National Marine Fisheries Service

NOAA Aquaculture Science Advice Handbook

Policies, Processes, Resources, and Opportunities

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NOAA Fisheries Office of Aquaculture
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Cover photo: An oyster farm in Tomales Bay, California, USA at low tide. *Ulva lactuca*, commonly known as sea lettuce, grows on the rack-and-bag structure used for growing farmed oysters.

Credit: Bill Dewey

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Introduction

With mounting interest in marine aquaculture development in the United States, there is a growing need to provide regulators with relevant and rigorously developed science advice to support and inform aquaculture management decisions. Science advice, for the purposes of this Handbook, refers to quality-assured scientific information developed by subject matter experts. Science advice must be responsive to the questions and needs of regulators and managers to support their ability to make sound, science-based, defensible decisions (Figure 1). Advice products range from scientific literature reviews to model simulations to risk assessments, among others (Table 1).

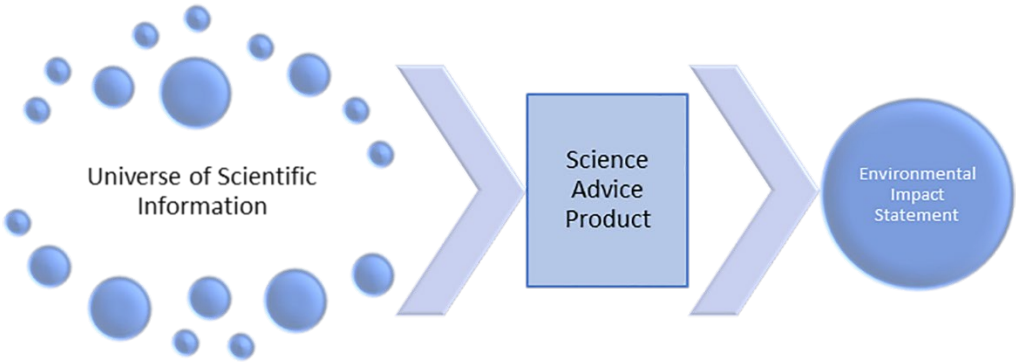

Figure 1. Science advice products provide a structured approach for integrating relevant, best-available scientific information into a format useful for supporting regulatory decision making.

While NOAA produces and funds meaningful aquaculture research products, national-level guidance has not previously existed to support the development of high-quality, usable scientific information to support aquaculture regulatory decision making.[1] This is in contrast to the well-defined processes governing development of science advice (e.g., stock assessments) for fisheries management under the Magnuson-Stevens Fishery Conservation and Management Act.

This Handbook provides an overview of fundamental laws and policies, processes, resources, and opportunities to strengthen the ability of NOAA scientists and

[1] For an overview of the permitting process for marine aquaculture in the United States, refer to *Guide to Permitting Marine Aquaculture in the United States* (NOAA 2022).

partners to develop science advice to support aquaculture permitting and management decisions within the purview of NOAA and other federal agencies. Objectives of this document are to describe:

- Federal laws, agency policies, and processes relevant to aquaculture science advice
- Successful models for aquaculture science advice development inside and outside of the United States
- Best practices for aquaculture science advice development
- Aquaculture science advice expertise and capacity within NOAA
- Opportunities and recommendations to strengthen NOAA capability in generating timely, rigorous aquaculture science advice

Table 1. Science advice product types and aquaculture-specific examples.

Science Advice Products	Examples
Subject matter expert consultation	Email, conference call, online meeting, memos
Workshop summary reports	Potential Protected Resources Interactions with Longline Aquaculture. Workshop summary (NMFS 2015)
Annotated bibliography	Aquaculture interactions with endangered species: bibliography (Rowley 2020)
State of the science literature review papers, meta analyses, or reports	Bivalve aquaculture and eelgrass: a global meta-analysis (Ferriss et al. 2019) Marine cage culture and the environment: twenty-first century science informing a sustainable industry (Price and Morris Jr. 2013) Ecosystem concepts for sustainable bivalve mariculture (OSB and NRC 2010)
Model runs or output	Aquaculture siting spatial analysis results

Best management practices guidance	Better management practices for bivalve molluscan aquaculture (Creswell and McNevin 2008). Best management practices for cage culture in the U.S. Caribbean (Price and Beck-Stimpert 2014).
Models or analyses	Offshore mariculture escapes genetics assessment (OMEGA) Model (NMFS 2012a) Benthic deposition and water quality models
Risk assessments (qualitative or quantitative, formal or informal)	Guidelines for ecological risk assessment of marine fish aquaculture (Nash et al. 2005). Advice from the assessment of the risk to Fraser River sockeye salmon due to *Piscirickettsia salmonis* transfer from Atlantic salmon farms in the Discovery Islands area, British Columbia (Mimeault et al. 2020).

Law, Policy, and Process Relevant to Aquaculture Science Advice

A number of federal laws and agency policies and processes govern the development of information products, including science advice. Below we describe some of these laws, policies, and processes most relevant to aquaculture science advice:

- Information Quality and Peer Review Directives that interact with the development of aquaculture science advice
- Relevant Magnuson-Stevens Fishery Conservation and Management Act requirements and processes
- NOAA Fisheries' *Center for Independent Experts* peer review process
- Science advice requirements developed for other federal agencies

Many of these provisions largely center on peer review processes, including establishing clear standards and mechanisms for ensuring information quality. A brief overview of the relevant laws and policies is shown in Appendix Table 1.

Information Quality and Peer Review Directives

Within NOAA Fisheries, leadership establishes Policy Directives to articulate agency policy and provide clarity to the public regarding existing requirements under U.S. law (NMFS 2020). Policy Directives are statements of, and instructions for, implementing important, high-level internal directions and positions. These Directives guide organization decisions and actions and promote accountability and consistency in management and science practices. While many Policy Directives have relevance to aquaculture, two have clear interactions with development of aquaculture science advice: the Data Quality Act (NMFS 2012b) and NMFS *Policy on the Internal Review and Approval of Fundamental Research Communications* (NMFS 2014).

