

TITLE: Patterns and Practices in Fisheries Assessment Peer Review Systems

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1. Introduction

Fisheries are important subsistence and economic activities globally, providing 17% of all animal protein consumed and accounting for US\$130 billion in trade [1]. As the world population grows, annual seafood consumption is expected to increase to 20 kilograms per capita. An estimated 40.3 million people engage in fisheries, of whom 90% are employed in small-scale fisheries. While efforts have been made to achieve sustainable harvests by reducing overcapacity, restricting impactful gears and techniques, and promoting sound (and even precautionary) management principles, 33% of all wild-capture fisheries are overfished, and 60% are fully utilized. The percentage of overfished stocks vary greatly by region, with some decreasing trends in certain developed countries such as the United States and New Zealand, but the global trend is increasing over the last four decades.

Stock assessments are complex scientific analyses that provide estimates of present and near-term stock conditions and trends. They provide critical, science-based advice for fisheries management decisions, such as quota setting. Shortcomings in the stock assessment process can impede objective, science-based, management decision-making and reduce the credibility of management decisions for stakeholders. Prioritizing the development and deployment of the best available science presents the best approach to tackle scientific uncertainty and its policy implications [2]. Peer review is a cornerstone of best available science that improves scientific quality, builds confidence, and increases stakeholder buy-in for stock assessments and the management decisions that depend on them.

Peer review is broadly defined as any “organized method for evaluating scientific work which is used by scientists to certify the correctness of procedures, establish the plausibility of results, and allocate scarce resources...” [3] and “a form of deliberation involving an exchange of judgments about the appropriateness of methods and the strength of the author’s inferences” [4]. The process, when rigorously applied, “uncovers scientific problems of method, interpretation, approach, or failure to provide sufficient detail to reproduce analytical results” [5]. Peer review is most commonly identified with the publication of scientific literature that is vetted using a variety of open/blind processes to ensure that the output utilizes an accepted set of procedures and analyses, and contributes to a body of knowledge [6]. Peer review is also used in determining research strategies, ranking and selecting programs and initiatives, and prioritizing funding. These various applications are part of the larger peer review framework, which is deployed in the production of scientific knowledge.

The configuration of fishery management systems varies considerably across the world, both in terms of the institutional arrangements and the decision-making authority. However, all systems with a modicum of capacity and an established legal and regulatory framework generate and utilize some level of scientific advice in decision-making, and include some type of peer review.

The focus of this paper is to compare the peer review approaches in stock assessment and related processes for selected national and multilateral fishery management systems. This includes assessing how and when in the scientific and management process peer review is conducted, the

types and frequency of peer reviews, peer review logistics, and – most importantly – the role that peer review plays in the development of best available science and generation of science-based advice. The comparative analysis can assist other systems in developing peer review approaches tailored to their needs, capacity, and legal and regulatory frameworks, especially as related to the tradeoffs that different types and levels of peer review present.

2. Methods

The identification, characterization, and analysis of peer review approaches from selected fishery systems developed from a 2017 American Fisheries Society (AFS) symposium: “National and International Perspectives on Improving Fisheries Science and Management Through Peer Review” (<https://afs.confex.com/afs/2017/meetingapp.cgi/Session/5298>). The symposium was organized by the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NOAA Fisheries) and the Center for Independent Experts (CIE). NOAA Fisheries develops fisheries information in the United States, and the CIE is an independent entity that conducts peer reviews of NOAA Fisheries assessments and programs. The information was obtained over the following three steps, from March 2017 to March 2018.

The first step involved inviting representatives from selected fishery systems to the symposium, based on prior knowledge of existing peer review approaches and the ability of representatives to participate. Consideration was given to including a diversity of national and multilateral systems, including regional fishery management organizations and an independent certification organization. Symposium participants discussed the following systems: United States (NOAA Fisheries, Southeast Data, Assessment, and Review [SEDAR], Stock Assessment Workshop/Stock Assessment Review Committee [SAW/SARC]); Canada (Department of Fisheries and Oceans [DFO]), European Union (International Council for the Exploration of the Sea [ICES]); Australia (Australian Fisheries Management Authority [AFMA]); New Zealand (Ministry for Primary Industries [MPI]); the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR); tuna regional fishery management organizations (tRFMOs, primarily the International Commission for the Conservation of Atlantic Tunas [ICCAT]), and the Marine Stewardship Council (MSC).

The second step consisted of pre-symposium planning and the symposium presentations. Symposium participants were requested to develop presentations based on a series of themes that focused on peer review and its role in the generation of best available science. The themes were: the context for peer reviews in each system (whether peer review is used to verify findings, improve acceptance, and/or build on the science); the history, scope, organization, and levels of peer review; the nature of the peer review process (prioritization, types of peer reviews, reviewer selection procedures, and evaluation of review products); and expected changes in how peer review will be used in the future.

The third step consisted of an online questionnaire that was sent to each representative to elaborate on the information presented at the symposium and to obtain standardized responses. The post-symposium survey was open for six weeks [7], then response data were used to characterize the different fisheries peer review systems.

3. Characteristics of fisheries peer-review systems

The characteristics describing peer-review systems are defined in this section. This analysis is focused on national or centralized fishery management and associated peer-review systems with authorities over national or international fisheries, and does not include systems with authorities over state or territorial fisheries.

3.1 Types of assessments reviewed

High quality stock assessments contain three fundamental types of data: fisheries-dependent data on catch (including bycatch) and fishing effort to quantify removals from a stock by fishing, and estimates of relative abundance, fisheries-independent data derived from scientific surveys to support estimates of abundance and mortality (including tagging data which enlist the cooperation of fisheries in tag recaptures), and biological data to provide information on reproduction, age and growth. These data are combined in analytical and statistical models to generate estimates of population parameters and management reference points. Information is communicated to fisheries managers on the effects of fishing and other ecological factors on fish populations, the uncertainty around the results, stock status (e.g., current status vs management reference point), and projections of near-term future catch levels and population dynamics. The quantity and quality of these types of information vary widely, as does the management context in which the assessment is conducted. The rigor of the peer review can vary as a function of any of these factors.

