tuna, so increased effort was devoted to tuna while swordfish fishing trended downward. CPUE decreased before stabilizing in recent years (PI Pelagic FEP SAFE Report, 2018). It was noted that future assessments may further explore the relationship between ex-vessel prices and CPUE.

The SWFSC responded that ex-vessel prices are available, but not routinely considered in assessments. Ex-vessel value (calculated as the ex-vessel price multiplied by the total pounds landed) can be used to inform review panels about the value of the fishery and how this changes over time. Ex-vessel value can also help refine the appropriate fleet selectivity structure in the developing stock assessment model, particularly for species that are sorted by size according to price (e.g., sablefish and dover sole). However, price or value information is not directly used to inform fishery selectivities.

Community and spatial distribution of landings information is available but not used by PIFSC, NWFSC, NEFSC, or AFSC. SWFSC uses this data type to inform the design and implementation of stock assessment data collection programs and in the structuring of stock assessment models.

Illegal catch estimates (also called levels of illegal, unreported, and unregulated (IUU) catch) are available but not used by the SWFSC. The PIFSC uses illegal catch estimates as data inputs to stock assessment models and in the development of stock projections. Estimates of unreported fishery catch were incorporated into the Bayesian surplus production model for Deep 7 bottomfish (Brodziak et al., 2011). The specific type of data available were time series of ratios of unreported catch to reported catch by species of Deep 7 bottomfish. Estimates of unreported catch were calculated based on these ratios. The total catch is the combination of reported and unreported catch. An estimate of total catch was included in the surplus production model, and was calculated similarly based on assumed reported catch to forward project catch from 2018-2022 (Langseth et al., 2018).

C. Quantitative and qualitative use of socioeconomic data in the stock assessment process at each center

Centers were asked to quantify how many stock assessments (wherein a stock status was determined and advice was provided to fishery managers) completed in the last five years included socioeconomic data in quantitative and qualitative ways. Overall, centers used quantitative and qualitative methods to incorporate socioeconomic information in a similar number of stock assessments.

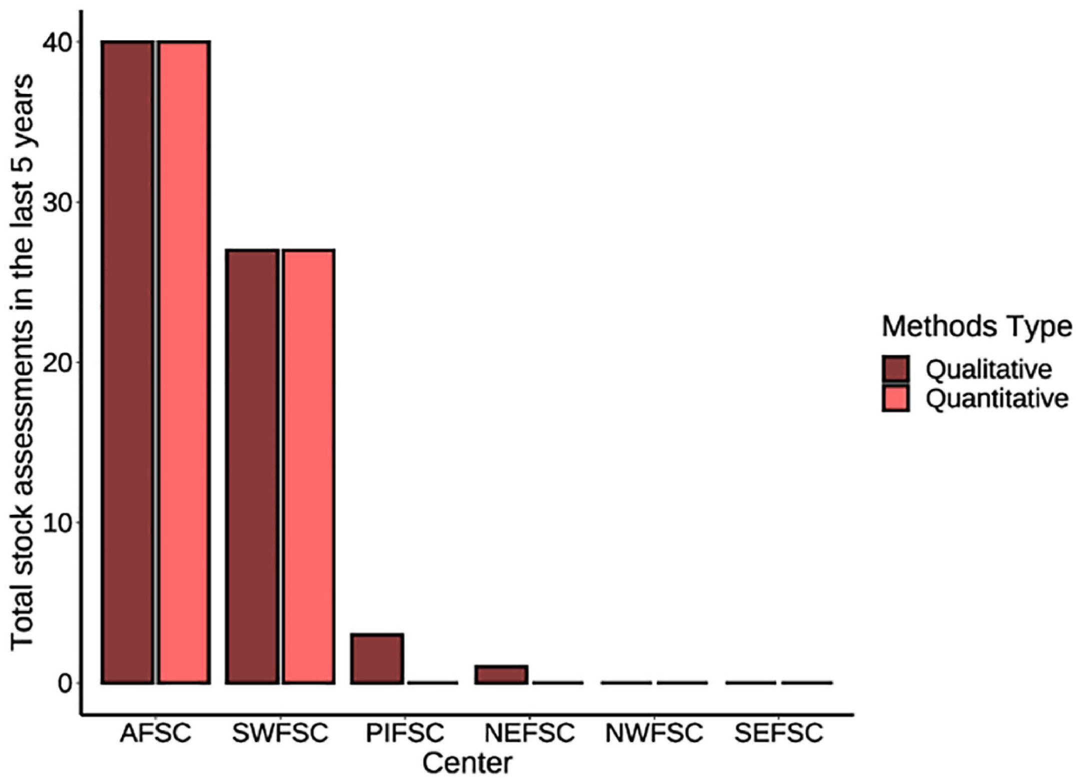


Figure A7: *The total number of stock assessments (completed in the last five years) wherein socioeconomic information was considered in qualitative and/or quantitative ways.*

At the PIFSC, there have not been demonstrated efforts to incorporate socioeconomic data in assessments in a quantitative way. Qualitative socioeconomic methods have advanced data filtering decisions and CPUE standardization considerations. Incorporation of estimated unreported catch ratios are supported by the fishing community and have resulted in improved stock assessments with improved scientific advice. For example, to inform subsequent Hawai`i bottomfish stock assessments, a series of five workshops were held in 2015-2016 with the fishing community to better understand targeting, fishing behavior, and data reporting (Yau, 2018). These workshops serve as a model for engaging with regional fishing communities to better understand key aspects of fishing to improve stock assessment data inputs and modeling decisions. Key findings included an improved data filtering method that was endorsed by the fishing community, and insights that were incorporated to improve the CPUE standardization process. Socioeconomic data have also entered the stock assessment process in qualitative ways through the WPRFMC SEEM process (see section below).

The AFSC has the highest number of stock assessments completed in the last five years that included socioeconomic information. Both quantitative and qualitative socioeconomic information is included in the appendix documents that accompany the stock assessment report in the stock assessment and fishery evaluation (SAFE) documents. At the time of the survey, three assessments had integrated the ESP data in the stock assessment documents for several groundfish and crab species over the last five years, although ESPs now exist for six assessments.

At the SWFSC, quantitative data include landings, price per pound, and the number of angler fishing trips by month and area. Qualitative data include indicators of community social welfare (e.g., poverty, divorce rates, graduation/dropout rates, and incidents of domestic violence).

D. Sources for socioeconomic data at each center

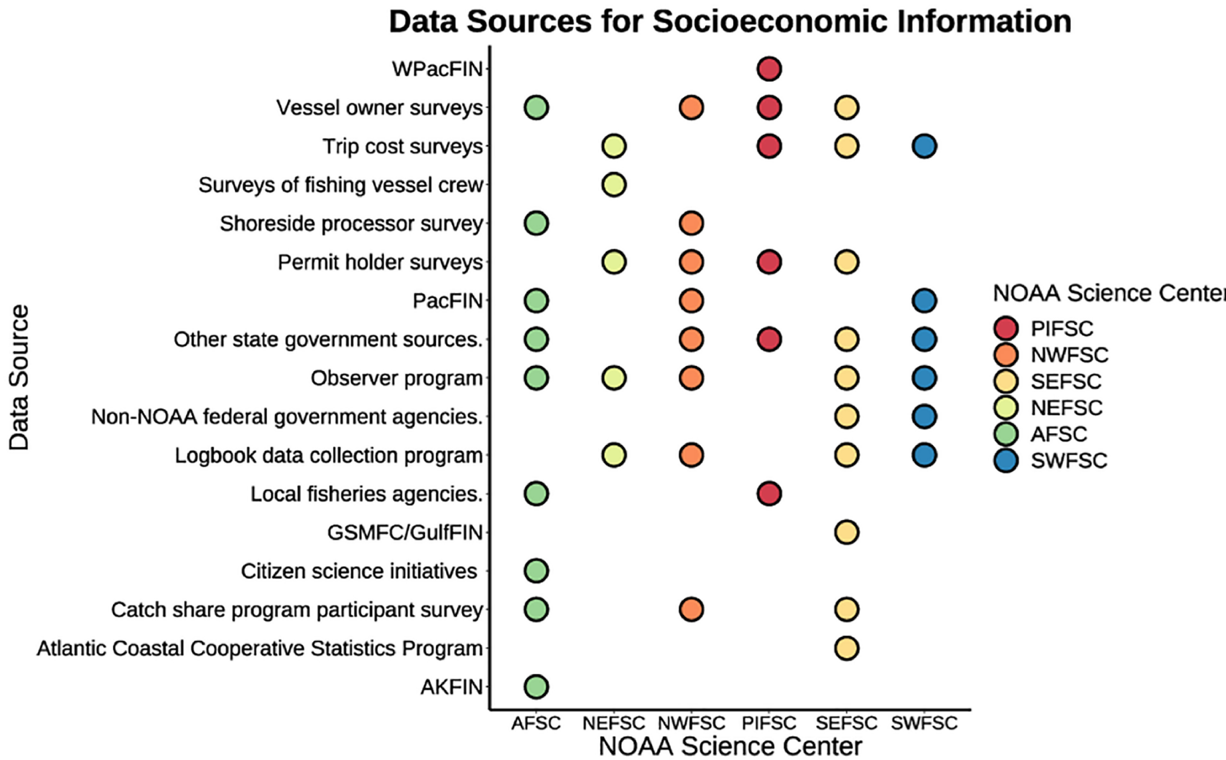


Figure A8: *Socioeconomic data sources used by each NOAA Fisheries science center in the stock assessment process.*

The PIFSC extracts information on cost estimates, levels of investment, profit assessments, vessel characteristics, targeting behavior and gear usage, market participation and catch disposition, independent estimates (relative to fishery-dependent sources) of effort, landings, CPUE and revenues, and indicators of cultural importance from vessel owner/permit holder and trip cost surveys (Marianas Fishing Survey, 2018, 2011; Hawai`i Small Boat Survey, 2020, 2014; American Samoa Small Boat Survey, 2014; Hawai`i Bottomfish Survey, 2010; Ongoing Territory Trip Cost Data Collections, 2009-present).

The NWFSC obtains information on the West Coast Groundfish Trawl Catch Share Fishery from EDC forms. All participants in the fishery are required to complete these forms annually (50 CFR 660.114). Data are also collected via the limited entry fixed gear survey and the open access groundfish, crab, shrimp, and salmon survey.

In reference to the “other state government sources” indicated in Figure A8, the SEFSC uses information collected from various trip ticket landings from state agencies.

The NEFSC noted the importance of the observer program for collecting trip cost data, and fishing vessel and crew surveys for collecting data on annual fixed costs, crew remuneration, job satisfaction, and demographics. The fishing vessel and crew surveys are conducted approximately every three years.

Interestingly, the AFSC alone considers data collected by citizen science initiatives, including the Local Environmental Observer (LEO) Network (which includes information on economic impacts) and information from subsistence fisheries in rural Alaska.

At the SWFSC, socioeconomic data is primarily provided by state fish and wildlife agencies, including information on sublegal sized fish encounters. CPUE data is collected by observer programs or calculated from logbook data. A lot of information comes from fish tickets directly, or is derived from fish ticket data. Limited spatial information is collected by vessel monitoring systems (VMS) or from logbooks. Aggregated export data is provided by other NMFS offices.