Data Quality Act

The Data Quality Act (or Information Quality Act) directs the U.S. Office of Management and Budget to issue guidelines for all federal agencies to ensure quality, objectivity, utility, and integrity in disseminated information. This Act also directs all federal agencies, including NOAA Fisheries, to develop and follow information quality guidelines (OMB 2002). These guidelines establish the quality that must be met for scientific information disseminated by NMFS, including the following standards:

- ***Utility*** standards require disseminated information to be "helpful, beneficial, or

serviceable to its intended users, or that the information supports the usefulness of other disseminated information by making it more accessible or easier to read, see, understand, obtain, or use."

- ***Integrity*** standards require disseminated information to be "safeguarded from improper access, modification, or destruction, to a degree commensurate with the risk and magnitude of harm that could result from the loss, misuse, or unauthorized access to or modification of such information."
- ***Objectivity*** consists of two elements: presentation and substance. *Presentation* "includes whether disseminated information is presented in an accurate, clear, complete, and unbiased manner and in a proper context. *Substance* "involves a focus on ensuring accurate, reliable, and unbiased information." Data subjected to independent, external peer review is presumed to be objective.

  Objectivity also includes standards for third-party information. Information from third-party sources used to develop information products or to form the basis of a decision or policy must be of known quality and consistent with NOAA information quality guidelines.

Additionally, these guidelines require ***reproducibility***, whereby information is capable of being substantially reproduced, and ***transparency***, which includes communication of how analytic results are generated, the specific data used, the various assumptions employed, specific analytical methods applied, and the statistical procedures employed.

Fundamental Research Communications

Fundamental Research Communications, which include papers submitted to journals or published internally by scientists, describe any NOAA communication intended or expected to have broad distribution outside the U.S. government and that deals with the products of research in science or engineering. Fundamental Research Communications published by NOAA must meet minimum review standards. If a communication also includes matters of policy, budget, or management, then it is not a Fundamental Research Communication.

Fundamental Research Communications must have an information quality file created, documenting a pre-dissemination review process that addresses specific questions relevant to the various types of information products considered as Fundamental Research Communication (OMB 2002; NMFS 2004). This process includes, at a minimum, review by the head of the operating unit to assess scientific quality, highlight any inconsistencies or weaknesses, and ensure that Data Quality Act standards are met. If additional peer review is deemed necessary by the head of the operating unit, peer reviewers are to be selected based on expertise, independence, a balance of viewpoints, and an absence of any conflict of interest.

Peer review must be transparent to the public and include reviewer names, reports, their written charge, and the relevant agency response to the reviewer report. Potential conflicts of interest and agency independence must also be addressed (NOAA RC 2016). The U.S. Office of Management and Budget peer review bulletin provides federal agencies discretion to determine the appropriate peer review mechanism (OMB 2002). Choice of reviewer will depend on the novelty and complexity of the information to be reviewed, importance of the information to decision making, extent of prior peer review, and expected benefits and costs of review (NMFS 2012b; OMB 2005).

Mechanisms for peer review could include, but are not limited to, letter reviews or ad hoc panels. Importantly, consensus reports from ad hoc panels (vs. individual reviewer reports) can trigger requirements under the Federal Advisory Committee Act (GSA 2022). NOAA guidelines allow authors to use a disclaimer when information is presented that is not supported by the agency. However, the internal review process in general should ensure that such material is not included in Fundamental Research Communications, and disclaimers should be used sparingly. Agency authors must include a disclaimer when a Fundamental Research Communication includes personal viewpoints that are beyond the scientific findings and do not reflect the views of NOAA or the Department of Commerce. Additional requirements, logistical considerations, and best practices are provided within the *Guidance on Internal Review and Approval of Fundamental Research Communications* (NMFS 2014).

Information quality guidelines also allow for the use of ***third-party*** information from both domestic and international sources (e.g., government agencies, academic institutions), depending upon the conformity of the products to these guidelines (i.e., level of rigor of information quality). However, when such information is used, limitations, assumptions, collection methods, or uncertainties must be taken into account and disclosed within the resource.

Examples of possible third party information that could be used include science advice products from other agencies, multilateral organizations, or other countries with robust aquaculture science advice processes (e.g., U.S. Environmental Protection Agency, International Council for the Exploration of the Sea, Fisheries and Oceans Canada, Norway, etc.). Conversely, other agencies (and perhaps countries) may benefit from science advice products developed by NOAA.

Influential Scientific Information

The Office of Management and Budget defines *Influential Scientific Information* and *Highly Influential Scientific Assessments* and provides minimum peer review requirements for each (OMB 2002, 2005). Scientific information is "influential" if it will

or does have a clear and substantial impact on important public policies or private sector decisions (OMB 2005). Scientific information that affects a broad range of parties (e.g., an entire industry or a significant part of an industry) is more likely to be "influential" than scientific information that affects a narrow range of parties. Federal agencies are required to have a systematic process for peer review planning[2] of Influential Scientific Information that the agency plans to disseminate in the foreseeable future.

Each piece of Influential Scientific Information must have a peer-review plan that includes timing, methods, and whether there will be opportunities for public comment. Agencies must provide the U.S. Office of Management and Budget with an annual report of peer reviewed Influential Scientific Information activities each year (OMB 2005). Influential Scientific Information disseminated in the course of an individual agency adjudication or permit proceeding is exempt from peer review unless the agency determines that peer review is practical and appropriate and that the information is novel or likely to have precedent-setting influence. The Data Quality Act does not apply to dissemination of information within the federal government.

Notably, the Office of Management and Budget indicates that study reports of the National Academies of Sciences, Engineering, and Medicine meet the requirements for Influential Scientific Information and Highly Influential Scientific Assessments: "Peer review as described in this Bulletin is only one of many procedures that agencies can employ to ensure an appropriate degree of pre-dissemination quality of Influential Scientific Information." (OMB 2005). Congress has assigned the National Academies of Sciences a special role in advising the federal government on scientific and technical issues. Their procedures are generally quite rigorous, and thus agencies should presume that major findings, conclusions, and recommendations of their reports meet the performance standards of OMB (2005).