The following terminology is adopted here for characterizing stock assessments, although this terminology is not applied in all systems. A benchmark assessment is a first or a new assessment that applies new analytical methods or uses new data sets or types. Benchmark assessments typically are subjected to highly rigorous peer reviews. A standard or operational assessment updates a benchmark assessment that has previously been reviewed with updated data and minor modifications of the methods. Given that the analytical methods and data sets used in these assessments have already undergone a rigorous peer review, peer reviews of these assessments are normally less intensive than reviews of benchmarks. An update assessment merely adds a new year (or years) of data to a previous assessment, and peer review is often limited. In the USA, NOAA Fisheries has identified research assessments [8], which are intended to test new methods and/or data sets, rather than to provide scientific advice for management. In some cases, research assessments that successfully pass through peer review can be used as first-time assessments in support of management advice.

3.2 Types of reviews

Two broad types of peer reviews are recognized according to the basic process by which the review is conducted. The number of reviewers involved with a particular review can vary, as can the range of expertise.

Desk review: Reviewers develop their individual reviews independently at their home institution, and do not meet together with other reviewers to discuss the assessment, though conference calls among the reviewers may take place.

Panel review: Reviewers develop their reviews in a process that includes meeting together. Panels can comprise individuals chosen specifically for a given assessment or be standing working groups with consistent membership across a range of (usually related) assessments. The final review could consist of individual reports, with or without a summary report, a consolidated panel report, or a consensus report.

3.3 Frequency of assessments and reviews

Annual assessment and review of a stock is uncommon and usually applied only for stocks that are inherently highly variable, fished at a rate close to the target, highly valuable, or otherwise sensitive. Stocks that are inherently more stable or less heavily fished might only be assessed and reviewed at an interval of several years. Assessment frequency is also heavily influenced by management priorities, regional resources, and assessment capabilities.

3.4 Review throughput

The number of stock assessments that are reviewed per year (or other unit of time).

3.5 Source of reviewers

The entities or organizations from which reviewers are recruited. An internal reviewer would be drawn from the same organization that conducted the assessment. An external or independent reviewer would not have any substantial relationship with the organization that conducted the assessment and little or no involvement with any fishery that takes the stock. There are gradations between these two extremes. For example, an internal reviewer might work for a different part of the agency that conducted the assessment being reviewed, or in a different ocean basin.

3.6 How reviewers are chosen

The entity or individual that chooses the reviewers and the criteria by which they are chosen. Criteria may include expertise, experience, credentials, reputation (for fairness, efficiency, etc.), ability to act in a professional manner under contentious circumstances, and lack of conflict of interests (see 3.7 below).

3.7 Conflict of interest criteria

Factors that could disqualify a potential reviewer, because they could lead to bias or the perception of bias that could compromise the objectivity of the peer review. These factors typically include financial conflicts, such as whether the potential reviewer has a financial stake in the outcome of the assessment; employment conflicts, such as whether the potential reviewer is employed by, or could be seeking employment by, an entity with a stake in the outcome of the

assessment; and whether a potential reviewer has a well-established viewpoint or history of advocacy that could affect their objectivity. These criteria can be extended to include immediate family members of the potential reviewer.

3.8 Reviewer compensation

Whether a reviewer is paid for conducting the review, e.g., honorarium, hourly rate. This would not include an internal reviewer's salary that they would have received regardless of whether or not they participated in the review, nor would it include reimbursement for costs incurred while conducting the review, such as airfare and lodging.

3.9 Reporting

The individual or organization to which the reviews will be provided. Reports can take various forms, ranging from detailed written documents and reports to less formal communications.

3.10 Consensus

A formal process through which the reviewers are brought to agreement on a review, which would be published in a jointly authored consensus report.

3.11 Public participation

Opportunities or mechanisms through which interested stakeholders and the general public can participate in or provide input into a stock assessment or to the review of a stock assessment.

4. Characteristics and comparisons of fisheries peer-review systems

Fisheries peer review systems vary considerably, both within and across national fisheries programs. These characteristics are shaped by ecological, political, historical, and socioeconomic factors. The fisheries systems and their respective peer review characteristics included in this study are described in this section.

4.1. United States

The United States has a federalized fisheries management system, which is organized spatially across eight regional fishery management councils. The system primarily is responsible for fisheries conducted in the U.S. Exclusive Economic Zone (EEZ) beyond state or territorial waters, typically beyond three nautical miles from the coast. This federal system also coordinates across state and federal boundaries to manage shared resources. The regional assessment and review systems are: Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) for the New England and Mid-Atlantic Fishery Management Councils; South East Data Assessment and Review (SEDAR) for the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; Stock Assessment Review (STAR) panels for the Pacific Fisheries Management Council; North Pacific Stock Assessment Review (NPSAR) panels for the North Pacific Fishery Management Council; and Western Pacific Stock

Assessment Review (WPSAR) panels for the Western Pacific Fishery Management Council. The guiding objective for the peer review system is National Standard 2 [9], which requires the use of “best available science” in support of fisheries decision-making. To meet National Standard 2, U.S. fisheries management has evolved to incorporate peer review across various stages of fisheries stock assessment development. Although details of the peer review process vary across regions, all regional systems comply with National Standard 2.

A unique component of the U.S. fisheries system is the use of an external peer review entity: the Center for Independent Experts (CIE) [10, 11]. The CIE, funded by NOAA Fisheries, but run under contract as an independent program, is utilized to conduct external peer reviews of highly influential and/or controversial science, including fisheries stock assessments. The CIE often is engaged in the regional assessment processes listed above. CIE characteristics include its use of external experts, the separation of reviewer selection from NOAA Fisheries control, the use of honoraria to compensate reviewers, and strong conflict of interest restrictions.