E. Assumptions about socioeconomic influences in stock assessments and projections varied by center

Centers were asked to generally describe the assumptions made related to socioeconomic factors in assessments, recognizing that assumptions will differ depending on the stock in question. The SEFSC did not report any assumptions, while the responses from the other centers are summarized below.

In the PIFSC, socioeconomic considerations such as unreported catch ratios are assumed constant through time and into the future (see Hawai`i Bottomfish assessments). In cases where there are clear changes in regulations over time, CPUE breaks are introduced and considered as needed in the models and projections (e.g., Main Hawai`ian Islands Kona Crab assessment).

For projections in the NWFSC, it is often assumed that relative catch by fleet/gear will remain the same, unless there is information to the contrary. When developing projections at the NWFSC, analysts rely on both recent catches by fleet, which can be well below catch limits, and information from the PFMC Groundfish Management Team on expected catches by fleet based on developing fisheries, competing opportunities, and other metrics. For example, the Groundfish Management Team reported expected decreases in fishing effort due to COVID-19 and the resulting Executive Order 20-12 (https://www.pcouncil.org/documents/2020/04/g-8-a-supplemental-gmt-report-1.pdf/).

In the West Coast groundfish catch share fishery, there is a catch projection that is sometimes produced by the WCRO. This model can be used to project catch and landings by fleet and individual vessel (Matson et al., 2017). Fleet size and the distribution of fleet allocations between vessels are assumed to match the most recent year of available data. However, correction factors can be applied if data from a different time period (e.g., based on market conditions) more closely approximates the future conditions of the projection. Their model is quasi-socioeconomic, but excludes some informative data types like price (Matson et al., 2017). The harvest specifications usually have economic impacts (e.g., changes in income or employment for harvesting vessels) estimated with them using the IO-Pac model (Leonard & Watson, 2011), but those are independent of the stock assessment.

In the NEFSC, there is a general understanding that catch and other data used in assessments are influenced by social and economic factors. However, the assessments take these data as given and do not incorporate behavioral change directly into assessments to determine stock status that becomes the basis used by the SSCs to make ABC recommendations to the NEFMC and MAFMC. Center social scientists use behavioral models to estimate social and economic impacts of catch limits that are derived from stock assessments.

Stock assessment scientists at AFSC make assumptions about selectivity of different fishing gear leading to mortality of fish stocks. Assumptions differ by species and region and they may also use information on CPUE from fishery data to inform the models. However, the stock assessment models do not specifically connect with fisher behavior models.

Finally, assumptions in the SWFSC differ by fishery. In some fisheries, no explicit assumptions regarding socioeconomic influences are made when making projections or determining stock status. However, allocation of future harvests by fleet level, given different selectivity functions for most fleets, has implications for projections. Assumptions made in other fisheries are usually fairly simple ratio estimators that do not account for possible changes in effort by fleet, gear type, or sector (e.g., commercial, recreational). For example, projected estimates of stock biomass for Pacific mackerel are influenced by assumptions about the fish dynamics (incorporating average historical recruitment vs. recent average recruitment) as well as assumptions about the fishery operations, particularly the fishery-selected age proportions outside of the United States. (Crone et al., 2019; Crone & Hill, 2017).

F. Considerations of socioeconomic data, analyses, and results during the scientific advisory process at each center

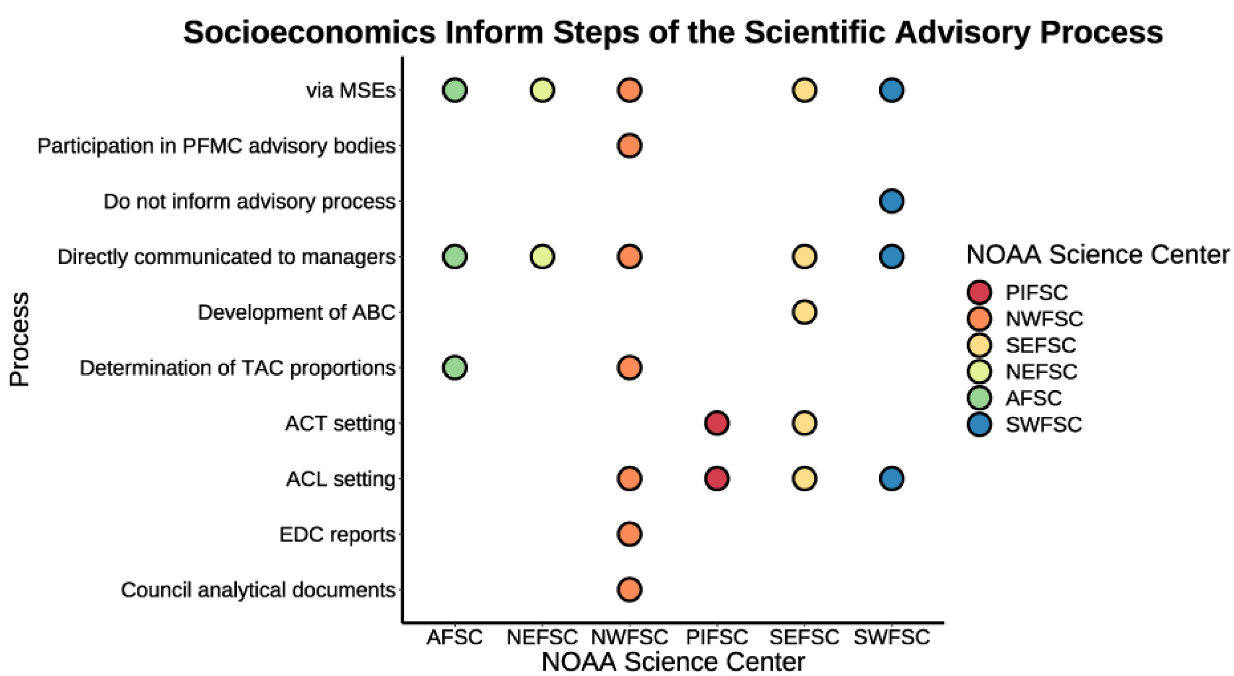


Figure A9: *Socioeconomic information enters the scientific advisory process through different steps (y-axis) depending on the NOAA Fisheries science center (x-axis and fill color).*

Almost all centers directly communicate socioeconomic information to managers and use it in Management Strategy Evaluations (MSEs) to some extent, with the exception of the PIFSC. However, there remain many opportunities for improving socioeconomic considerations in MSEs (Stohs et al., in prep). Most centers also reported that socioeconomic information is considered during the ACL-setting process. More details on how each center considers and communicates socioeconomic data, analyses, and results when providing scientific advice to managers is included below.

Interestingly, only the SEFSC uses socioeconomic information in the development of ABC through SSC ABC decision tools. Specifically, the SAFMC incorporates productivity-susceptibility analyses into the ABC control rule that determines the acceptable risk of overfishing (SAFMC, 2011). The "susceptibility" portion of these analyses are partially determined by the desirability of the stock, which includes market desirability (commercial catch value of the fishery in dollars per pound) and historical importance of the stock (MRAG, 2009). A revision to the amendment for the ABC control rule is in progress, which includes an alternative that would remove the stock productivity and susceptibility analysis from the uncertainty determination. Instead, the SAFMC would choose a risk of overfishing (P*) that would be added to the SSC uncertainty adjustment (SAFMC, 2019), similar to other fishery management councils (see below). The SAFMC's proposed approach for determining the acceptable P* still includes human dimensions attributes to help determine the size of the buffer between the OFL and the ABC. For example, one attribute considers the importance of a species to the total annual revenue of all the species in the fishery management plan (FMP), calculated as the percentage of total annual revenue (see the story map on the Comprehensive ABC Control Rule for more information).

Socioeconomic data is also incorporated into FMP amendments, where the possible social and economic impacts of different management measures on communities are assessed in accordance with the MSA (National Standard 8). The SEFSC uses socioeconomic information during the ACL/ACT setting process. A Gulf of Mexico Fishery Management Council (GMFMC) Amendment describes a method for determining the ACL/ACT, which is then reviewed by a socioeconomic panel. This panel may adjust the ACL/ACT level after considering economic and social factors (GMFMC, 2011). An example of how both direct and indirect economic and social impacts are considered when deciding between alternative ACLs can be found in Amendment 47 to the FMP for vermilion snapper. Differences in sector landings, ex-vessel commercial revenue, consumer surplus for the recreational sector, and the likelihood of an in-season closure are considered for alternative ACLs (GMFMC, 2017).

Both the NWFSC and the SWFSC work with the PFMC to manage fisheries on the West Coast of the United States. In the development of ABC, socioeconomic information may affect the PFMC's choice of the level of acceptable risk (P*), which, along with scientific uncertainty (σ), determines the buffer between the OFL and the ABC (Prager & Shertzer, 2010). A description of how the PFMC implements its P* ABC Control Rule can be found in Amendment 23 to the Groundfish Fishery Management Plan. Briefly, the SSC characterizes the scientific uncertainty of the OFL estimate (σ), which is related to a range of P* values. The buffer between the OFL and the ABC that would result from each P* value in the range is calculated, and then based on this information, the Council selects a preferred P* value (PFMC, 2010).

Different approaches to communicating socioeconomic information to the PFMC are undertaken by the NWFSC and SWFSC. As shown in Figure A9, the NWFSC uses Economic Data Collection (EDC) Reports of information from fishery participants in the West Coast Groundfish Trawl Catch Share Fishery. All permit holders for the limited entry trawl, motherships, catcher processors, and quota share owners, as well as first receiver license owners and shore-based processors, must submit EDC forms to support ongoing economic data collection (50 CFR § 660.114). Because all participants in the catch share program are required to report economic data for all the fisheries they engage in, including non-catch share fisheries, there has been a substantial increase in available economic data since 2009. The communication of economic trends is facilitated by an interactive tool for exploring, analyzing, and downloading data (Fisheries Economics Explorer (FISHEyE)). With this tool, managers, analysts, and stakeholders can compare revenue, costs, and net revenue of catcher vessels. In terms of setting risk, assessing tradeoffs for rebuilding species, and projecting catch by fleet/area/gear and apportioning the ACLs, NWFSC representatives reported that socioeconomic data has improved management advice.

In the SWFSC, the socioeconomic effects of proposed salmon fisheries are presented to managers as part of the annual pre-season reports. For example, an analysis of impacts on resource users and fishing communities demonstrated projected effects of regulatory alternatives on area-specific ex-vessel values, the number of recreational angler trips, and community income levels (Salmon Preseason Report II, 2020). Recent rebuilding plans for specific salmon stocks were required to have a section on the social and economic impacts of management alternatives as part of the EIS (e.g., Sacramento River Fall Chinook Salmon Rebuilding Plan, 2019). Socioeconomic data improved management advice in these instances because a large part of the process for setting salmon seasons involves allocation of fishing opportunity over space and across commercial, recreational, and tribal sectors. Socioeconomic information is also helpful when structuring models with respect to fleets, but is not directly applicable in most cases. Occasionally, MSEs presented to the PFMC include differences in fleet revenue between the alternatives. The PFMC rarely considers economic data in their decision process. A notable exception is the groundfish catch shares five-year review, during which economic and social information were provided to the Council for notification purposes only.