Risk assessments are a form of science advice increasingly used to inform aquaculture management on a range of issues, such as risk of disease transmission or genetic risks from fish escapes. For Influential Scientific Information disseminated by federal agencies that constitutes formal *risk assessments* (i.e., human health, safety, or the environment), Office of Management and Budget and NOAA Information Quality Guidelines provide specific guidance on how these must be conducted.

[2] Peer review standards under NMFS are established by the *Office of Management and Budget Peer Review Bulletin Guidance*, which was issued in compliance with the Information Quality Act (OMB 2002) and the *Final Information Quality Bulletin for Peer Review* (OMB 2005). Note that the Information Quality Act has no statutory name and is also sometimes called the Data Quality Act.

Specifically, this guidance specifies adoption of the principles of the Safe Drinking Water Act Amendments of 1996 respecting risk assessments, as well as the National Research Council paradigm of 1983, as updated in 1994 (NRC 1983, 1994). The following Safe Drinking Water Act principles were adopted for NOAA:

- NOAA will use the best available science and supporting studies (including peer-reviewed science), conducted in accordance with sound and objective scientific practices
- Data must be collected by accepted or best available methods

Risk assessments for aquaculture questions are likely to be largely qualitative; however, the National Academies 1983 and 1994 reports further specify the following additional principles that apply to risk assessments that are quantitative in nature:

- Each ecosystem component, including population, must be addressed by any estimate of applicable risk effects
- The expected or central estimate of risk for the specific ecosystem component, including the affected population
- Each appropriate upper-bound and/or lower-bound estimate of risk
- Data gaps and other significant uncertainties identified in the process of the risk assessment and the studies that would assist in reducing the uncertainties
- Additional studies known to the agency and not used in the risk estimate that support or fail to support the findings of the assessment and the rationale of why they were not used

Highly Influential Scientific Assessments

Highly Influential Scientific Assessments face higher peer review requirements than other types of scientific information. A Highly Influential Scientific Assessment has a potential impact of more than $500 million in any one year on either the public or private sector, is novel or controversial, is precedent-setting, or has significant interagency interest. Such an Assessment cannot be reviewed by scientists employed by the sponsoring agency (unless the scientist is employed only for the purpose of conducting peer review). Peer review of Highly Influential Scientific Assessments must include the charge to the reviewers and their credentials. A written response to the peer review report must be provided to explain the agency's response to the report and how that response satisfies key concerns in the report.

Magnuson-Stevens Fishery Conservation and Management Act

The scientific rigor involved in developing and approving a Fisheries Management Plan under Magnuson-Stevens Act provides a suitable model for

comparison of the characteristics that could be applicable for aquaculture science advice needs. Note that this model is presented below as an example, but is not necessarily directly applicable for aquaculture science advice.

As mandated by the Magnuson-Stevens Act, NOAA Fisheries has developed National Standards guidelines to be followed in the development of any Fishery Management Plan (NMFS 2010). Of particular relevance to the generation of science advice is *National Standard 2 - Scientific Information* (CFR 2018). National Standard 2 guidelines establish criteria and processes for use of scientific information to inform conservation and management measures, including definitions of scientific information, methods requirements, and peer-review processes.

A focus is placed upon use of established science (i.e., scientific knowledge that tends to be agreed upon without controversy), while emergent science is suggested to be considered more thoroughly. Additionally, multiple criteria are provided for evaluating best scientific information, including:

- *Relevance* of the scientific information to the fishery being managed
- *Inclusiveness* of the range of scientific disciplines relevant to the decision, including alternative scientific points of view and local and traditional knowledge
- *Objectivity* of scientific information
- *Transparency* and *openness*, whereby public input is possible at varying times and methods, uncertainties, and data limitations are communicated
- *Timeliness*, whereby the best available information should be used to inform the management decision
- *Verification* and *validation* to ensure reproducibility of the analysis and quality of the resultant information
- *Peer review* to ensure the quality and credibility of the scientific information and methods used

Scientific and Statistical Committees

The Magnuson-Stevens Act specifies that each of eight regional Fishery Management Councils establish and maintain a *Scientific and Statistical Committee*. This Committee is to be composed of federal and state employees, academics, or independent experts with strong scientific or technical credentials and experience (e.g., economists, biologists, social scientists (NOAA 2013). These Committees are responsible for reviewing the scientific basis of Council management plans and actions, developing fishing level recommendations in accordance with national fisheries management guidelines, and supporting the development of stock assessments for Council-managed resources. Scientific and Statistical Committees also employ a Socio-Economic Panel

composed of social scientists and economists to advise the Fisheries Management Councils regarding social and economic impacts of fishery management measures.

Through its *Framework for Determining that Stock Status Determinations and Catch Specifications are Based on the Best Scientific Information Available* (NMFS 2019), NOAA Fisheries established the following recommended process for considering best scientific information available in fishery management actions:

1. A draft stock assessment is prepared.
2. The draft stock assessment is peer-reviewed by the Scientific and Statistical Committee or another Council entity according to a process compliant with *National Standard 2*. Compliance requires consideration of stock status relative to the Fishery Management Plan, overfishing status, projections used to limit harvest, and any existing harvest control rules or management plans.
3. The stock assessment is revised by the authors to address peer-review recommendations.
4. The Scientific and Statistical Committee considers the peer-reviewed assessment and makes catch recommendations to the Council, and NOAA Fisheries generates a stock status determination based on the final assessment.
5. The Council develops catch specifications.
6. NOAA Fisheries reviews the Council catch specifications and via approval, certifies that the specifications are consistent with National Standards and other requirements. Final approval provides certification that the actions are based on the best scientific information available.

At least 14 days before review, NMFS peer review panels are announced in the Federal Register to allow public comment during meetings. Background documents for peer review and peer-review reports, including name and affiliation of reviewers, scope, objective, findings, and conclusions, are made publicly available as per Magnuson-Stevens Act Provisions (NOAA 2013; CFR 2018).