4.1.1 SEDAR example

The SEDAR process [12], which organizes and evaluates stock assessments for fisheries under three regional fishery management councils (Caribbean, Gulf of Mexico, South Atlantic), exemplifies the U.S. system. SEDAR is a cooperative organization among these three fishery management councils, the Atlantic States and Gulf of Mexico Marine Fisheries Commissions, and NOAA Fisheries. Peer reviews in the SEDAR process occur at the end of the assessment process to review the final assessment product. SEDAR recognizes three “approaches,” which align closely with the types of reviews described in this paper. The benchmark approach develops first-time assessments for stocks or incorporates new datasets or analytical methods into existing assessments. This entails three distinct stages over approximately 12 months to develop, analyze, and review the data for the assessment; develop the quantitative analysis and estimate population parameters; and bring in independent experts from the CIE for peer reviewing the information. The standard approach, which requires 6-9 months, incorporates new information into existing, previously reviewed methods, with the possibility for some modest changes to the data or analysis. A technical panel from a SEDAR cooperator, such as a fishery management council’s science and statistical committee, provides peer review. The update approach incorporates recent information into an existing assessment, and requires about 3-6 months. Here too, peer review is provided by a SEDAR cooperator. Plans are for SEDAR to adopt the research track and operational assessments and reviews in 2020.

Overall throughput for SEDAR ranges between 14 and 20 reviews conducted per year, about evenly split between internal and external panels. SEDAR benchmarks are conducted and reviewed at intervals of five or more years. Reviewers provided by the CIE are compensated for their work, while internally sourced reviewers do not receive compensation beyond their normal salary. Reviewers provided by the CIE must meet the CIE’s conflict of interest criteria. Review panels are expected to reach consensus, but individual opinions from external reviewers are allowed.

SEDAR processes are designed to be publicly accessible. Workshops and webinars are announced in advance and are open to the public, with the information posted on the SEDAR

web site. Comments are accepted throughout the process, including during reviews. These comments can be in writing or in person. The reviews are conducted in public, and reviews are posted on the SEDAR web site.

4.2. Canada

Under Canada's Fisheries Act, the overall fisheries system is organized as a partnership between Fisheries and Oceans Canada, which is the national-level fisheries agency charged with managing the nation's fisheries and related resources, and provincial fisheries institutions, in that the centralized agency has authority over fisheries production, and provincial governments oversee dockside sales and processing [13]. Possessing a variety of fin fish and invertebrate stocks across a vast EEZ, species management varies across regions, but often involves advisory processes or species groups that provide recommendations to the Minister of Fisheries and Oceans, who holds ultimate decision-making authority.

The Canadian Science Advisory Secretariat (CSAS) [14], under Fisheries and Oceans Canada, coordinates the production of scientific advice related to fisheries science and assessment decisions, including peer review. The CSAS complies with the Government of Canada's Framework for Science and Technology Advice [15], which requires that the science advisory process follow procedures that assure the quality and reliability of science, including scientific peer review. Transparency is achieved through publications; the CSAS only publishes documents that have undergone peer review.

Fisheries peer reviews are organized as both desk and panel reviews, and the CSAS director and regional coordinator, in conjunction with advisors, are responsible for reviewer selection. Peer reviewers can only participate by invitation, based on their technical knowledge. Conflict of interest is informally considered in the selection process, based on the expectation that the potential reviewer will be objective. External reviewers are compensated, and their travel costs are reimbursed. Since they are already being paid their regular salaries, internal reviewers are not provided additional compensation, but their travel costs are reimbursed. Benchmarks (termed "frameworks") are conducted on one- to five-year intervals, depending on the sensitivity of the stock. Assessments of most major stocks are updated annually. Overall, 60-80 fishery management questions are addressed per year. In order to provide scientific advice, reviewers are required to reach consensus, defined as the absence of opposition to the conclusions and advice based on the current data and analyses, and the absence of influences by external considerations. If complete agreement cannot be achieved, consensus can be based on the weight of evidence, and in some cases a minority report documenting the dissenting views can be provided.

The CSAS also conducts "Science Response Processes" to provide scientific advice on an ad hoc basis. These responses fall into two distinct types: 1) when advice is needed to address urgent and unforeseen issues, such that a comprehensive scientific analysis and peer review are not feasible in the available time, or 2) when an advisory framework on the issue has already been fully developed, including the appropriate peer review. In both of these cases the peer review may be adapted to the circumstances, and efforts are made to include the contributions of

stakeholders that could be affected by the issue. Results are documented in publications in the “Science Response Series” [16].

4.3. Australia

Australian coastal and marine fisheries are managed via a divided jurisdiction, in which state governments manage their respective fisheries from the shoreline to three nautical miles, and the Commonwealth manages fisheries from three nautical miles through Australia’s EEZ. The Commonwealth is also responsible for managing stocks that occur in the waters of several states, highly migratory species, and international fisheries. The Australian Fisheries Management Authority (AFMA) [17], operating under the Fisheries Administration Act of 1991, the Fisheries Management Act of 1991, and the Environment Protection and Biodiversity Conservation Act of 1999 is charged with implementing the management of Commonwealth fisheries, ensuring that fisheries are exploited in an ecologically sustainable manner, maximizing net economic benefits to the nation, and understanding the state of marine environments that support fisheries.

The AFMA has three main responsibilities: science and research, management and regulation, and monitoring and enforcement. Under science and research, the AFMA develops research plans, establishes and oversees data collection programs, and commissions fisheries stock and ecological risk assessments through research agencies such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) [18]. Within the research program, the AFMA includes Resource Assessment Groups (RAGs) and Management Advisory Committees (MACs), which assist in identifying research needs, assess research proposals, and evaluate research outcomes. Each major Commonwealth fishery is covered by a RAG, which provides advice and recommendations to the MACs and the AFMA Commission on stock status, revenues, and fishery impacts. RAG membership includes fishery scientists, industry representatives, managers, and interest group members, though RAG members are included based on their ability to provide technical input, rather than on their affiliation. The RAG chair is independent of the fishery and cannot be an employee of an affiliated government agency. The assessment author is usually a RAG member or observer. RAG members are paid a sitting fee and travel is compensated.