In the NEFSC, Center social scientists serve on plan development teams of the NEFMC and MAFMC. Social science data and analyses inform Council decisions of the social and economic impacts through their ACL/ACT setting process. Social science data was used in the Atlantic herring MSE to assess alternative HCRs. Public meetings were held to engage stakeholders directly in the MSE process and communicate trade-offs of alternative control rules to stakeholders using different graphical representations (Feeney et al., 2019). Attendees helped identify acceptable ranges for performance metrics that informed the MSE models. Feedback from stakeholders was used to build the closed-loop simulation portion of the MSE (Deroba et al., 2019). Notably, the MSE also included an economic submodel, enabling economic performance metrics such as median revenues to be included in the evaluation of alternative HCRs. Stakeholders expressed interest in the stability of net revenues as a performance metric.

The primary way the WPRFMC considers socioeconomic effects is through the SEEM (social, economic, ecological, management uncertainty) process, which was recently revised and offers a clear framework for the consideration of socioeconomic information in support of ACL and ACT recommendations (Hospital et al., 2019). Briefly, the perfected SEEM* process provides guidance on reducing the ACL below the ABC based on social, economic, and ecological considerations, while the level of management uncertainty may dictate whether an

ACT should be set below the ACL. Multiple socioeconomic data types are considered qualitatively during the SEEM process, including levels of illegal, unreported, and unregulated catch, employment/jobs, income/wages, ex-vessel price, revenue, licenses (as a measure of fishery participation), and cultural importance. The working group is composed mostly of fishers, and includes one economist or other social scientist. Multiple SEEM working groups were held within the past five years (2015 Territory Bottomfish, 2017 Hawai`i Deep 7 Bottomfish, 2018 Main Hawai'ian Islands Kona Crab, and 2020 Territorial Bottomfish). The SEEM process has successfully resulted in the establishment of ACTs (Hawai`i Bottomfish, 2012, Hawai'i Kona Crab, 2018) and recommendations (that were not endorsed by the Council) of reductions in ACLs (Territory Bottomfish, 2015), even prior to its revision.

The AFSC includes trends in employment/jobs, ex-vessel prices, size-specific price information (for sablefish only), and revenue in supplemental documents to the stock assessment report. Social scientists also provide information on social conditions affecting fishing communities and fishers to the Council that may be considered during the TAC setting process. Four different documents submitted with the stock assessment report contain this economic and social information: the Ecosystem Status Reports, Economic Status Reports, Economic Performance Reports, and ESPs. Ecosystem Status Reports (Slater et al., 2017) support EBFM in part by describing large-scale trends in physical, biological, economic, and social factors (e.g., trends in fish prices, unemployment rates, and school enrollments). Economic Status Reports provide summary statistics on multiple economic factors (e.g., ex-vessel prices, revenue, and first wholesale production volume) to describe economic activity and output. While Economic Status Reports include all fisheries and sectors within larger management groupings (e.g., all groundfish fisheries), Economic Performance Reports are completed for individual stocks and are usually included as appendices to stock assessments (e.g., Fissel, 2020). Lastly, ESPs are also provided as appendices to certain stock assessments, but serve to identify specific socioeconomic indicators that could be integrated in the stock assessment process (Shotwell, 2018; Shotwell & Downs, AB15).

In the survey, the AFSC reported that socioeconomic data types considered in ESPs include employment/jobs, ex-vessel price, size-specific price information, revenue, and exports. The NPFMC uses this and related information in various spatial and sectoral allocation decisions for managed species. For example, an MSE is being conducted for sablefish to evaluate apportionment options to be presented to the Council for area apportionment of Alaska-wide TAC based on biological ABC limits and fleet value, capacity, and community-related information. Socioeconomic data provide fishery managers with information on the relative value of catching certain stocks over others, the degree to which certain fleets or communities are dependent on those stocks, and who will reap the economic benefits. The existence of the 2 million metric ton OY or ecosystem limit on the aggregate TAC in the entire Bering Sea and Aleutian Islands system necessitates difficult Council trade-off decisions regarding the total amount of economic value that can be created by different TAC allocations, as well as the parties to whom that value flows.

G. Requests from managers and stakeholders to incorporate socioeconomic considerations in the stock assessment process

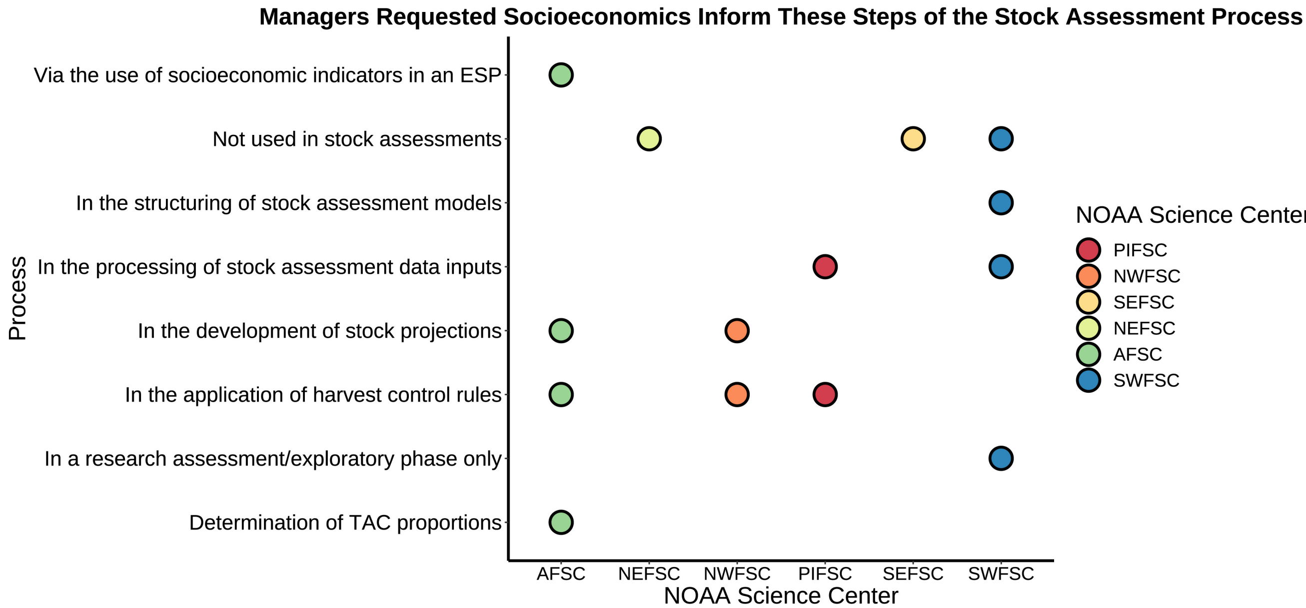


Figure A10: *Managers and stakeholders requested that socioeconomic information be incorporated in different steps of the stock assessment process (y-axis), depending on the NOAA Fisheries science center (x-axis and fill color).*

Both the SWFSC and PIFSC indicated that managers/stakeholders requested socioeconomic information be used in the processing of stock assessment data inputs. The WPRFMC and SSC requested that the PIFSC pursue data workshops (modeled off the Hawai`i bottomfish data workshops) to inform and improve data filtering decisions and CPUE standardizations for future stock assessments (Yau, 2018). The P* and SEEM working groups have been established as key aspects of the stock assessment/ACL setting process and have been requested upon completion of each regional stock assessment.

The SWFSC responded that stakeholders may request additional socioeconomic information beyond what is routinely reported. For example, in the common thresher shark assessment, the effect of management changes (e.g., time-area closures and Marine Protected Areas) on CPUE was considered (Teo et al., 2018). Changes in fisher targeting behavior depending on the catchability and market prices of either pelagic sharks or swordfish was also accounted for in the relative abundance indices.

The AFSC and NWFSC both received requests related to incorporating socioeconomic information in the development of stock projections. The NWFSC highlighted the importance of understanding how developing fisheries and rebuilt species will affect catch by fleet and how those changes can be incorporated into projections. Contrastingly, the AFSC pointed to the motion by the NPFMC, which clarified that socioeconomic information should not be incorporated into the ABC recommendations, and should only inform the TAC setting process (Council Motion C2, October 2018). However, the Council was not referring to changes in catchability or selectivity when they made this motion.

H. The science centers were asked to describe any existing plans to use socioeconomic data more frequently in future stock assessments

At the PIFSC, data workshops are likely to be developed for future stock assessments in the region. A proposal was recently submitted to the FY20 MSA Implementation Funds RFP to pursue a pilot project that seeks to improve consideration of socioeconomics in forthcoming stock assessments (uku and/or territory bottomfish). If there was interest from managers, social scientists could revisit past work to consider pricing effects and consumer surplus of ACL decisions (Hospital & Pan, 2019). The PIFSC maintains many information resources that are available to support improved socioeconomic profiles in future assessments (e.g., community engagement, reliance, and vulnerability).

In the SEFSC, there have been discussions between the economic and stock assessment divisions about how to better incorporate the existing economic data, but constraints on staff time have made it difficult to move forward with concrete proposals.

The NEFSC has adopted a stock assessment process that includes industry engagement to identify research needs for informing future stock assessments. This process aims to identify key science issues that may benefit from additional research. In general, these are understood to be biological in nature, but may include social science research on an ad hoc basis. At present, there are no existing plans for increased engagement of social scientists or social science data in future stock assessments.

At the AFSC, ESPs have not been prepared for all species, but the number of ESPs being prepared is expected to increase as relationships between the environment, socioeconomic factors, and stock populations are better understood. Stock assessment authors are responsible for identifying and including such relationships, in collaboration with social scientists, and including this supplementary information in their stock assessment reports.

In the SWFSC, there is some interest, but no clear path forward. The NWFSC also currently has no plans to increase the use of socioeconomic information in stock assessments.

I. Protocols for prioritizing or determining which stock assessments are expanded to use socioeconomic data at the science centers

Centers were asked whether there was an existing process to determine which stock assessments would be expanded to incorporate additional socioeconomic information. The responses received are summarized in Table A2 below (note: not all centers provided a response to this question).

***Table A2**: Summary of center responses describing the presence or absence of existing processes for selecting which stock assessments incorporate additional socioeconomic information.*

Center	No Process	Existing or Developing Process
PIFSC	There is no process currently in the Pacific Islands Region.	
NEFSC	There are no systematic protocols at present to determine how or when stock assessments use social science data. The industry engagement part of the new stock assessment process may identify social science data/research needs on an ad hoc basis.	
AFSC		Prioritization is often linked to the economic value of the stock, number of fishers involved, or linked to large changes in the size of the stock. If the public is likely to be impacted in some notable way, socioeconomic information can be a critical input for understanding the magnitude of the impacts, which would elevate the priority of the stock.
SWFSC	The accepted model used for socioeconomic analyses for salmon is IOPAC. Socioeconomic data is used in some stock assessment prioritization processes, but there are no existing protocols to evaluate when or how assessments should use this data.	