Risk Assessment

An additional consideration relevant to implementation of the Magnuson-Stevens Act is the management of risk and uncertainty by regional Fishery Management Councils. One way the Councils address these uncertainties is through the establishment of a formal *risk policy* to provide guidance to the Councils and Scientific and Statistical Committees on accounting for risk and uncertainty in Fishery Management Plans. Risk policies can ultimately help make fishery management more transparent, understandable, and predictable, while better achieving objectives of a Fishery Management Plan, given uncertain information and imperfect implementation.

Center for Independent Experts

To review *Influential Scientific Information* and *Highly Influential Scientific Assessments*, NOAA Fisheries has an existing process using an external group called the Center for Independent Experts. This group was established in 1998 by NOAA Fisheries as a mechanism for strengthening its science quality assurance in accordance with mandates of the Magnuson-Stevens Fishery Conservation and Management Act (NMFS CIE 2022). The group provides a consistent and reliable process for obtaining external, independent, and expert reviews of the agency's influential science programs and scientific products,

The Center for Independent Experts is used for policy decisions that meet the requirements of the Magnuson-Stevens Act guidelines for scientific information (NOAA 2013). Center processes are compatible with mandates of NMFS Policy Directives centered around NOAA science quality assurance, including the *Data Quality Act* and *Policy on the Internal Review and Approval of Fundamental Research Communications* (NMFS 2012b, 2014). External peer review requests are submitted to the NOAA Fisheries Office of Science and Technology. These requests include expertise requirements and terms of reference for each peer review (NMFS CIE 2022a,b).

Through the contract agreement with the Center for Independent Experts, which is administered by the Office of Science and Technology, the Center conducts an independent selection process to identify and recruit highly qualified reviewers who adhere to rigorous peer review standards, including independence from the science under review and other strict conflict of interest standards.

Center for Independent Experts manages a database of qualified, independent scientists for conducting reviews. Reviewers are required to meet academic or experiential training requirements (e.g., PhD in a relevant field or 5+ years relevant experience), as well as substantive experience requirements (e.g., 10+ relevant publications, record of participation in stock assessments). Reviews can range from panel review meetings (in-person or virtual) to desktop reviews, and these are typically conducted in an expeditious yet efficient manner (i.e., within a 30-day period of performance) addressing often complex terms of reference.

Reviewers are compensated at a rate typically not in excess of $800 per day, and related expenses such as travel and incidentals are reimbursed by the Center for Independent Experts. Each reviewer provides an individual peer review report, which is evaluated by the Center technical team. Reports are deemed final only when the team agrees that the report meets the review terms of reference.

Depending on the subject matter, a representative of a Fishery Management Council's Science and Statistical Committee may serve as the chair of a Center panel, providing a chair summary report in addition to the individual reviewer reports. The Office of Science and Technology ensures that Center for Independent Experts reports are compliant with contract requirements, that each term of reference was addressed, and that the reports are publicly available online (NMFS CIE 2022a,b).

The typical process for requesting peer review through the Center is during an annual data call (circa October/November of each year), circulated by the Deputy Director of the Office of Science and Technology to the Deputy Directors of each Office. (e.g., Deputy Director of the Office of Aquaculture). Central to the use of the Center is development of a *Performance Work Statement*, which specifies details of the requested review and provides the Center with elements of the review-specific contract. Overall, each Performance Work Statement addresses:

- Scope of the review (e.g., description of the product to be reviewed and rationale for review)
- Requirements for peer reviewers (e.g., exact expertise required to conduct the review, which can be prescriptive or general, based on scope, tasks, and terms)
- Tasks for peer reviewers, which can include pre-review materials (e.g., background literature to contextualize the review), a webinar conducted by the project contacts to brief the reviewers and answer questions, and details of the review and contract deliverables (both of which can be specified in detail in attached Annexes)
- Period of performance for the review, and schedule of milestones and deliverables (typically within 30 days of initiating a review)
- Project contacts and contact information
- Annexes, which may include report format and content requirements, as well as terms of reference for the peer review, specifying the product to be reviewed and the questions that must be addressed

Typically, the Performance Work Statement is provided to the Office of Science and Technology Center for Independent Experts Coordinator at least three months in advance of the requested review date. This allows time for the Center Coordinator to provide feedback and suggest revisions to the work statement. The statement must be approved by the Deputy Director of the requesting Office to initiate the contracting process for the review.

Prior to the review, the Center will provide confirmation of the identified reviewers. Project contacts can approve or recommend rejecting a reviewer on the basis

of insufficient or unsuitable expertise or based on a conflict of interest (as related to a financial-based, advocacy-based, or perceived conflict of interest). This recommendation is then adjudicated by the Center technical team's steering committee. Once initiated, reviews are typically conducted within 30 days, and reviewer reports are provided back to the Office of Science and Technology.

Federal Agency Science Advice Requirements

The U.S. Army Corps of Engineers (USACE) and Environmental Protection Agency (EPA) are the primary federal agencies responsible for aquaculture permitting decisions,[3] relying on relevant scientific information to guide decision making. It is therefore important that scientific advice generated by one agency is acceptable to all agencies. This may be facilitated by benchmarking how each agency applies the Data Quality Act, and assuring that processes are compatible and substantively equivalent.

The Data Quality Act establishes standards that all federal agencies are required to meet. As described above in the *Information Quality and Peer Review Directives* section, NMFS' application of these standards include a range of quality requirements for scientific information generated by NMFS. These include peer review requirements for scientific products deemed *Fundamental Research Communications*, or those with broad external dissemination, as well as *Influential Scientific Information* and *highly influential science assessments*.

Guidance provided by the USACE regarding compliance with the Data Quality Act indicates that the quality assurance requirements of USACE information products are compatible with standards adopted by NMFS, and vice versa (USACE 2022). Specifically, USACE has adopted requirements regarding objectivity, utility, and integrity of information, as well as those regarding pre-dissemination reviews (DOA 2004). Likewise, the EPA has established similar, rigorous compliance standards for the Data Quality Act that are aligned with the standards adopted by NMFS (EPA 2002).