The AFMA recently published a new policy document on science quality assurance [19]. The comprehensive policy includes a requirement for peer review of the key information that underlies fishery-management decisions. All reviews must have specific terms of reference, and be thoroughly documented. The policy describes several stages of peer review, with the RAGs responsible for organizing and providing peer review of stock assessments. Reviewers are chosen by the assessment author. Consensus among the reviewers is not required. Conflicts of interest for each agenda item are clearly articulated and a process of determining whether a member can be present for the discussion or advice components is decided without the person present. This process is undertaken at the start of each meeting. The public is not invited to these reviews, but all meetings are recorded.

Thus, the fisheries peer review for most assessments in Australian Commonwealth fisheries can be at best described as internal, in that, while stock assessments do undergo a peer review, the review system is conducted as part of the RAG process prior to the release of the assessment to

the general public. In addition, the RAGs have a general rule that key harvest strategies are tested using Management Strategy Evaluation (MSE), and that this research is published in peer reviewed journals. These MSE tests highlight the strengths and weaknesses of the whole stock assessment process from data collection to final decision and implementation. The reality is that MSE testing has not always been kept up to date within the RAG process when changes were made to a harvest strategy over time. This is often because small changes may not justify the cost of MSE testing (although the cumulative impacts may be large over time meaning that testing should have been undertaken). The degree of rigour is also not consistent between RAGs, often due to differing workloads and capacity. About seven to ten assessments are internally reviewed by the RAGs per year.

The policy also provides an independent expert peer review alternative to the RAG peer-review when uncertainty in results carries substantial risk if the information is used without further review. One to three ad hoc desktop reviews are undertaken annually by State agencies and the AFMA for contentious assessments. Reviewer selection for these reviews is expertise-based and favors a high degree of independence, as the reviewers cannot be affiliated with the relevant governmental agencies or have fishery-related conflicts, and reviewer selection is based on a rigorous identification and ranking process. Conflict of interest criteria include financial and employment factors, plus history of advocacy or a perceived conflict of interest. Consensus among reviewers is not required. Public participation in these reviews is allowed, and the reports from these reviews are usually publicly available.

Finally, a Status of Australia Stocks report [20] is published biennially, which describes the status and management of key fished species within Australia. Each chapter is peer reviewed by at least three independent experts in a process managed by the Fisheries Research and Development Corporation (FRDC), a partnership between the Commonwealth government and the fishing industry.

4.4. New Zealand

The Ministry for Primary Industries (MPI) of New Zealand [21] includes four business units, of which Fisheries New Zealand is charged with fisheries research and management. The agency is charged with administering the Fisheries Act of 1996, including advising the Minister of Fisheries on the allocation of total allowable catch across customary, commercial, and recreational fishery sectors. Fisheries New Zealand also commissions and oversees fisheries research, which covers the major stocks and fishery habitats, incidental impacts on protected species, and stock assessment.

All research approaches and findings are subject to the agency's Research and Science Information Standard which is a policy statement of best practice in relation to the delivery and quality assurance of research and science information that is intended or likely to inform fisheries management decisions [22]. Peer review is among the key principles for research and science information quality, which the agency defines as an "organized process that uses peer scientists with appropriate expertise and experience to evaluate the quality of research and scientific information." The purpose is to ensure that scientific methods, results, and findings meet the accepted quality standards and accepted practices of the scientific community. The

agency recognizes the trade-offs required in implementing peer review and considers the following criteria: independence and expertise; balance of expertise among reviewers; inclusiveness; transparency and openness; relevance; timeliness; management of conflict of interest; and reporting of uncertainty and risk. For larger, more complex, or contentious projects, MPI undertakes staged technical guidance of the work rather than simple peer review of final products. In all cases, it is a requirement that the raw data and analytical code are made available to MPI to ensure transparency and repeatability. Control code files are frequently appended to stock assessment reports.

The agency also identifies a number of peer review types. Simple peer reviews of final research reports are conducted by one or more qualified scientists. Reviews of evaluations of fisheries issues or findings, including most stock assessments, are conducted by science working groups. Some reviews are conducted by participatory workshops, where the information covers a broad area, multiple disciplines, or new methodologies, and will attract diverse stakeholder interest or are particularly novel or contentious. Independent expert peer reviews are conducted where the research is novel or contentious, there are strong industry or agency conflicts of interest, or past attempts at committee or panel peer review have encountered serious problems. Such fully independent reviews are also conducted periodically for “routine” stock assessments or other analyses that could inform fishery management decision making as a means of maintaining currency and best practice. The characteristics of the peer review process vary among these review types.

The most common method of peer review for stock assessments and other analyses in New Zealand is through standing working groups that are facilitated by the agency. Throughput is over 15 assessments and reviews per year. The government seeks inclusiveness in its working groups by allowing the participation of stakeholders and choosing expert reviewers based on their expertise, knowledge of the particular fishery, and sector. All working group members must agree to keep preliminary papers confidential. Given that its inclusive working group process includes stakeholders who may have conflicts of interest, the agency requires strong working group chairs. Such chairs must have a proven record for being objective and have skills and experience managing conflicts of interest, preventing peer review processes from being unduly influenced by potential management implications of results or conclusions, and facilitating consensus where possible, while ensuring the transparency and integrity of the process and findings. Chairs always strive for consensus but retain the right to determine final conclusions or escalate particularly complex matters for decision. If consensus cannot be reached, diverging opinions are documented. The agency recognizes that these are very demanding chairing roles. In addition to the standing working groups, 3 to 5 reviews are conducted each year by fully independent expert peer review panels that are facilitated by a qualified independent expert. External reviewers are compensated with an honorarium and reimbursement of expenses.

4.5. International Council for the Exploration of the Sea

Fisheries in the Northeast Atlantic are managed nationally by Norway, Iceland, Greenland, Faroe Islands, Russia, and the European Union (EU). The fisheries of EU members are organized under the Common Fisheries Policy that allows member states access to EU waters (12-200 nautical

miles from the coast) across national boundaries. All parties use the International Council for the Exploration of the Sea (ICES) [23] for fish stock assessments and scientific advice on biological aspects of management, such as setting annual quotas and evaluating the ecosystem effects of fishing.