J. Barriers to incorporating socioeconomic information in the stock assessment process

In the survey, centers were asked to select which types of socioeconomic data they would benefit from using, but there is some barrier to incorporating this information. Centers were presented with four types of barriers: data is not available, methods are not developed, insufficient time, and insufficient staff. The aggregated responses are summarized in Figure A11 below.

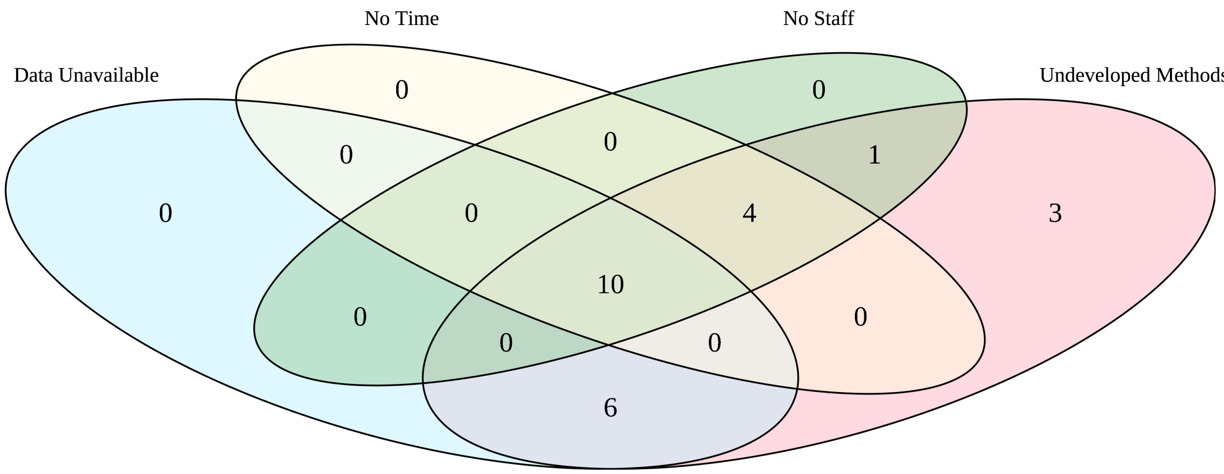


Figure A11: *Four-way Venn diagram showing the four barriers to including more socioeconomic information in stock assessments. Numbers within ovals indicate the number of socioeconomic data types prevented from inclusion by each barrier or combination of barriers.*

In total, there were 24 unique socioeconomic data types that would be informative for the stock assessment process in at least one center. All 24 of these data types were not included in stock assessments due to a lack of developed methods (Figure A11). The use of most of these data types were impeded by three or four barriers (n=14), indicating that in most cases there are overlapping reasons for not expanding stock assessments to include more socioeconomic information.

Additional barriers were noted in the “free response” section of the survey, or were identified during workshop discussions, and are summarized below.

Consistent communication: Lack of frequent communication between socioeconomic and stock assessment staff about data availability, data products, data needs, and model structures is hindering collaboration. If authors are not aware of the available socioeconomic data, then it will not be included in stock assessments.

Appropriate spatiotemporal data resolution: The resolution of social and economic data was also identified as an issue. These data are typically collected at the fishery or community level rather than at a species or stock level. Data for all sectors harvesting a species is often unavailable. For example, it is unclear how data on fisher targeting behavior from a multispecies fishery would be included in a single species stock assessment. In addition, socioeconomic data is often not collected as often as biological data. SEASAW participants noted that the current workflow for complying with the Paperwork Reduction Act substantially hinders timely data collection for socioeconomic and some biological information.

Accessible socioeconomic data: Restricted socioeconomic data sharing between Centers that assess similar stocks may be hindering some progress in this area.

Representative fisher survey data: Current funding levels limit how much outreach can be completed to ensure representative angler survey participation. Survey responses are important for characterizing changes in fisher behavior under different management strategies, and assessing levels of noncompliance with regulations. Ensuring the survey participants are representative of the population demographics is a challenge. The survey may need to be conducted in different languages and include equal representation of income brackets.

Appendix 2: SEASAW Agenda

The Socioeconomic Aspects in Stock Assessments Workshop (SEASAW)
February 11-13, 2020
Hilton New Orleans Riverside, Churchill B

Time	**Day 1 – Tuesday, Feb. 11**
9:00-9:30am	Introductions, Overview of Workshop
9:30-10:00am	Doug Lipton - Using Economics to Assess Fish Stocks
10:10-10:40am	Rick Methot - Entry Points for Economic Connections to Stock Assessments
10:50-11:10am	Break
11:10am-12:00pm	Andrea Chan - A Survey of Current Practices for Incorporating Socioeconomic Aspects in Stock Assessments at the NOAA Science Centers (and discussion) *Discussion Facilitator: Andrea Chan* *Rapporteur: Jeffrey Vieser*
12:00-1:30pm	**Lunch**
1:30-1:50pm	Zhenshan Chen - Anglers' Preference, Noncompliance, and Fishing Effort under Alternative Management Strategies: A Choice Experiment Approach
2:00-2:20pm	Marysia Szymkowiak - Accounting for Changing Fishing Practices in Stock Assessments – A Case Study of Adaptive Behaviors in the Alaska Sablefish Fixed-Gear Fishery
2:30-2:50pm	Break
2:50-3:10pm	Melissa Krigbaum - The role of economic data in determining effort by gear and sub-fleet: A case study of West Coast Sablefish
3:20-3:40pm	Kelsi Furman - Developing and Piloting a Social Equity Framework for Fisheries Management
3:50-5:00pm	*Discussion - Barriers to using Socioeconomic Data, e.g., Data Gaps* *Discussion Facilitator: Andrea Chan* *Rapporteur: Justin Hospital*

Time	Day 2 – Wednesday, Feb. 12
9:00-9:20am	Skyler Sagarese - Enhancing single-species stock assessments through socioeconomic and ecosystem contributions: a case study for Gulf of Mexico Red Grouper (*Epinephelus morio*) and red tides
9:30-9:50am	Lisa Pfeiffer - The importance of modeling fishery attainment in stock assessment
10:00-10:50am	*Discussion - How can we scale up case studies to different regions?* *Discussion Facilitator: Jeffrey Vieser* *Rapporteur: Kristan Blackhart*
10:50-11:10am	Break
11:10-11:30am	John Walter - Maximum sustainable __? What should we optimize for in fisheries management?
11:30-12:00pm	*Discussion - Balancing Multiple Management Objectives* *Discussion Facilitator: Alan Haynie* *Rapporteur: Scott Crosson*
12:00-1:30pm	**Lunch**
1:30-1:50pm	Stephen Stohs - National workshop on integrating economic considerations into Management Strategy Evaluations
2:00-2:30pm	*Discussion - Socioeconomic Considerations and Trade-offs in Harvest Control Rules* *Discussion Facilitators: Aaron Mamula and Owen Hamel* *Rapporteur: Kristan Blackhart*
2:30-2:50pm	Break
2:50-3:10pm	Stephen Stohs - Did recreational Pacific Bluefin Tuna bag limits lead to increased post-release mortality?
3:20-3:40pm	Deborah R. Hart - Modeling fleet dynamics in the Atlantic sea scallop fishery
3:50-4:30pm	*Discussion - The role of socioeconomics in ground-truthing forward projections* *Discussion Facilitator: Russell Brown* *Rapporteur: EJ Dick*

Time	**Day 3 – Thursday, Feb. 13**
9:00-9:20am	Alan Haynie - Lessons and Challenges from a Dozen Years of Life as an Economist on the Bering Sea and Aleutian Islands Groundfish Plan Team
9:30-9:50am	Kalei Shotwell and Mike Downs - Developing the Ecosystem and Socioeconomic Profile (ESP) for next generation stock assessments
10:00-10:20am	Diana Stram - Do decision tables affect management decisions?
10:30-10:50am	Break
10:50am-12:00pm	*Discussion - What strategies are useful in different regions for communicating socioeconomic risks to SSCs and councils?* *Discussion Facilitators: Kalei Shotwell and Diana Stram* *Rapporteur: Anna Henry*
12:00-1:30pm	**Lunch**
1:30-1:50pm	Scott Steinback - A bioeconomic model of recreational angling in the Northeast U.S. groundfish fishery
2:00-2:20pm	Emily Markowitz - Commercial and Recreational Fisheries Economic Impact Input/Output Model: Tool Update and Increasing Accessibility for Managers and Scientists
2:30-2:50pm	Break
2:50-3:20pm	Patrick Lynch - Rethinking Forecasting to achieve Climate-Ready, Ecosystem-Based, Sustainable Fisheries Management *Discussion - Improving Collaboration* *Discussion Facilitator: Patrick Lynch* *Rapporteur: Justin Hospital*
3:20-3:50pm	*Discussion - Short and Long Term Resource Needs and Research Goals* *Discussion Facilitators: Andrea Chan, Alan Haynie, Patrick Lynch* *Rapporteur: Lisa Pfeiffer*
4:00-5:00pm	Summary and Tech Memo Writing

Appendix 3: SEASAW Presentation Abstracts

This section contains all of the abstracts corresponding to presentations in the order at which they were given at SEASAW. The presenting author is listed next to the abstract (AB) number, and the full author list and affiliations are included below the title. Some abstracts refer to specific themes from the call for abstracts, which are listed below.

SEASAW Presentation Themes

1. Case studies of useful and/or novel socioeconomic data for informing stock assessments, including novel and/or generalizable methods for incorporating socioeconomic data in stock assessments.
2. Defining circumstances where it is useful and/or necessary to include socioeconomic information in stock assessments, e.g., when stocks are data-limited or subject to significant bycatch.
3. The role of socioeconomics in ground-truthing forward projections of stock parameters.
4. Strategies for successfully communicating socioeconomic risks to managers when, for example, providing scientific advice on acceptable biological catch (ABC).
5. Understanding how fisheries management councils consider socioeconomic trends in the harvest control rule development process.
6. Balancing multiple management objectives, e.g., maximizing opportunity for anglers vs. maximizing stock yield.
7. **Open session:** If you have an abstract that does not fit under one of the above themes but is still relevant to the overall workshop purpose, please submit your abstract under this session.

AB1: Doug Lipton[1] - Using Economics to Assess Fish Stocks

[1]NOAA Fisheries Senior Research Scientist for Economics (douglas.lipton@noaa.gov)

It is well known that there are major limitations to the use of fishery-dependent data in the assessment of fish stocks. Unlike fishery-independent surveys which are designed to obtain a statistically valid sample, the fishing fleet, including both commercial and recreational fishermen, sample with bias. Theoretically, it is possible to estimate that bias and correct for it in order to obtain a relative measure of fish abundance. In one example, we took advantage of the spatial and temporal overlap of a fishery-independent winter dredge crab survey with the commencement of the crab fishing season to calibrate a profit model of crab fishing location tied to spatially explicit abundance during the remainder of the season when no fishery-independent survey was operating. Greater use of research fleets to fill in the gaps (areas and times) that are costly to obtain from fishery-independent surveys are another step in the direction towards becoming more efficient in conducting stock assessments. Careful utilization of commercial vessel and individual angler data can lead to better and more efficient design of fishery-independent surveys by reducing the number or frequency of surveys that must be conducted, sampling in areas or habitats (e.g., shallow water) not efficiently sampled by the fishery-independent survey vessels, and accounting for dynamic factors such as range extensions.