A rigorous comparison of NMFS, USACE, and EPA information quality guidelines is not the focus of this document. However, examination of these guidelines is warranted and should include comparable guidelines established by other agencies active in the field of aquaculture, including the U.S. Food and Drug Administration, U.S.

[3] With regards to permitting aquaculture operations within federal waters of the U.S., the USACE has permitting authorities related to location and navigation for aquaculture structures under Section 10 of the Rivers and Harbors Act, and the EPA has permitting authorities related to discharge from aquaculture operations under the Clean Water Act. As part of the permitting process, consultations may be required under the Endangered Species Act, Magnuson-Stevens Act, Marine Mammal Protection Act, and/or National Historic Preservation Act.

Department of Agriculture Animal and Plant Health Inspection Service, and U.S. Fish and Wildlife Service. Such an examination is likely to find that all agencies have compatible processes, given similar requirements under the Data Quality Act.

Successful Aquaculture Science Advice Models

This section focuses on successful domestic and international science advice models that generate products analogous to those that would be generated in addressing NOAA aquaculture science advice questions. The processes and organizations described here are useful both as a benchmark of existing NOAA processes and in considering integration of appropriate elements from these models into an improved, aquaculture-focused process. It may be advantageous to establish equivalence across these processes so that advice can be shared and harmonized across organizations. This section begins that process by describing alignment of requirements and existing NOAA policies for use of third-party information.

National Marine Fisheries Service Policy Directives 04-108 Data Quality Act and 04-113 NMFS Policy on the Internal Review and Approval of Fundamental Research Communications include provisions that allow for the use of third-party information from both domestic and international sources, dependent upon the conformity of the products to NOAA guidelines. When such information is used as a NOAA Fisheries resource, limitations, assumptions, collection methods, and uncertainties must be taken into account and disclosed within the resource.

We chose to review models from the following organizations, each of which have expertise and processes relevant to aquaculture science advice: the U.S. National Academies of Sciences, Engineering, and Medicine (NASEM), the Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) and the International Council for the Exploration of the Sea (ICES). For comparison, a brief overview of these models is shown in Appendix Table 1.

National Academies of Sciences, Engineering, and Medicine

The National Academies of Sciences, Engineering, and Medicine (NASEM) is a private, non-profit organization established by an Act of Congress in 1863. The organization is charged with providing independent, objective advice to the nation on matters related to science and technology (NAS 2022b). The National Research Council (NRC), now referred to as the NASEM, serves as the operating branch of the institution; it was organized in 1916 to link the broader science and technology communities with the Academy's purpose of furthering knowledge and advising the federal government.

The individual academies of Sciences, Engineering, and Medicine are honorary societies that provide oversight to the work of NASEM, while NASEM is composed of

multiple program divisions, such as the Division of Earth and Life Studies. Within these divisions are multiple boards, such as the Ocean Studies Board (NAS 2022c). The Ocean Studies Board is composed of approximately 20 marine scientists who provide national leadership on science, policy, and infrastructure needs related to improving our understanding, management, and conservation of coastal and marine environments and resources.

The Ocean Studies Board is charged with undertaking studies at the request of federal agencies, Congress or other sponsors, or upon its own initiative. Studies led by the Ocean Studies Board have ranged from status assessments of marine and coastal environments to technology and infrastructure needs assessments for ocean research to reviews of specific agency programs. The Ocean Studies Board (and other NASEM boards) are tasked with evaluating requests for studies, which are often posed by sponsors (notably, the availability of funding to support a study is a consideration in the evaluation process). The study evaluation process focuses on determining whether the issue to be examined can be effectively addressed by the OSB through an NASEM study. Criteria include:

- Whether the study will make a difference to a sponsor and/or the nation
- If the study has clearly stated objectives and a well-defined product
- Interest of Ocean Studies Board members and potential sponsors in the project
- Access of the Ocean Studies Board to individuals with the necessary expertise and willingness to participate in the study

A formal *statement of task* is designed by the OSB and staff, in consultation with potential sponsors, and sets bounds on the scope of the study based on the specific set of questions to be addressed. This statement is ultimately subject to approval by the institution's Governing Board Executive Committee). A prospectus, which includes the *statement of task*, also describes the duration and cost of the study and the basic work plan, as well as providing the basis for determining the expertise and balance of perspectives needed on the study committee.

Ad hoc committees of volunteer experts are assembled to conduct approved studies (NAS 2022d). Through a call for nominations, highly qualified experts are identified and selected to provide a balance of expertise and perspectives to address specific topics to be covered in the study. Selection also includes consideration of gender, ethnicity, geographic, and institutional balance. Committee members are subject to a 20-day public comment period, a review of potential conflicts of interest, and assessment of the committee composition for expertise and balance.

Committees gather information through public meetings, submissions of information by external parties, reviews of scientific literature, and investigations by committee members and staff. All materials submitted to committees for consideration are available upon request in a public access file maintained by the National Academies' Public Access Records Office. In addition to public information-gathering sessions, committees may meet in closed sessions for confidential deliberation on study tasks and discussion of potential findings and recommendations. Only committee members and staff are included in closed meetings; brief summaries are posted on the study website.

All National Academies reports—including studies, summaries of workshop proceedings, and other documents—undergo an independent, anonymous external review process overseen by the institution (NAS 2022a). The review process evaluates whether the report adequately addressed its study charge, did not exceed its scope, and whether its findings and conclusions are supported by the scientific evidence. The committee is required to consider all reviewer comments and to revise the report accordingly.

After all committee members and Academy officials have signed off on the final report, it is transmitted to the sponsor and released to the public. The report is considered final at this point; changes are limited to correcting minor editorial and factual errors. Names and affiliations of report reviewers are listed in the front matter of the final report.