ICES is an intergovernmental scientific organization based in Copenhagen, Denmark that represents the 20 states that border the North Atlantic. Its roles are to promote and coordinate marine scientific research, publish research results, and provide objective scientific advice to member states and international regulatory bodies in the North Atlantic. The ICES Council, consisting of a president and two delegates from each of the 20 member states, is responsible for decision and policy making. Under the Council, the Advisory Committee (ACOM) has one scientist from each member state (not representing the state but acting as an independent expert) and is facilitated by a chair and three vice-chairs (also independent scientists). ACOM provides scientific advice (including for fisheries), based on peer reviewed analyses.

Peer review in the ICES advisory process is highly structured and follows strict protocols. Advice is not published without a review of the methods and their application. ACOM is responsible for reviewer selection, following conflict of interest guidelines to maximize independence and transparency. Reviewers are sourced from within the ICES system, but they must come from a different region or discipline, and they cannot be involved in the subject for which the advice is being sought. ICES does not compensate reviewers, but does reimburse them for travel and per diem expenses.

The processes for developing and reviewing benchmark and routine update stock assessments differ. Benchmark assessments are conducted every three to five years to reach consensus on methodology. Although benchmarks address single stocks, the intent is to integrate relevant ecological information into the assessment, and the process considers all relevant information, such as data sources, models, and reference points. Benchmark meetings are open to experts and stakeholders. Benchmark reviewers participate in the entire five- to seven-month process, including method development. When completed, the benchmark review is considered valid until the next benchmark. In contrast, update assessments that add an additional year of data using the accepted benchmark methods are conducted by ICES expert groups. This type of assessment is reviewed within the expert group. Expert group and the review reports are used by an advice drafting group, with final advice approved by the ACOM. Interested stakeholders can observe review and advice-drafting meetings with the approval of the ICES Secretariat, and benchmark workshops can be attended by individuals with appropriate expertise. Reviewers produce a consensus report, but individual opinions are allowed within these reports. Eleven to fifteen assessment reviews are conducted per year.

In addition, the ICES system also develops advice on a range of specialized topics. These projects are also conducted by expert groups. Peer review of such expert group reports is provided by independent experts prior to the advice being written.

4.6. Commission for the Conservation of Antarctic Marine Living Resources

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) [24] is an international body tasked with the conservation and sustainable use of Antarctic marine living resources in an ecosystem-based management approach. The Commission was established in 1982 by international convention, and contains 25 member states. The Commission is the Convention's decision-making body; the Convention separately established a Scientific Committee to provide scientific advice. The Commission is supported by two standing committees, on implementation and compliance, and on administration and finance.

CCAMLR's Scientific Committee is tasked with providing the best available scientific information on quota levels and other management issues for Commission decisions. The Committee has a representative from each member state. It utilizes information provided by member states, as well as data generated from a number of commission-led programs, including fisheries monitoring, observer data, and ecosystem monitoring and marine debris initiatives. The Committee has established four working groups and one specialist subgroup to assist in developing scientific advice. These groups work on ecosystem monitoring, stock assessment, statistics, fisheries bycatch, and research methods.

Peer review is encouraged in the Commission's scientific findings and advice, as described under Resolution 31/XXVIII (2009). The Resolution calls on the use of best available science in the formulation and adoption of conservation measures and encourages the collection, review, and application of scientific information in an open and transparent manner.

The principal form of peer review within the CCAMLR system is internal, in that peer review is conducted by representatives of the member states in the Scientific Committee and its various working groups. Because of this, reviewers are not compensated, and there are no explicit conflict of interest criteria. The process is hierarchical, such that findings are reviewed at the working group level and by the Scientific Committee, after which the Scientific Committee provides the Commission with its advice. The priority is placed on consensus rather than independence, but member states can withhold consensus, which would be documented in Commission-related publications and reports. Throughput ranges between two to six internal reviews per year. Transparency is addressed by publishing meeting reports of the Scientific Committee in four languages, which can be downloaded by registered users.

In addition to internal peer review, CCAMLR periodically engages in external peer reviews. CCAMLR brought in independent experts to provide peer reviews of its stock assessment methods in 2006 and 2018 [25, 26] and also has conducted two whole-program Performance Reviews involving independent experts [27, 28]. These external reviews do not require consensus among reviewers. Finally, member states may elect to conduct peer reviews of CCAMLR and other national program data, but these activities are not part of a programmatic process.

4.7. Tuna regional fisheries management organizations

There are several tuna-based regional fisheries management organizations (RFMOs) that manage a majority of the high seas and straddling stocks of tunas and other highly migratory species. These RFMOs include the Inter-American Tropical Tuna Commission (IATTC), Indian Ocean

Tuna Commission (IOTC), International Commission for the Conservation of Atlantic Tunas (ICCAT), Commission for the Conservation of Southern Bluefin Tuna (CCSBT), and Western and Central Pacific Fisheries Commission (WCPFC). The scientific structures of these RFMOs vary considerably (e.g., assessments for different RFMOs are conducted by staff, contractors, or scientists from member states), with carry-over effects on their peer-review processes. Thus, there is no single system that represents the peer review processes employed by all the tuna RFMOs, but all seek to base their management decisions on high-quality science, which can include peer review.

4.7.1 ICCAT example

The focus of this discussion is on ICCAT as an example of these tRFMOs. ICCAT is charged with the conservation and management of tuna and certain other high-seas, tuna-like stocks in the Atlantic Ocean and Mediterranean Sea. The ICCAT Commission was established by convention in 1966 and at present has 52 contracting parties [29]. Based mainly on consensus, the Commission is responsible for making recommendations on total allowable catch, which become effective six months after the notification from the Commission to the contracting parties. Contracting parties not in favor of a recommendation may raise an objection, which prevents the recommendation from becoming active for the objecting party.