AB2: Richard Methot[1] - Entry Points for Economic Connections to Stock Assessments
[1]NOAA Fisheries Senior Scientist for Stock Assessments (richard.methot@noaa.gov)

Potential connections between economic factors and stock assessment assumptions exist and need clear articulation to spur their development. These connections fall into three categories: population estimation, reference points and control rules, and projections. The population estimation connection is through assumptions regarding the technical characteristics of the fishery and how it changes over time. Some assessments treat fishery selectivity and catchability as constant over time; others treat these factors as random effects with great potential variation. A logical middle ground would be the use of economic models to hindcast how the fishery probably evolved its behavior over time and to embed these predictions into the assessment model. The reference point and control rule connection includes the concept of using Maximum Economic Yield as a guiding factor for Optimum Yield, but limit reference points also could be considered. Current implementations of harvest policies treat the Maximum Sustainable Yield and associated overfishing limit as a factor that is derived entirely on biological considerations. There may be opportunity to bring more economic considerations into the MSY calculations when one considers that the calculations are dependent upon the prevailing technical characteristics of the fishery, hence are mutable in response to economic factors. The third category of connection is the projection of future catch levels that will implement the codified harvest policy. Here the connection is based on similar factors as those affecting the historical estimation. For example, changes in fishery characteristics in response to new regulations, natural events (such as large year classes), or market changes could be taken into account when projecting impact of future Annual Catch Limits.

AB3: Andrea Chan[1] - A Survey of Current Practices for Incorporating Socioeconomic Aspects in Stock Assessments at the NOAA Science Centers (and Discussion)
Andrea Chan[1]*, Alan Haynie[2], Patrick Lynch[1], and the SEASAW Steering Committee
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There is an ongoing effort by the National Stock Assessment Program to make stock assessments more holistic, in part by incorporating socioeconomic information. However, there is a lack of understanding of current practices for incorporating socioeconomic data in the stock assessment process, which includes data collection, data processing, stock assessment models, forecasts, stock assessment review, and management advice. We developed a survey to obtain high-level regional information from the six NOAA science centers (centers) on collaboration between economists/social scientists and stock assessment scientists, socioeconomic methods and data that are most useful for improving stock assessments, and how socioeconomic data/analyses/results inform the scientific advisory process. Results show that while both economists and social scientists participate in management advice at the most centers, only economists are involved in stock assessment models and forecasts. When looking at socioeconomic data usage across all centers, the highest diversity of data types was used in the application of harvest control rules. A number of socioeconomic data types were noted as available but not used in stock assessments. Centers with these available data types can collaborate with centers that use this data in their assessments, thus facilitating knowledge transfer between regions. Other important topics included assumptions about socioeconomic influences and socioeconomic considerations during the scientific advisory process. These survey results will be instrumental in identifying recommended practices as well as short and long term research goals for the inclusion of socioeconomic factors in the stock assessment process.

AB4: Zhenshan Chen[1] - Anglers' Preference, Noncompliance, and Fishing Effort under Alternative Management Strategies: A Choice Experiment Approach

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Theme number: 1

The current approach to projecting the impact of regulatory efforts to control harvest assumes that anglers do not alter their fishing behaviors under alternative management policies. However, anglers strategically optimize effort and may change their rate of compliance to achieve their objectives. These changes in angler behavior reduce the accuracy of projections and undermine the ability to accomplish management goals. We employ a choice-experiment survey instrument to elicit recreational anglers' preferences, fishing effort, and expected noncompliance under current and alternative management scenarios for an overfished stock (Long Island Sound tautog). To identify preferences, each choice question incorporates the status quo minimum size limit and two alternatives drawn from a set including more restrictive minimum size limit and several slot limit options. In each choice scenario, options for season length, possession limit, and enforcement level varied randomly. In some choice sets, scenarios include attributes representing changes in future fishing experience that are derived from stock assessment projections. Effort and noncompliance are assessed via follow-up questions after each choice set. The survey additionally collected baseline data on fishing behavior, preferences and demographics. Almost 2000 tautog anglers in CT and NY completed the survey in 2019. Preliminary results indicate that respondents prefer slot limits over a more restrictive minimum size limit. Anglers indicated a slight increase in future effort with either a narrow slot limit or status quo regulations; 10 - 20 percent of anglers may not comply with slot limits. With these results, more precise biological models can be developed to predict the potential outcomes under alternative management approaches, taking better account of changes in angler behavior.

AB5: Marysia Szymkowiak[1] - Accounting for Changing Fishing Practices in Stock Assessments – A Case Study of Adaptive Behaviors in the Alaska Sablefish Fixed-Gear Fishery

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Theme number: 1

As marine ecosystems and management regimes change, fishermen adapt by employing a number of diversified strategies to mitigate any potential revenue losses. Although some of these adaptations are manifest in changes observed in data that should be incorporated into stock assessments, such as adjusting location and gear usage to change the age structure of the catch, the diversity of ways in which adaptive behaviors could affect stock assessment models are not well understood. This presentation focuses on examining these dynamics within the Gulf of Alaska marine ecosystem, through a case study of adaptive behaviors in the sablefish fixed-gear fishery. The sablefish stock in Alaska witnessed a historically unparalleled recruitment class following the marine heat wave of 2014, which is now dominating the stock composition, causing average dockside prices to plummet due to the large price premium on larger fish. With expectations of above average year classes to continue with warming waters into the future for sablefish in the region, understanding the ways in which fishermen are responding to these changes is of critical import to both the socioeconomic conditions and to the biological sustainability of the fishery. This presentation focuses on the variety of adaptive behaviors that are being employed by sablefish fishermen in Alaska and the potential, varied implications of these for the stock assessment process, from shifting temporal and spatial fishing distributions to employing gear-specific selectivity curves as fishermen switch gear types.

AB6: Melissa Krigbaum[1,2] - The Role of Economic Data in Determining Effort by Gear and Sub-Fleet: A Case Study of West Coast Sablefish

Melissa Krigbaum[1,2], Chris Andreson[1]
[1]University of Washington
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Theme number: 2, 7

Sablefish is a commercially important species with catch allocated across multiple sectors and gear types on the U.S. West Coast. Since 2011, the shorebased trawl fishery has been managed by an Individual Fishing Quota (IFQ) program, which importantly includes a flexibility provision which sanctions those with trawl permits to target sablefish with fixed gear, such as longlines or pots. The trading of quota between gear-types within the IFQ program allows the total-effort by gear-type to be partially determined by market forces. Participation decisions such as leasing quota or reallocating effort to other target species, which will impact total attainment of TAC, will depend on the relative economic success of sablefish operations. Each of the sub-fleets and gear-types targeting sablefish have different cost structures as well as variable gear-specific and size-specific pricing. Due to the dynamic interdependence of economic and biological systems, it is crucial to include the behavioral response of fishers to economic conditions when projecting gear-specific catch. This presentation will discuss my work on developing an economically-sophisticated management strategy evaluation, and more broadly the role of economic cost and earnings data in providing information that can be used to better reflect and predict effort by gear-type and sub-fleet in stock assessments. I will discuss the types of information needed, potential pitfalls and complications based on the data, and the (complicated) potential to model participation and effort in a multi-species context.

AB7: Kelsi Furman - Developing and Piloting a Social Equity Framework for Fisheries Management

Kelsi Furman[1], Shannon Cass-Calay[2], Skyler Sagarese[2], Steven Scyphers[1]
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As fisheries management moves towards an ecosystem-based fisheries management approach, an understanding of social outcomes and potential inequalities is essential. Previous studies have shown the importance of understanding natural resource-based livelihoods, well-being, and the overall socioeconomic context in which fishers participate. While advances in the literature have led to a call for greater inclusion of social impact assessments in fisheries, social equity remains understudied and is rarely accounted for in formal fisheries management. Knowledge gaps surrounding these social outcomes have led to data uncertainties in stock assessments. Filling these data gaps is crucial to promote a just and equitable system as the field progresses into an ecosystem-based framework. This presentation will describe a project to develop, pilot, and assess an equity framework for fisheries management and stock assessment through collaborative modeling. Specifically, we will 1) co-develop a conceptual framework on how social equity can be effectively integrated into three key phases of fisheries management: fishery-dependent data collection, stock assessment, and management strategy development and evaluation and 2) conduct interviews with experts involved in each phase of fisheries management to measure perceptions of the framework, with an emphasis on barriers and enabling conditions. Our specific approach to collaborative modeling will involve fuzzy-cognitive mapping (FCM), a semi-quantitative representation of a system's core variables, interactions, and feedbacks. We will target a variety of interview participants with fisheries expertise, including managers, scientists, and fishers. The resulting framework and collaborative models will be reviewed through follow-up interviews with fishers and other stakeholders. This research will not only aid in understanding potential inequities currently existing but will also contribute to our overall understanding of socioeconomic data incorporation into fisheries stock assessments.

AB8: Skyler Sagarese[1] - Enhancing Single-Species Stock Assessments Through Socioeconomic and Ecosystem Contributions: A Case Study for Gulf of Mexico Red Grouper (*Epinephelus morio*) and Red Tides

Skyler Sagarese[1], Nathan Vaughan[2], John F. Walter III[1], Mandy Karnauskas[1], Matthew McPherson[1], Suzana Blake[3], Amanda Stoltz[3] and Emily Muehlstein[4]

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Theme number: 1, 2, 3, 4

Impacts of *Karenia brevis* red tide blooms have been an increasing cause of concern for fisheries management on the West Florida Shelf. Red tide mortality has been incorporated into grouper stock assessments since the mid-2000s. Traditionally, this has been achieved by including extra natural mortality during historical years with severe red tides (i.e., 2005), ideally based on analyses of satellite data. The most recent Gulf red grouper stock assessment was confronted with new challenges of parameterizing red tides during both historical and forecasted time-periods, and growing uncertainty about standard methods used to quantify red tide severity, as well as suspected mortality due to associated bloom stressors (e.g., hypoxia). We will discuss alternative data streams used to determine how to treat the 2018 red tide when projecting tactical catch advice in the near-term. In response to stakeholder concerns, an initiative was put into place by SEFSC to systematically explore local ecological knowledge regarding red tides with individual and small groups of fishermen using oral history and participatory mapping. Results supported a negative impact on the red grouper stock, as most interviewees (>90 percent) described the 2018 red tide as “devastating” or “major” and many observed groupers in fish kills. Similar observations were reported by stakeholders through the Gulf of Mexico Fishery Management Council’s “Something’s Fishy” online tool. These results were considered by managers in conjunction with a decision table of projected catch advice across red tide severity scenarios, and ultimately catch advice was recommended assuming red tide mortality in 2018 approximated 2005.