A notable example of Ocean Studies Board involvement in generating science advice related to aquaculture management is the 2009 report, *Shellfish Mariculture in Drakes Estero, Point Reyes National Seashore, California* (OSB and NRC 2009). This report resulted from the assembled Committee on Best Practices for Shellfish Mariculture and the Effects of Commercial Activities in Drakes Estero, Point Reyes National Seashore, California. This study was requested by the U.S. National Park Service (NPS), given the impending expiration of an NPS special use permit for Drakes Bay Oyster Company, which operated within the estero. Specifically, NPS expressed concern about the scope and intensity of impacts of the shellfish culture operations on the estero ecosystem in association with the scheduled expiration of the permit to operate the oyster farm. The report captured:

- The state of knowledge of shellfish aquaculture environmental and societal interactions
- Conclusions that could be drawn from that scientific basis
- The accuracy of prior scientific information used to generate decisions regarding the National Park Service special use permit for Drakes Bay Oyster Company

In addition, the Ocean Studies Board committee that produced the report developed a broader, synthesis report titled, *Ecosystem Concepts for Sustainable Bivalve*

Mariculture (OSB and NRC 2010). The synthesis report focused on nationally and globally relevant issues such as best management practices, ecological effects, mariculture vs. wild fisheries effects, carrying capacity, economic and policy considerations, and ecosystem services of bivalves.

Given the breadth of scope of the Ocean Study Board's work, the ability of NASEM to scale up generation of routine aquaculture science advice to address current and future advisory needs is limited. However, on high profile or broadly scoped aquaculture science advice needs, NASEM-formed study committees inclusive of broad expertise (including outside of the federal government) could play an important role. NASEM can also provide external support for convening scientific expertise in various formats to provide advice from individual experts and summaries of the issues (e.g., workshops, standing committees). Study sponsor(s) provide the funding for projects with costs estimated to be between $400-600K per consensus study, $50 -200K for convening activities such workshops and standing committees (such as the Committee on Science and Assessment [COSA] for the Bureau of Ocean Energy Management).

Compatibility with NOAA Fisheries Science and Technology Policy Directives

The National Academies of Sciences, Engineering, and Medicine study process, as specified within the guidelines governing conduct of studies (NAS 2022d), and as clarified by the Office of Management and Budget (OMB 2005), is compatible with processes specified by NMFS Policy Directives. For example, the NASEM process requires screening of study participants for conflicts of interest, broad and transparent availability of materials used within studies, and multiple layers of internal and external peer review via established processes for products generated through NASEM studies.

NASEM consensus studies are conducted in compliance with the Federal Advisory Committee Act, Section 15. The Office of Management and Budget Peer Review Bulletin Guidance clarifies that "…the procedures of the NAS are generally quite rigorous, and thus agencies should presume that major findings, conclusions, and recommendations of NAS reports meet the performance standards of this Bulletin" and thus generally do not require additional peer review (OMB 2005).

Canadian Science Advisory Secretariat

The Canadian Science Advisory Secretariat is the official body that coordinates, develops, and publishes formal science advice for Fisheries and Oceans Canada (DFO). Science advice is provided on issues related to fisheries, aquaculture, species at risk, invasive species, marine and freshwater ecosystem ecology, marine protected areas, and the use of living aquatic resources (CSAS 2020). The peer review process at DFO dates

back to the 1970s with the establishment of smaller structured peer-review bodies for generating national and regional fisheries advice.

As responsibilities of the DFO grew with adoption of new regulations and new legislation, these earlier bodies formed into the Canadian Science Advisory Secretariat in 2001. The Secretariat is operated with a national headquarters-based manager and coordinators positioned within regional offices of DFO.

Depending on the request, the Canadian Science Advisory Secretariat produces one of two types of advice documents: a *Science Advisory Report* or a *Science Response*. The four main publication products generated by the Secretariat include:

- Science Advisory Reports
- Science Responses
- Research Documents
- Proceedings

Science Advisory Reports include advice on stock status, frameworks and guidelines on the assessment or evaluation of specific issues including impacts of human activities on ecosystem components as well as recovery assessment on a species or population. ***Science Responses*** are generally used to respond to urgent and unforeseen requests for scientific information or advice. They are also used in response to requests for which advisory precedents already exist and in other case-specific situations.

Both Science Advisory Reports and Science Responses document the peer-reviewed scientific advice developed through consensus of the peer-review meeting participants. Participants are subject-matter experts on the topic being reviewed. Consensus is defined as the absence of opposition to meeting conclusions and advice that are based on scientific data and information and not external considerations. ***Research Documents*** describe the scientific studies and analyses that were peer reviewed during a peer review meeting. They are typically generated by a DFO-assigned expert science lead in advance of peer-review meetings. ***Proceedings*** document the discussions that occur during a peer-review meeting.

Structure of the Canadian Science Advisory Secretariat is underpinned by principles established by the Government of Canada (SCTA 1999). Specifically, six guiding principles underwrite the Secretariat's process. These include:

I. *Early identification* of issues requiring science advice.

II. *Inclusiveness*, wherein advice is drawn from a variety of relevant sources and experts to capture the full diversity of schools of thought.

III. *Consideration of sound science and advice in decision making,* underpinned by government measures to ensure quality, integrity, objectivity.

IV. Assessment, communication, and management of *uncertainty and risk.*

VI. *Transparency and openness* in advice development and decision making.

VII. *Review* of science-based decisions periodically to evaluate whether recent advances have an impact on the science advice used to reach a decision.