Science used to provide recommendations and other management and policy advice is conducted through ICCAT's Standing Committee on Research and Statistics (SCRS). The SCRS, which consists of member state representatives, is charged with ensuring that the fisheries data and analyses used to assess the populations of the fish in the convention area are complete and current. This includes abundance, biometry, and ecology of these species and human impacts on their abundance. The Commission is mainly reliant on fisheries information provided by official agencies from the contracting parties, although it may use other institutions, such as NGOs, to conduct limited fisheries science research. The Committee also promotes coordination of various national research and monitoring activities, develops cooperative research programs, completes stock assessments, and generates conservation and management advice.

The SCRS primarily relies on an internal process of stock assessments conducted by species groups consisting of participating national scientists. The analyses are conducted by a subset of the species group members with the requisite technical expertise. The remaining members review their work as it is developed, rather than providing peer review as a separate review process. This system has challenges, because the technical abilities of the national representatives on the species groups vary widely. Because peer review is provided by members of the species group, review is considered internal. Since the reviewers are receiving their regular salary to participate in the species group, they do not receive additional compensation for serving as reviewers. There are no formal requirements related to conflicts of interest beyond acceptance of broad ICCAT principles related to integrity, independence, and objectivity. The final assessment report is a consensus report from the species group. The species group meetings are not open to the public, but observers (e.g., from NGOs) can attend if they register ahead of time and pay a required fee. Benchmarks are assessed and reviewed at three- to five-year intervals,

with updates conducted and reviewed between benchmarks. Assessments for three to six stocks are conducted and reviewed per year.

Recently the SCRS has established a periodic review of selected assessments by independent, external scientists. This process is now part of the SCRS Strategic Plan [30]. Selection of the reviewers is conducted by a panel consisting of the chair of the species group responsible for the assessment being reviewed, a representative of the secretariat, and the SCRS chair. The reviewers are chosen from a list of candidates maintained by the ICCAT secretariat. As these reviewers are external to ICCAT, they are compensated for their reviews. They are not required to reach consensus in their independent reviews. In developing the management advice, the SCRS is required to consider, but not necessarily follow, the recommendations provided by these independent reviewers.

There is a challenge in implementing this independent review process, because the most qualified reviewers tend to come from the most developed countries. Thus, representatives from less developed member countries can perceive that there is a potential bias against their interests, which leads to differences in the priority accorded by member countries for funding independent reviews. Nonetheless, ICCAT remains committed to continue both the internal and external scientific peer review processes, and finances at least one independent review per year of an ICCAT stock assessment.

ICCAT also contracts independent peer reviews of large research programs that they implement, such as the Atlantic bluefin tuna research program and the Atlantic tropical tuna tagging program. At the Commission level, ICCAT has contracted independent reviews of ICCAT operations, including all science operations, in 2008 and 2016.

4.8. Marine Stewardship Council

The Marine Stewardship Council (MSC) [31] is an independent, non-profit organization that provides the standard and framework for third-party audits by Conformity Assessment Bodies (CABs) for evaluating the sustainability of fisheries. Established in 1997, the MSC system works globally, and is not tied to any specific region. The evaluation process involves assessing whether fisheries are achieving minimum standards related to the status of the target stocks, impacts of fishing gears, and governance, among other factors. Neither the CABs nor the peer reviewers in the MSC system provide actual reviews of stock assessments as performed by the other systems described above. Rather, the peer review in this case is an important part of the assurance framework built into the MSC assessment and certification process. As a component of the MSC certification process, CABs review stock assessments to determine if they meet the MSC standard.

To ensure that CABs perform to the level required to accurately and consistently assess fisheries, the MSC developed two checks in a quality control system: an annual review of CAB performance by an outside auditor, Accreditation Services International (ASI) [32], and technical oversight, consisting of peer review by non-MSC experts and an oversight review by an MSC internal fishery team conducted prior to fishery certification. In addition, a second follow-up stage of peer review is included in the certification process when the reviewers are invited to

comment again on the responses of the CAB teams to their initial comments. The CABs also include their second response in the final draft report released into the ‘objections stage’ of the certification process.

In 2014 the MSC decided to develop a Peer Review College to add independence and rigor to the peer review of the MSC certifications, increase the pool of peer reviewers, ensure consistency and effectiveness in the inputs, and monitor and improve the speed and efficiency of peer reviews. The Peer Review College started voluntary pilots in 2016 and was formalized for all new fisheries on September 1, 2017. A designated MSC team runs the College and is responsible for liaising with the CABs and peer reviewers. The MSC team manages the peer review system, recruits and contracts peer reviewers, ensures that peer reviewers do not have conflicts of interest, and provides a quality check on peer reviews. Conflict of interest criteria include financial and employment factors for the potential reviewers and their immediate families, advocacy, and perceived conflicts. The MSC team is supported in these regular activities by up to three independent third party experts. The Peer Review College Oversight Committee, comprising up to five representatives from the MSC Stakeholder Advisory Council and one from the Technical Advisory Board, provides input on the College procedures and guidelines, and reviews the College’s ongoing and overall performance. ASI works with the Peer Review College in reviewing conflict of interest procedures, evaluating any potential conflicts, and investigating stakeholder concerns about conflicts. The MSC process has a public consultation stage on the shortlist of peer reviewers to be included in each fishery review. Any conflicts of interest raised by stakeholders are considered by the Peer Review College Team in collaboration with ASI, and the peer reviewer candidate can be removed from the shortlist if appropriate.

As of 31 March 2017, 315 fisheries in 34 countries had achieved MSC certification, though certification for 17 of those fisheries had been suspended [33]. In the previous year, 46 fisheries had completed the certification process, and 86 more were in review.

5. Discussion

Peer reviews of fish stock assessments are intended to provide an objective quality check for assessments and related scientific products. They share a number of common features, but the scope and scale of peer reviews are affected by several factors and challenges. Thus, there is not one ideal peer review process that can be followed in all circumstances. Instead, the design and conduct of peer reviews are typically adapted to the particular circumstances. These include the sensitivity and complexity of the assessment under review and the resources, expertise, and time available for the review.

5.1. Comparing and contrasting key components of peer review systems

For scheduling and organizing peer reviews of stock assessments, fishery management systems can adopt programmatic approaches, meaning that there are established criteria and defined processes that are followed; ad-hoc approaches, meaning that reviews are scheduled and organized on an as-needed, rather than a systematic basis; or more commonly there is a combination of both approaches. These range from infrequent checks on ongoing research to

embedded programs established to oversee all major aspects of the stock assessment process, especially for benchmark assessments.