AB9: Lisa Pfeiffer[1] - The Importance of Modeling Fishery Attainment in Stock Assessment

Lisa Pfeiffer[1] and Erin Steiner[1]
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Theme number: 2, 6

Many fish stocks are assessed infrequently and stock projections are used to set management guidelines in the years between assessments. However, stock assessment models often assume that actual catch equals the Annual Catch Limit (ACL). In reality, attainment is lower for many stocks, especially in multispecies fisheries where catches of some stocks are constrained by others. This property can cause a variety of possibly compounding errors for stock projections and models based on stock projections.

Forecasts of abundance assuming full attainment are often preferred by managers as the most "conservative" estimate, but it prevents explicit analysis of the costs associated with that assumption. Currently, scientifically weak models are used to estimate attainment. In addition, the stock assessment prioritization process down-weights stocks that are under-attained, leading to a self-reinforcing cycle of longer periods between assessment updates and a larger divergence from actual status of the stock.

We use a simulation to show the conditions under which the assumption of full attainment would lead to lower ACLs. The divergence could prove costly for the fleets that depend on these stocks, as ACL projections are important information for harvesters considering future quota and capital investments. In addition, stock projections are used for many scientific purposes, and the assumption of full attainment can limit the usefulness of multi-year stock projections. We use the West Coast groundfish trawl IFQ fishery to describe these issues and propose alternative economically-grounded models of attainment.

AB10: John Walter[1] - Maximum sustainable __? What Should We Optimize for in Fisheries Management?

John Walter[1], Nathan Vaughan[2], Alan Haynie[1], Rick Methot[1], Sarah Gaichas[1], and Scott Crosson[1]
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Theme number: 6

Fishery management is predicated on the concept of achieving maximum sustainable yield (MSY). Often we consider MSY to be based upon the biology of the species and stationary characteristics of the environment. Yet MSY is temporally dynamic due to both changing ecosystems and changing biology. Further, it can vary substantially based upon socioeconomic decisions related to fleet allocations and fishing practices with the conditional (e.g., based on current fleet allocations and selectivity) MSY often differing substantially from the global MSY. Given that even the basic target of optimization is, itself, a socioeconomic construct, it may be necessary to identify other targets for optimization such as maximum economic yield (MEY), maximum sustainable opportunity (MSO), Maximum Ecosystem Yield (MECOY) and other conceptual management objectives such as fishery stability, desirable catch rates, trophy fisheries or ecosystem considerations. This is particularly relevant at a time of rapid ecosystem changes that question the stationarity of many current MSY-based benchmarks and as management strategy evaluation is more widely used to screen performance of alternative management options across a panel of objectives.

AB11: Stephen Stohs - National Workshop on Integrating Economic Considerations into Management Strategy Evaluations

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Theme number: 7

Management strategy evaluation (MSE) is a simulation-based approach for estimating and comparing future fishery operations under alternative management strategies. The development of management strategy evaluation (MSE) has largely addressed concerns about the effectiveness of management actions in maximizing yields and reducing variation in harvests and the risk of depleting biological populations. Hence, MSEs to date have primarily focused on developing alternative management strategies to control population impacts on target fish populations of concern, and performance metrics that measure the impacts of alternative harvest strategies on the future time path of the population status.

Management decisions generally require assessment of socioeconomic as well as biological impacts. Past efforts have put relatively little emphasis on the development of performance metrics for the human dimensions of fisheries. Omitting these metrics potentially masks management trade-offs between the future health of fish populations and the effects on fishermen and fishing communities that depend on the fishery. Similarly, management strategies that differ little in terms of achieving population objectives may produce very different economic impacts.

The U.S. National Marine Fisheries Service conducted a September 2019 workshop in Seattle, Washington to discuss the integration of economic considerations into MSEs. Participants included economists and MSE modelers representative of the various NMFS regions, and a number of invited MSE experts from NOAA and academic institutions. The goal of this presentation is to report on workshop outcomes, and to provide a progress report on efforts underway to write a paper summarizing workshop results.

AB12: Stephen Stohs - Did Recreational Pacific Bluefin Tuna Bag Limits Lead to Increased Post-Release Mortality?

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Theme number: 3

Pacific bluefin tuna (*Thunnus orientalis*) is one of three bluefin species found worldwide. They are harvested by many nations and considered one of the most valuable fish in the ocean, both for consumers of high-end sashimi and as a prized game fish for recreational anglers.

On July 9, 2013, the National Marine Fisheries Service declared the Pacific bluefin tuna stock to be overfished. In response, the Pacific Fishery Management Council, under the scope of its

Highly Migratory Species Fishery Management Plan, adopted a recreational bag limit for both the Commercial Passenger Fishing Vessel fleet and private recreational anglers of two fish per day and up to six fish per multi-day trip, effective August 13, 2015. The bag limit was adopted rather than a full catch moratorium in part to avoid economic harm to the U.S. West Coast recreational fisheries and fishing communities in exchange for an inconsequential reduction to overfishing.

Bag limits introduced the prospect of increased post-release mortality in the recreational bluefin tuna fishery, due to regulatory discards once the bag limit is reached. We propose to use existing data sources, including Commercial Passenger Fishing Vessel logbooks and California Recreational Fisheries Survey records of private recreational angler catch, to estimate regulatory discards due to reaching the bag limit and estimate discard mortality using an appropriate estimation methodology. Socioeconomics will inform assessment of self-reported logbook data under the bag limit regulation. The results of this analysis are anticipated to inform the upcoming International Scientific Committee assessment for Pacific bluefin tuna.

AB13: Deborah R. Hart - Modeling Fleet Dynamics in the Atlantic Sea Scallop Fishery

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The Atlantic sea scallop fishery is one of the most valuable and successful fisheries in the United States. It is managed using a complex area management system. Some areas are closed to fishing, either long-term or rotationally; others are “access areas”, typically recently reopened closed areas, that are managed under essentially a form of area-specific IFQs with limited transferability. The remainder of the fishing grounds are “open” areas that are managed with days-at-sea. The SAMS (Scallop Area Management Simulator) model has been developed as a forecasting tool for such area management; the current version models 22 separate areas, each with its own population dynamics that are connected to other areas only via recruitment and fishery behavior in the open areas. Open area fishery effort distribution is forecast in the current version of the SAMS model using the simple assumption that effort per unit area is proportional to catch rate (LPUE). While this may be a reasonable first approximation, decisions by scallopers as to where to fish are more complex, and involve additional factors such as distance to port and the price of different scallop market categories. We will present preliminary analysis of spatial data linking scallop catch with scallop biomass, with the aim of improving predictions of overall open area catch rates and landings.

AB14: Alan Haynie[1] - Lessons and Challenges from a Dozen Years of Life as an Economist on the Bering Sea and Aleutian Islands Groundfish Plan Team

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The North Pacific Fishery Management Council has ‘Plan Teams’ for each of its fishery management plans where science center, state agency, and university scientists review stock assessments and provide other input. For most of the history of the Plan Teams, there has been one economist on each of the Bering Sea and Aleutian Island and Gulf of Alaska groundfish plan teams as well as the crab and scallop plan teams. I have been the economist on the Bering Sea and Aleutian Islands Groundfish Plan Team since 2008. In this talk, I will share my experiences from the process and guide a discussion to capture other people's experiences with the benefits and potential challenges for economists serving on stock assessment review panels.

AB15: Kalei Shotwell and Mike Downs - Developing the Ecosystem and Socioeconomic Profile (ESP) for Next Generation Stock Assessments

S. Kalei Shotwell[1], Michael Downs[2], Ben Fissel[1], Brian Garber-Yonts[1], Dana Hanselman[1]
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[2]Wislow Research Associates LLC

Ecosystem-based science is at the forefront of effective marine conservation and resource management; however, the gap remains between conducting ecosystem research and integrating within stock assessments. Primary obstacles are the lack of a consistent approach to deciding when to incorporate ecosystem and socioeconomic information into a stock assessment and how to test the reliability of this information for identifying future change. Over the past several years we have developed a new standardized framework termed the Ecosystem and Socioeconomic Profile (ESP) for operationalizing the integration of ecosystem and socioeconomic factors within the NOAA Fisheries' stock assessment enterprise. The ESP uses data collected from a variety of sources in a four-step process to generate a set of standardized products that culminate in a focused, succinct, and meaningful communication of potential drivers on a given stock. ESPs have been produced for Alaska sablefish, Eastern Bering Sea Pacific cod, Gulf of Alaska pollock, Gulf of Alaska Pacific cod, Bristol Bay Red King Crab, and St. Matthews Blue King Crab. The socioeconomic sections of the ESP provide a stock-specific historical synopsis of fishery economics and community engagement, and an indicator assessment that identifies trends in fishery performance for qualitative risk assessment and TAC considerations. Identification of which indicators can be useful for annual or semiannual assessments requires engagement by assessment authors, socioeconomic scientists, and stakeholders and will be key to successful incorporation of these data. Future priorities and improvements for the socioeconomic sections of the ESP include timely, efficient, and current year data delivery, defining tracking criteria for indicator analyses, and exploring options for developing relevant community engagement indicators.

AB16: Diana Stram - Do Decision Tables Affect Management Decisions?

James Ianelli[1], Diana Stram[2]
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[2]North Pacific Fishery Management Council, Anchorage AK
Theme number: 4

The North Pacific Fishery Management Council (NPFMC) strives to incorporate ecosystem and socioeconomic information in making informed management decisions. Stock assessments are key to integrating such information as part of this advice. The extent that such activities improve stock assessment accuracy, and stewardship of marine resources is debatable. Presently, although the NPFMC has some of the best fishery monitoring systems for some fisheries, there remain substantial data gaps to evaluate fleet behavior in a way that can effectively improve advice to managers. In this study, we evaluate a decision table approach to guide considerations where TAC might be advised to be lower than acceptable biological catch levels as determined from the Fishery Management Plan's harvest control rule. We present case studies comparing approaches where the TAC is constrained by other factors (e.g., eastern Bering Sea pollock and the 2 million ton Optimum Yield for groundfish species in the FMP) with ones where market conditions and bycatch affect TAC specifications. Finally, we highlight difficulties in understanding factors considered in developing TAC policy among decision makers.

AB17: Scott Steinback - A Bioeconomic Model of Recreational Angling in the Northeast U.S. Groundfish Fishery

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Theme number: 1, 3, 5

We will describe a bioeconomic modeling tool that combines a utility-theory consistent model of demand for recreational fishing trips with an age-structured stock dynamics model. The economic component of the model is a recreational demand model that is parameterized with a choice experiment survey. Angler effort is a function of trip costs, trip length, and expectations about landings and discards. Landings and discards on a trip are dependent on angler selectivity, catch-per-unit-effort, recreational fishing regulations, and stock structures of fish. The stock structures of fish are modeled using an age-structured fish stock-dynamics model. The integrated model is characterized by two-way feedback loops between angler effort and fish stocks. Angler effort, angler selectivity, stock sizes, and regulations jointly determine recreational fishing mortality, which, in turn, affects both future stock levels and future recreational fishing outcomes.