Through the formal Canadian Science Advisory Secretariat peer-review process, specific topics in need of science advice are identified and prioritized (Figure 2). The agency uses a formal intake form titled, *Request for Peer-Reviewed Science Information and/or Advice*. Intake forms are collated annually by a Secretariat coordinator. At present, a web application to fill out the form electronically is available in pilot phase (Appendix Figure 1). Each request must include information on:

- Whether the advice could be applicable to other regions and/or sectors
- Details of the issue requiring information and/or advice
- Identification of DFO science staff who assisted in developing the question or request
- Rationale or context for the request
- Consequence of not receiving the information
- Latest timeline to receive the advice and rationale
- Availability of funds to cover the request

Requests are collated and prioritized at the regional as well as at the national level, but note that advice requests for aquaculture are one among multiple topical areas covered under these requests. Key determining considerations for which advice requests are selected include:

- When advice is needed by requestor
- Availability of data to fulfill the request
- Capacity of DFO science to fulfill the request
- Availability of funding to complete the request

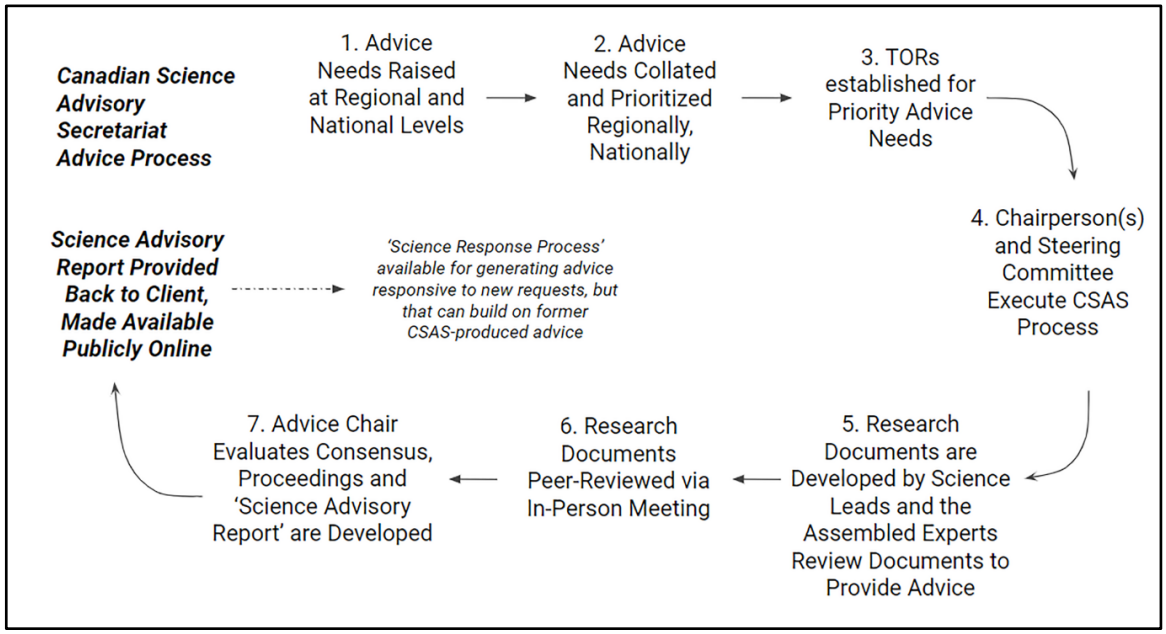

Figure 2. Overview of the Canadian Science Advisory Secretariat (CSAS) process.

Once a determination is made to proceed with development of science advice, terms of reference (TORs) for the peer review process are assembled, which define:

- The context and focal region of the request
- Study scope
- Chairperson(s) of the peer review process
- Specific objectives to be addressed during the peer review process
- Expected publications
- Expected participation
- A date and location for the peer-review meeting

Considerable emphasis is placed on ensuring the objectives and anticipated product(s) of the terms of reference are responsive to clearly delineated and communicated advice needs. Each science advice process has a Steering Committee that focuses on handling logistics for managing advice generation, including representation from the CSAS office, DFO science, a client representative (i.e., representing the recipient of the advice) as well as other subject matter experts.

The Steering Committee is responsible for identifying and securing experts to participate in the peer-review meeting and in doing so, must seek to include diverse

representation from the academic community as well as environmental non-governmental organizations, industry, regulatory partners, and other key groups. Participants do not serve as representatives of organizations, but rather participate as individual experts. Participation and conflict of interest policies are in place to assist the Steering Committee in ensuring that participants have the appropriate scientific expertise relevant to review the topic under discussion at the meeting.

Costs associated with generating science advice products center around meeting logistics (e.g., venue, some travel costs), staff time, and time for coordination and publication of documents (including translation into French and Inuktitut, where applicable). These costs are covered by DFO at the national or regional level, depending on which organization hosts the peer review process. National processes are coordinated and paid by DFO Headquarters Science, and regional processes by DFO Regional Science.

The core of the Canadian Science Advisory Secretariat process is a deliberative peer-review meeting used to generate consensus on the advice produced. Peer-review meetings are typically 3-5 days, wherein *Research Documents* that are typically generated by DFO-assigned expert science leads in advance are reviewed and critiqued by all peer-review meeting participants. The chairperson(s) typically facilitates development of the science advice, coordinating the participating peer-review group from inception to publication of the advice products. Final advice products are based on consensus of experts at the peer-review meeting.

A typical timeline for generation of advice from the Secretariat is 12 months. During this period, a chairperson is determined, *terms of reference* with an overall timeline are defined, working documents are prepared, a peer-review meeting is conducted, and final advice documents are completed and published.

Compatibility with NOAA Fisheries Science and Technology Policy Directives

In 2000, Innovation, Science, and Economic Development Canada (Industry Canada) published their *Framework for Science and Technology Advice* (Industry Canada 2000). These guidelines correspond directly with the six guiding principles of the Canadian Science Advisory Secretariat review process, which are listed above and include early identification of issues, inclusiveness of diverse and relevant scientific expertise, use of sound science and science advice, consideration of uncertainty and risk (including the development of a risk management framework), transparency and openness of scientific information, and subsequent review of science-based decisions to evaluate the possible impact of recent scientific advances.

Of note regarding the compatibility of DFO science and science advice products is the third guideline, which prescribes the use of sound science and science advice by the Government of Canada. This guideline states that "The government should employ measures to ensure the quality, integrity, and objectivity of the science and science advice it uses, and ensure that science advice is considered in decision making." The guideline further specifies rigorous internal and external peer-review of all findings, analyses, and recommendations of science advisors. Further guidance is provided regarding conduct, management and use of science, and enforcement of conflict of interest guidelines. These requirements align closely with NMFS Policy Directives. Where appropriate for use by NOAA, Canadian Science Advisory Secretariat products should be evaluated for the limitations and concerns described above and be described and disclosed within the resource developed by NOAA.