Most peer review systems emphasize transparency, which serves to ensure stakeholder confidence in the results of what is often a time-consuming and expensive process, and that can strongly impact key issues, such as quotas. Conversely, peer review systems vary considerably in matters of reviewer selection and management of conflicts of interest. The US federal fishery management process, for example, has developed a wholly independent peer review program for high-profile assessments, the CIE, which detaches the federal fisheries agency from reviewer identification and selection, and from assessment evaluation, while imposing a strict conflict of interest framework that considers financial, employment, advocacy, and perceived conflicts. The MSC has also recently adopted an independent Peer Review College mechanism by which reviewers are provided to each fishery for assessment against the MSC standard. By contrast, some other peer review systems employ a less rigid process, allowing for internal reviews (Australia, ICCAT) and identification and selection processes for internal reviewers that may be aided by outside advice (Canada). Such systems recognize and manage the influences of conflicts of interest through the review process, which may enable a wider range of interests to be heard and increase stakeholder acceptance of the results.

Factors such as scientific capacity, funding, resource base, and culture affect peer review systems. Stakeholder views on institutional expertise and integrity are often more important in international systems such as tRFMOs and CCAMLR, where member state consensus and international political concerns will drive funding and influence compliance with scientific advice and management decisions.

5.2. Challenges

Many challenges affect the scale and scope of fish stock assessment peer reviews (Table 1). Funding is a primary challenge that constrains peer reviews. A lack of sufficient funding will reduce the number of stocks that can be reviewed or limit the number of reviewers that participate, especially if the reviewers are compensated and require re-imbusement for their travel. The time available for reviewers is a challenge that can be closely tied to financial resources, but can also stem from timetables for management decision making and implementation. Less time for a review limits the opportunity for reviewers to evaluate the strengths and weaknesses of an assessment.

Another leading challenge is the limited pool of available reviewers with the necessary expertise. The field of fish stock assessments is relatively small and highly specialized. Many of the most technically competent stock-assessment scientists work for fisheries agencies, so involving them in a peer review of their own agency's stock assessment gives rise to conflict of interest concerns. Similarly, stock assessment specialists working for industry groups can have conflicts of interest if they are included in working groups or review panels. Not all technically qualified experts are willing to participate in reviewing stock assessments (e.g., academics might prefer to devote their time to original research or teaching), nor are all experts willing to devote the time and effort to produce a high-quality review. As stock assessments become more multi-

disciplinary (e.g., by incorporating ecological drivers or multi-species interactions), assembling a review panel will require a wider range of expertise. Also, there is reviewer temperament and conduct; good reviewers need to be critical of the technical content of the work without being critical of or confrontational to the people who conducted the work. Temperament and conduct are especially important during panel reviews conducted alongside assessment meetings. The scarcity of reviewers has prompted proposals to develop a consolidated pool of peer review tuna experts to be used by all tRFMOs [34].

The highly technical nature of stock assessments leads to reviews that are also highly technical, and, therefore, not easily communicated to the affected stakeholders. Related to this issue, external review panels with expertise that focuses on the analytical aspects can lack local knowledge of the stocks, fisheries, and nuances of the data sets. This raises the possibility that the reviewers may not appropriately consider such local factors and, even if such factors are considered, their conclusions might not be perceived as credible by affected stakeholders.

Finally, there is the challenge of post-review follow up. Peer review outputs frequently include recommendations for improving the assessment and the underlying data. Implementing such recommendations is beyond the purview of a peer review, but it is a source of frustration for reviewers when the recommendations of a previous review are not followed. In this situation, shortcomings that have already been identified can continue to be shortcomings in the future. Conversely, poor quality reviews, especially if there is no face-to-face discussion to tease out issues, can be a source of frustration for analysts and agencies who may have to commit scarce resources to rebutting unfounded, trivial or irrelevant criticism or conducting additional analyses. Recipients of peer reviews thus need to put in their own due diligence to assess the validity of the comments they receive. Some jurisdictions (e.g., New Zealand) have formal processes for escalating such disagreements for resolution, in much the same way as the editor of a scientific journal makes the final decision on conflicts between authors and reviewers of papers submitted to their journal.

5.3. Trade-offs and best practices

Peer-review programs for stock assessments are subject to many competing or conflicting demands, priorities and constraints. For example, a peer review can be thorough, or it can be quick and inexpensive, but it cannot be both because it takes time and expertise to understand the implications of all the calculations and assumptions in a complex analysis. This section provides an overview of the potential costs and benefits of potential solutions to the challenges, and considers how trade-offs among these solutions can be addressed (Table 1).

Every potential solution has some cost and some benefit. Some tradeoffs are obvious – conducting a less comprehensive review will cost less, but may result in less information obtained from the review. Others may be more subtle. For example, expanding the pool of technically qualified reviewers by seeking international experts can result in a review panel with strong technical expertise, but with less knowledge of the actual stocks being assessed. The

output from such a panel could be correct from the technical perspective, but could miss significant local factors that affect the assessment, such as fine-scale nuances of the data sets.

The design of a comprehensive peer-review program needs to identify these compromises to maximize the overall value of the program for fisheries management. No program will have the fiscal and human resources to conduct frequent comprehensive reviews of all their stocks. Assessments for some stocks merit more comprehensive and/or more frequent reviews than others. Effectively managing a stock that is heavily exploited, at low abundance, or that is sensitive to environmental or other drivers may require a detailed assessment and thorough peer review annually, while managing a stock that is lightly exploited and has a relatively stable history of abundance or landings may require a much lower level of assessment and review.