While the modeling tool has primarily been used to provide policy relevant catch advice to managers of the groundfish fishery in the Northeast United States over the past eight years, the inclusion of the size-structure of both standing biomass and recreationally caught fish allows us to project how changes in recreational policies will affect future biological conditions. We will provide a case study that compares short-term biological projections generated from our model, with stock assessment projections that are developed to bridge the gap between the terminal-year of the assessment and the year fisheries managers set recreational fishing policies. This approach will provide some insight into understanding how important it may be for stock assessment projections to link angler effort to changes in both management measures and stock conditions.

AB18: Emily Markowitz - Commercial and Recreational Fisheries Economic Impact Input/Output Model: Tool Update and Increasing Accessibility for Managers and Scientists

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Theme number: 5, 6, 7

Economists and fisheries managers are repeatedly tasked with assessing how proposed changes to fisheries regulations will alter economic impacts for harvesters, processors, wholesalers, restaurants, and grocers. Currently, a user spreadsheet tool created in Microsoft Excel is used to estimate the national and state-level commercial fisheries impacts. However, as is a chronic issue with Excel spreadsheet calculators, this decade-old tool is overly cumbersome to use, issue-prone, and very burdensome to update and maintain. Additionally, usage for analysis of management options requires data entry (no automation), which can introduce errors, especially given the tight timeline associated with conducting management analyses.

Recently, this tool has been recreated in R Shiny with some notable improvements. Shiny provides an elegant and powerful web framework for building web applications using R and can increase the accessibility of tools and knowledge-sharing for scientists, managers, and the public. This new tool has also been expanded to calculate the national, regional (where applicable), and state-level impacts for commercial and recreational fisheries. This tool is more flexible than its predecessor and can be used for additional analyses because it allows the end-user to select from preloaded data sets, edit data within the tool, and use uploaded data from the end-user. The tool also provides an intuitive interface for the end-user and eliminates opportunities to inadvertently edit data and manipulate equations. This tool can now also be used as a management-friendly decision-making tool and is outfitted for live demonstrations in council meetings and for creating report summaries.

AB19: Patrick Lynch - Rethinking Forecasting to Achieve Climate-Ready, Ecosystem-Based, Sustainable Fisheries Management

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Theme number: 3

Systems are changing at rates previously unobserved, with many systems experiencing increased variability in system characteristics (e.g., marine heat waves), and a steady drift away from historical conditions (e.g., increasing average temperature) and episodic events (e.g. harmful algal blooms). These changes represent the challenge facing fishery management and its ability to ensure long-term sustainability. Given the degree of change occurring in marine ecosystems, it is an opportune time to invest in research and development of forecasting techniques that support the advisory process. This proposal outlines a shift in the advisory process that maintains the continued use of stock assessments to evaluate the historical effects of fishing, estimate key biological and fishery parameters, and make a stock status determination. However, rather than conducting single-species forecasts to obtain catch advice, the results of these assessments would be provided to an interdisciplinary forecasting team (similar to how forecasts are developed for weather, climate, and extreme events such as hurricanes). This team (which would include stock assessment modelers, ecosystem modelers, and experts in human dimensions) would work at the system scale, and would be able to provide catch advice for one stock, or many stocks simultaneously (e.g., stocks within a fishery management plan). Ideally, these forecasts would be conducted in a way that is inclusive of all stocks for which an advice package is being delivered to a management body. This proposed shift in the science advisory process is driven by the degree of change occurring in marine ecosystems and the resultant effects on stocks as well as communities. This new process is believed to support the development of management advice that continues to be sustainable, while also being robust to future change, and closely aligned with ecosystem-based fisheries management and societal objectives.

Appendix 4: SEASAW Discussion Summaries

In this section, we will summarize the discussion sessions that were an important component of SEASAW where regional perspectives were shared and recommendations were developed. There were nine discussions total of varying length (see agenda). The two discussions from Day 1 (a discussion of survey results and barriers to using socioeconomic data in stock assessments) were included in the previous sections. The remaining seven discussion sessions are summarized below.

How can we scale up case studies to different regions?
Facilitator: Jeffrey Vieser
Rapporteur: Kristan Blackhart

Guiding questions:

- Where can we integrate socioeconomic analyses/data/indicators into fisheries management?
- What could contribute to a general framework for how and when it is appropriate to integrate socioeconomics into stock assessments?

This discussion focused on how we could examine case studies to identify best practices from each region that could be applied to other regions. Some case studies were presented at the workshop, and a number of recommendations were developed based on these case study presentations (see workshop recommendations section). Sustained collaboration between economists, social scientists, and stock assessment scientists was identified as key for continuing to move the field forward. Opportunities for communication between disciplines should be incorporated into the assessment process in each region. Attendees suggested that a future interdisciplinary working meeting should be held where specific case studies that incorporate novel linkages between socioeconomic and stock assessment factors could be further developed. Workshop participants noted that focusing on improving reference points and designing robust harvest control rules could be beneficial to all regions. While this document focuses on improving assessments with socioeconomic information more generally, additional effort is needed to focus in on specific assessment parameters that have overlap with economics and integrated modeling techniques (e.g., improving models of unreported catch, price elasticity, and socioeconomic models that inform estimates of virgin stock biomass). Peer-reviewed, methodologically sound, robust socioeconomic data and analyses identified in case studies will be more informative (less biased) to the SSC and fishery management councils, and will provide context for anecdotal information contributed by individuals at council meetings.

Balancing multiple management objectives
Facilitator: Alan Haynie
Rapporteur: Scott Crosson

Guiding question:

- What are the main challenges for you when trying to juggle several different objectives?

A number of challenges were identified by attendees in response to this question. It is difficult to balance conservation values with the value of harvesting additional catch. This requires defining utility functions for non-consumptive objectives like the utility of a healthy ecosystem or habitat. Balancing commercial and recreational values is also a challenge. It was noted that recreational and commercial fishing groups argue over potential management actions because they do not share the same objectives and goals when fishing. Improved models of recreational utility are needed, which likely differ from situations where yield is maximized. Maximum recreational utility may depend more on quantities such as maximum opportunity to fish, high catch rates, or catching large individuals (e.g., trophy fishery). It would also be beneficial to characterize stakeholder preferences for harvest variance vs. harvest stability. Would fisheries resource users accept a small reduction in take if it would reduce the variance in catch? It was noted that the National Standards 1 technical memorandum on carry-over and phase-in of changes may address some of what is permitted in smoothing out harvest (Holland et al., 2020).

Additionally, economists described the challenges they face when explaining technical concepts to fishery management councils. Distinguishing between economic impacts (e.g., IMPLAN modeling) and economic value (social benefits minus costs) is difficult, but is also important for allocation discussions between sectors. It would be useful for all regions to have a toolbox of tested examples/comparisons for explaining more technical materials to fishery management councils, stakeholders, and the general public for concepts such as impact analysis vs. value, the equimarginal principle and allocation, etc.

Socioeconomic considerations and trade-offs in harvest control rules
Facilitators: Aaron Mamula and Owen Hamel
Rapporteur: Kristan Blackhart

Guiding questions:
- How do socioeconomic and stock assessment data/models work together to define rebuilding policy? If they do not work together, why not?
- Can increased use of or higher quality socioeconomic data reduce scientific uncertainty when comparing alternative harvest control rules?
- How do socioeconomic factors trigger revisions of harvest control rules in different regions?

The facilitators for this discussion began the session with a presentation on the rebuilding analyses for widow rockfish. Rebuilding simulations define a relationship between harvest control, catch, and fishing mortality. More sophisticated models including fleet dynamics (e.g., gear switching behavior) could potentially alter the available choices of feasible rebuilding strategies. Social scientists could possibly help improve our understanding of the relationship between harvest constraints and observed/predicted catch by incorporating the response of fisher behavior (i.e., fishing effort) to the different harvest constraints, quota prices, fuel costs, etc. There was some question of whether additional social science information should be included directly inside a model or simulation, or more qualitatively in supplemental documents provided alongside model results. Social scientists should determine the potential benefits of better integrating social science in rebuilding analyses. The way social science is used to choose optimal rebuilding strategies currently needs to be better understood. To help prioritize these strategies, social scientists and collaborators need to understand what conditions or characteristics make some stocks better candidates than others for more socioeconomic integration in rebuilding simulations.

In order to best serve the needs of the community, the councils must consider socioeconomics when choosing between alternative harvest control rules. In some regions, this does not involve any communication between social and biological scientists. The stock assessment scientists generate the potential rebuilding strategies, and then the Council considers these alternatives within the EIS/rule-making process. In the Northeast, rebuilding plans are often designed to take an easy approach in the early years while leaving the largest "payment" due in the final years. This process is complicated by Council member turnover between the initial and final years of the rebuilding plan. A possible solution identified at the workshop was developing an economic analysis that takes into account the short- and long-term impacts of Council decisions. However, these economic analyses can quickly become complex. Whether this is part of a rebuilding analysis or conducted for a relatively abundant target stock, setting a harvest constraint (for example, a constant fishing rate) imposes different aggregate costs/benefits and different distributions of costs/benefits depending on how the harvest is allocated to the different fishery sectors/fleets.

The different uncertainties in rebuilding timelines must also be considered when comparing different projected catch levels. Attendees noted that the process for selecting uncertainty buffers would benefit from additional research. The uncertainty is often reverse engineered based on choosing the P* that corresponds to the required yield. Risk analyses should also be conducted for alternative control rules.

The role of socioeconomics in ground-truthing forward projections

Facilitator: Russell Brown

Rapporteur: EJ Dick

Guiding questions:

- How can we improve our projection models with respect to socioeconomic assumptions?
- What research/data needs must be met before we can do so?
- What circumstances might necessitate more complex representations of future socioeconomic dynamics in projection models?

Forward projections of stock dynamics can be improved by addressing assumptions about socioeconomic influences. Common assumptions about socioeconomic influences in stock forecasts were identified. For example, it is often assumed that fishery participants will conduct their fishing operations in a similar way to recent years. However, fishers are adjusting their effort in response to factors other than catch limits, including changing costs and market values. Fisher interviews would be informative for understanding this trend. Analysts can still project the central tendency, but should also include uncertainty and multi-year projections should be treated as probability distributions. While projections are typically conducted for single species, fishery operators must consider multiple species on each trip. If the fisher can switch gears and target different species, then the expected ex-vessel value will likely contribute to the choice of target. Fleet interactions with state-managed fisheries on the West Coast also complicates forecasting. Socioeconomic analyses can help improve our understanding of fishers' cross-investment across multiple fisheries. This will improve predictions of changes in fishing mortality among correlated fleets/species. Projections could be linked from assessments within a multispecies fishery. Species can be evaluated together to determine if any single stock will affect the catch of other species. Projections also often do not account for dynamics related to the needs of individual operators.

When projections fail to accurately represent future dynamics, it is imperative to consider which assumptions of the model were violated. The assumptions regarding socioeconomics may not be representative of what is going on in the fishery, and additional data may need to be collected by social scientists. Out-of-sample prediction was recommended by workshop participants as an important tool for learning about the important drivers of fishery systems.

In addition to the uncertainty of the forecasts themselves, the managers' response to forecast results is biased. For example, favorable catch results are often accepted with few issues raised, while restrictive forecasts are scrutinized more. Attendees also noted that increasingly complex models will be more difficult for managers and stakeholders to understand.