NOAA Fisheries' new stock assessment improvement plan [8] contains an in-depth discussion of how stock assessments and the peer reviews associated with them can be adapted to the circumstances of the stock while maximizing efficient use of the resources available for the assessments and reviews. Implementation of the plan is currently under development. High points of that discussion are summarized here. Three general categories of stock assessments are described: research, operational, and stock monitoring update. Each has an appropriate level of peer review. A research stock assessment is a first assessment of a stock, or a major revision of an existing assessment, such as the use of new analytical methods and/or new data sets. This type of an assessment is not intended to provide management advice; the intent is to advance the state of the science for incorporation into a benchmark or an operational assessment in the future. As such, a research assessment requires a comprehensive, objective, independent peer review that can identify strengths and weaknesses and make recommendations for improvements. The term benchmark assessment is not included in this system, but if a research assessment is accepted through peer review, its results can be used for management advice, so it is functionally equivalent to a benchmark assessment. An operational assessment is used to provide management advice. It relies on analytical methods and data sources that have previously been thoroughly documented and reviewed, and are applied with minimal change. Thus, the peer review of operational assessments can be streamlined to focus primarily on quality assurance, and potentially be conducted by a standing committee of regional experts. A stock monitoring update is used to update management advice. It is conducted between operational assessments and simply updates the previous operational assessment by adding a new year of catch data. As such, minimal peer review is required, since the assessment contains little new information or analysis.

Many developed nations and tRFMOs are now developing or using Management Procedures for fish stock management that aim to greatly reduce the need for annual stock assessment and peer review while providing greater surety of desirable outcomes [35]. Management Procedures differ from the traditional stock assessment approach in that the inputs to (for example) advice on a catch limit are pre-specified and the formula for calculating the catch limit has been rigorously tested by simulation to confirm that it is likely to achieve acceptable trade-offs among the conflicting objectives commonplace in fisheries management [36]. The simulations to test and support Management Procedures are usually called Management Strategy Evaluations [37] and it is at this stage that management objectives, the uncertainties in the stock assessment approach, and possible different states of nature must be addressed in great detail. Identifying and

simulating this wide range of uncertainties is critical to the robustness of the approach and is very resource intensive for agencies, stock assessment scientists, and stakeholders. Equally, of course, thorough peer review by experts with a range of backgrounds is required to provide surety that management objectives have been properly captured and the uncertainties have been identified and fully addressed in the simulations. Thus, Management Procedures “front load” much of the assessment and peer review work during an intense development phase, meaning implementation in the years between re-assessment (typically five years) is largely mechanical and requires limited review.

6. Conclusions

Peer review of stock assessments, which provide the scientific basis for many fisheries management actions, such as quota setting, is important to science quality assurance and to stakeholder acceptance. Thus, peer review systems are key components of well-developed national and international fisheries management systems. All systems covered in this paper employ processes that consider major aspects of peer review, including the sourcing, selection, and independence of reviewers; reviewer qualifications and compensation; conflicts of interest; and transparency. However, there are substantial differences among peer-review systems in how these factors are addressed, and also differences within systems, depending on the sensitivity and type of assessment being reviewed (e.g., benchmark vs update assessment). Also, tradeoffs are inherent in the design and conduct of peer reviews, such as the tension between timeliness and level of detail, or between inclusiveness and conflicts of interest. There are differences in how conflicts of interest are addressed, with some systems enforcing strict guidelines about financial interests or previous statements or positions on an issue, while others allow stakeholders to serve as reviewers while explicitly acknowledging and managing their potential biases. The diversity of approaches is influenced by the specific legal framework and culture under which the assessment is conducted, the funding and time allotted for the assessment and review, and available expertise. No perfect system exists, and it is important to note that reviews are not sacrosanct; thus, agencies seeking to establish a new or improved peer review system should specifically and deliberately consider the various trade-offs together with their particular circumstance when designing their approach.

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Challenge	Potential solutions	Benefits	Costs
Lack of funding	Conduct fewer or less comprehensive reviews	Reduces funding needs	Reduces quantity and/or quality of reviews
	Use fewer reviewers per review	Reduces funding needs	Provides less input to the review
	Use reviewers that do not need to be paid	Reduces cost per reviewer	Reduces incentives for external reviewers to participate
	Conduct virtual panel reviews or desk reviews	Eliminates travel costs	Reduces opportunities for reviewers to interact
Lack of time for the review	Conduct fewer or less comprehensive reviews	Takes less time	Reduces quantity and/or quality of reviews
	Simplify the review process	Reduces time needed per review	Reduces comprehensiveness of reviews
Limited pool of technically qualified reviewers	Pay the reviewers	Increases incentives for external reviewers to participate	Increases funding needs
	Seek international reviewers	Increases pool of technically qualified reviewers	Reviewers have less knowledge of stocks being reviewed; could increase travel costs
Limited pool of local expertise	Include mix of external and local experts; provide forum for local stakeholders to comment	Provides access to local knowledge	Some information provided could be biased or of questionable technical merit
Real or perceived conflicts of interest	Require full disclosure from all reviewers	Increases transparency; reduces risk of reviewers with hidden conflicts	None

	Seek to balance conflicts within review panel	Enables access to experts with different points of view and acknowledged interests	Could lead to conflicting conclusions
Limited pool of reviewers with suitable temperament	Empower panel chair to enforce code of conduct	Helps ensure appropriate discourse	Increases demands on panel chair
	Avoid re-using confrontational reviewers in panel reviews	Reduces disruptive inter-personal conflict; retains access to well-qualified reviews for desk reviews	Reduces available technical expertise for panel reviews
Quality control	Employ multiple reviewers	Compensates for a low-quality review	Increases funding needs; may lead to conflicting conclusions
	Avoid re-using poor-performing reviewers	Eliminates poor-quality reviews	None
Difficulty communicating with stakeholders	Use simplified template with relevant conclusions	Provides key information in easy-to-understand format	Reduces visibility of nuanced technical information
	Add more meetings to review process	Increases opportunities for stakeholder engagement	Adds time, complexity, and cost to review process
Lack of post-review follow-up to reviewer recommendations	Assign responsibilities for responses; develop and use tracking system	Increases likelihood that recommendations will be addressed	Responding to recommendations is beyond the purview of a peer review

Table 1. Peer review challenges, potential solutions, and benefits and costs of the potential solutions.