What strategies are useful in different regions for communicating socioeconomic risks to SSCs and councils?

Facilitators: Kalei Shotwell and Diana Stram
Rapporteur: Anna Henry

Guiding questions:

- How are socioeconomic influences and risks for different stocks communicated to councils?
    - Does a standardized framework have utility in other regions?
    - Do other regions have frameworks similar to the Ecosystem and Socioeconomic Profile (ESP)?
    - To what extent do you communicate to the actual council?
- Is there top-down support for additional analyses or decision support tools connecting socioeconomic factors and stock dynamics?
    - Does transparency in this practice come with a cost?
    - Are there ways we can communicate better to the Council?
    - Do other regions have experiences like the North Pacific?

This discussion followed three relevant presentations on communicating with Plan Teams, the SSC, and the Council in Alaska. The first presentation described an economist's experience and lessons learned from serving over ten years on the BSAI Groundfish Plan Team (Haynie). The economist emphasized the important role of social scientists to provide stock assessment authors with a more realistic understanding of fisher behavior and aid in interpreting observed fishery data. The next presentation highlighted the ESP framework, which is used to consistently communicate ecosystem and socioeconomic data and trends to the Council

(Shotwell & Downs). This framework also serves as an adaptable process for identifying important socioeconomic indicators that may be integrated in the stock assessment models themselves. The final presentation in this session was on using decision tables to communicate socioeconomic concerns to councils, and the associated impact on management decisions when setting the TAC (Stram, AB16). Decision tables can communicate different research results.

After hearing the presentations, workshop attendees wanted to know how ESPs were related to IEAs. ESPs are conducted on the level of individual stocks, and connect ecosystem and socioeconomic information to stock specific management. Interdisciplinary ESP teams involve IEA specialists, who help facilitate communication between IEAs and the stock assessment process. The target audience for the ESP reports are decision bodies, such as the NPFMC. ESPs provide a way to communicate dedicated research on specific species, and can help these bodies identify research priorities. ESPs have also been presented to stakeholders. Some of these stakeholders provided feedback that they wanted to see different information than what was presented to plan teams and the SSC. The adaptive framework of ESPs allows the authors to tailor the information for these different audiences.

Regardless of region, communication of socioeconomic data and trends as they relate to stock assessments can be improved by creating useful, accessible documents that avoid redundancy. Stakeholders should be provided with a roadmap of what information to expect in each document. There needs to be a balance between standardization of indicator reporting and oversimplification of issues in different fisheries. Socioeconomic indicators are not necessarily directional, and may impact stocks in different ways. Interdisciplinary meetings and workshops, like the ESP workshops in Alaska, are necessary to ensure adequate communication between social scientists and stock assessment scientists, and to help identify the most appropriate indicators for each stock. An added benefit of systematic communication of socioeconomic indicators is that community protection measures will be revisited more frequently than the typical five year review cycle. There are currently no ongoing checks to determine whether the protection measures were successful in fulfilling the Council's intent in providing for sustained participation of fishing communities. Developing a small number of indicators that are checked annually would be beneficial, such as measuring engagement and dependency relative to revenues for the different fishery sectors.

Notably, some workshop participants stressed that more frequent and systematic reporting will create recurring and increased work demands under the same or increased resource limitations. Automatic data reporting and data repositories for socioeconomic information can potentially increase efficiency and streamline the process of compiling socioeconomic performance metrics.

Scientists from regions other than Alaska were then asked to describe their framework for communicating socioeconomic information to managers as part of the stock assessment process. In the Pacific Islands, they form SEEM (social, economic, ecological, and management) working groups that include fishing community members and one social scientist or economist to discuss uncertainty in the fishery related to social or economic factors. Results from these workshop discussions have impacted catch targets for the Kona crab fishery. In the Southeast, any socioeconomic information intended for the Council must first be reviewed by the socioeconomic panel that is a subcommittee of the SSC. The Pacific Council does not have a standardized framework for communicating socioeconomic information related to stock assessments, and instead is communicated on an ad hoc basis. Finally, the SEASAW attendees recommended that frequent communication between science center staff and council staff can help inform how to best communicate socioeconomic information to councils.

Rethinking Forecasting: Improving collaboration and achieving climate-ready EBFM
Facilitator/Presenter: Patrick Lynch
Rapporteur: Justin Hospital

Instead of specific guiding questions, this discussion began with a presentation on proposed changes to stock assessment forecasts. The facilitator noted that the current process for developing forecasts of stock dynamics is less developed compared to forecasting approaches for large weather events (e.g., hurricanes). With the continuing impacts of climate change, developing forecasts based on limited single species information will be prone to compounding errors. Interdisciplinary forecasting teams could provide the diversity of expertise required to evaluate a multitude of trade-offs. The development of system-level forecasting tools was proposed, which would yield catch advice from combined data on multiple species, fishing fleets, and fishing sectors as well as climate/ecosystem/socioeconomic effects.

After the presentation, the workshop participants discussed how to move a more interdisciplinary forecasting approach forward. The appropriate scale of the effort was discussed. Some attendees suggested that joint research projects should be a starting point, with collaborative research as an evaluation criteria. Others stressed the need to conduct cross-regional efforts. Improving communication between the disciplines was stressed, perhaps through a forum, listserv, webinars, or additional workshops. Communication needs to be improved both between economists and stock assessment scientists at individual centers, as well as across regions. Attendees also recommended closer examination of successful examples of cross-disciplinary efforts to determine commonalities across examples, as well as region-specific factors that contributed to success.

Short- and long-term resource needs and research goals
Facilitators: Andrea Chan, Alan Haynie, Patrick Lynch
Rapporteur: Lisa Pfeiffer

Guiding questions:

- What other topics should this group be thinking about?
- How do we move toward more holistic assessments?
- How do we ensure socioeconomic influences are communicated to stock assessment authors?

Workshop attendees stressed the need to conduct research on multi-species stock assessment models, and multi-species modeling more generally. Simpler fisheries systems with two to three species would be a good place to start. Different software programs for multi-species MSEs show promising improvements, including a small number of species linked by fisheries.

The question of how stock assessment science can help economic efforts was raised during discussion. Economists may need parameters that are already estimated by the stock assessment model. Stock assessment scientists can help locate the required information.

Participants recommended that a list of key case studies should be developed, and interdisciplinary discussions on how to improve those case studies should be revisited at a later workshop. Working groups should look at the stock assessment models and related economic models and/or economic data, and determine how these could better fit together. This exercise would be useful for identifying more specific data needs and necessary modeling advancements. It was noted that the MSE leads at each center should be involved, since future MSEs should include socioeconomic components.

Appendix 5: SEASAW Steering Committee Members and Workshop Participants

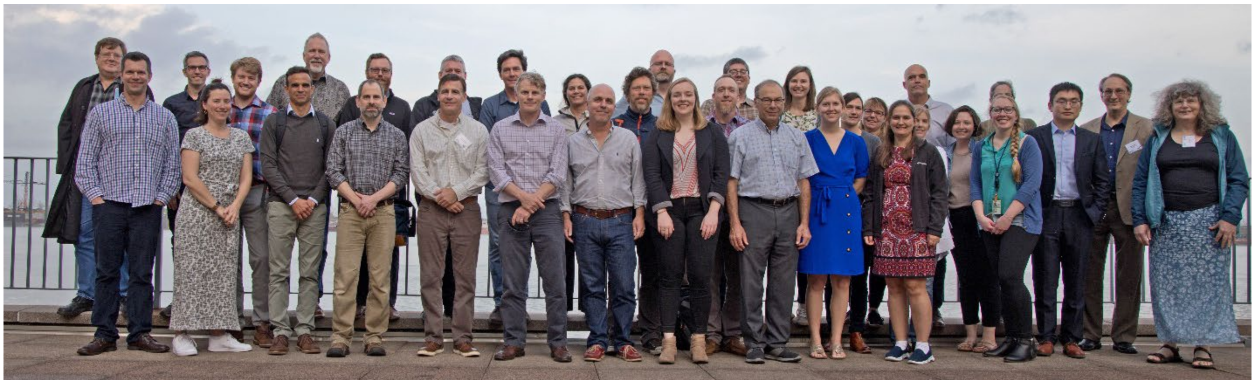

Figure A12: *Group photo of SEASAW workshop attendees. Front row, from left to right: Alan Haynie, Kristan Blackhart, Felipe Carvalho, Owen Hamel, Scott Steinback, John Walter, Scott Crosson, Melissa Krigbaum, Rick Methot, Kelsi Furman, Skyler Sagarese, Andrea Chan. Back row, from left to right: Mark Miller, Patrick Lynch, Jeff Vieser, Mike Downs, Todd Jones, Russell Brown, EJ Dick, Kalei Shotwell, Aaron Mamula, Howard Townsend, Justin Hospital, Lee Benaka, Lisa Pfeiffer, Anna Henry, Diana Stram, Rita Curtis, Steve Lindley, Emily Markowitz, Stephanie Oakes, Zhenshan Chen, Stephen Stohs, Deborah Hart. Missing: Doug Lipton, Marysia Szymkowiak.*

Table A3: *The names and affiliations of SEASAW steering committee members and workshop participants. An "X" in the Steering Committee or Workshop columns denotes participation in each.*

Name	Affiliation	Steering Committee	Workshop
Alan Haynie	AFSC	X	X
Marysia Szymkowiak	AFSC		X
Kalei Shotwell	AFSC	X	X
Jim Ianelli	AFSC	X	
Russell Brown	NEFSC	X	X
Eric Thunberg	NEFSC	X	
Scott Steinback	NE		X
Deborah Hart	NE		X
Kelsi Furman	Northeastern University		X
Diana Stram	NPFMC		X
Anna Henry	NPFMC		X
Owen Hamel	NWFSC		X
Ian Taylor	NWFSC	X	
Lisa Pfeiffer	NWFSC	X	X

Name	Affiliation	Steering Committee	Workshop
Lee Benaka	OST		X
Jeff Vieser	OST	X	X
Emily Markowitz	OST		X
Kristan Blackhart	OST		X
Rick Methot	OST		X
Doug Lipton	OST		X
Patrick Lynch	OST	X	X
Andrea Chan	OST	X	X
Rita Curtis	OST		X
Stephanie Oakes	OST		X
Howard Townsend	OST		X
Felipe Carvalho*	PIFSC	X	X
Justin Hospital	PIFSC	X	X
John Syslo*	PIFSC	X	
Todd Jones	PIFSC		X
John Walter	SEFSC	X	X
Skyler Sagarese	SEFSC		X
Scott Crosson	SEFSC	X	X
Mark Miller	SE		X
Aaron Mamula	SWFSC	X	X
EJ Dick	SWFSC	X	X
Stephen Stohs**	SWFSC	X	X
Dale Squires**	SWFSC	X	
Steve Lindley	OST (Acting), SWFSC		X
Zhenshan Chen	University of Connecticut		X
Melissa Krigbaum	University of Washington/NWFSC		X
Mike Downs	Wislow Research Associates		X

*Stock assessment alternates for the PIFSC.
**Economist alternates for the SWFSC in La Jolla, CA.

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