International Council for the Exploration of the Sea

The International Council for the Exploration of the Sea (ICES) is an intergovernmental science organization that coordinates and promotes marine research in the North Atlantic and adjacent seas. ICES' mission is to "advance and share scientific understanding of marine ecosystems and the services they provide and to use this knowledge to generate state-of-the-art advice for meeting conservation, management, and sustainability goals."

Approximately 150 expert groups, composed of over 3,000 scientists, largely from member countries, play a critical role in developing relevant information that is the basis for ICES science advice. All ICES expert groups are established, dissolved, and guided by the Science Committee and the Advisory Committee. The Science Committee oversees all aspects of ICES' scientific work, while the Advisory Committee oversees advice generation and relationships with recipients of advice. Seven standing steering groups (including an Aquaculture Steering Group) support interactions between committees and expert groups. Requests for scientific advice are received from public authorities and member country governments (ICES 2022).

ICES has established policies to ensure that its advice is based on the best available science and data, is considered legitimate by both authorities and stakeholders, is relevant, and is actionable (if possible) to the policy or management challenge in question (ICES 2021). Production of advice follows the advisory framework shown in Figure 3. The framework involves iterative dialogue with advice requesters and ICES wherein an advice request is established and the process and roles of contributors are confirmed.

ICES expert groups conduct knowledge synthesis, collect data, generate assessments, and provide the scientific basis responsive to the advice request (i.e., expert group report). Expert group reports are comprehensive, detailed, and technical in nature, and are subject to peer review by three independent experts who evaluate the methods, data, and conclusions. The report, along with the independent peer reviews, are then utilized by a separate advice drafting group (ADG) to generate draft advice.

Draft advice is subject to approval by the Advisory Committee, which approves all advice and has overall responsibility for all advisory products and for the ongoing development and improvement of the advisory process. All advice is published on the ICES website.

ICES may also, on its own initiative, draw the attention of competent authorities to marine matters which may require policy and management attention. Through its expert groups, the ICES community proactively identifies the need for advice products. ICES publishes *Viewpoints* with the nature and scope established through internal consultation before their production. Production of *Viewpoints* follow the advisory framework, with final approval by the Advisory Committee.

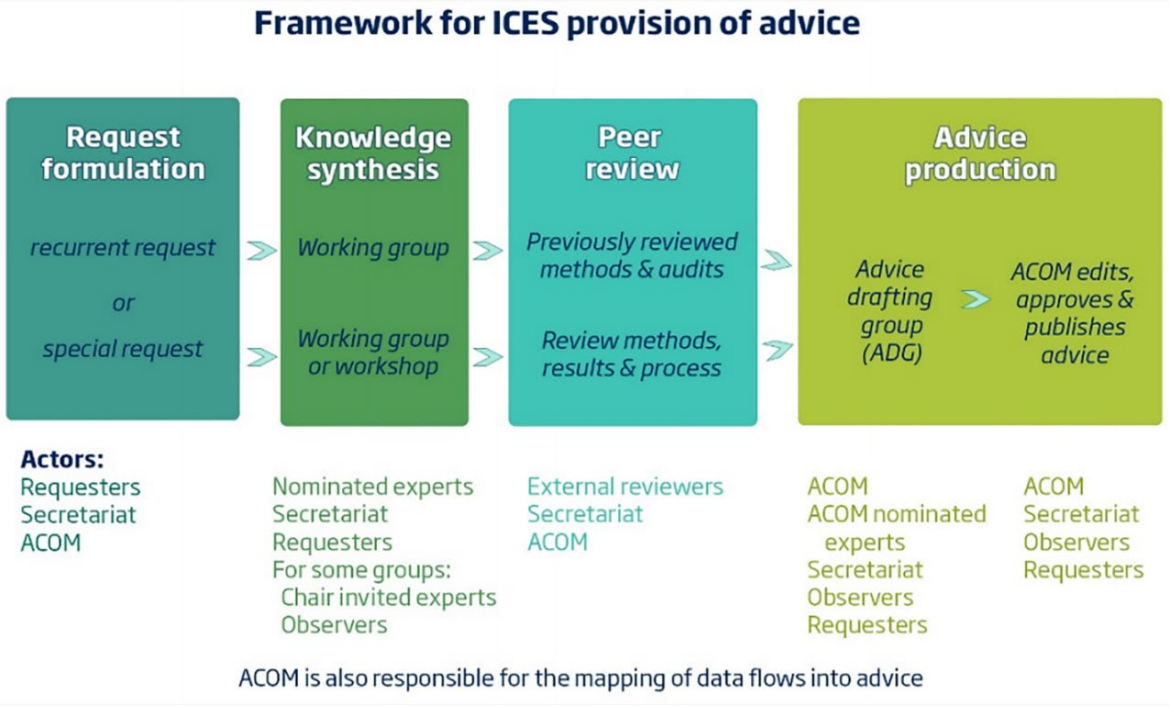

Figure 3. Overview of the International Council for the Exploration of the Sea (ICES) science advice framework (from ICES 2021).

In December 2020, ICES released an updated *Guide to ICES advisory framework and principles* (ICES 2021) which lays out ten principles that apply to production of all ICES advisory products:

1. The guidelines and procedures to produce ICES advice are documented, openly accessible, and up-to-date.
2. Final request formulation is agreed through dialogue to clarify the requester's needs and expectations, the ICES process, likely resource implications, timelines, format of advice, and roles and responsibilities of the engaged parties.
3. Where possible, existing policy goals, objectives, and the level of acceptable risk relevant to the advice request are identified. Where these objectives and descriptions are unclear, ICES will identify these in the advice and, where possible, provide options for management action and the consequences of the options and their trade-offs.
4. The deliberations of all relevant expert groups are published by the time the associated advice is published.
5. The best-available science and quality-assured data are used. ICES selects and applies relevant methods for any analysis, including the development of new methods. The methods are peer reviewed by independent experts and clearly and openly documented.
6. Data are findable, attributable, researchable, reusable, and conform to ICES data policy. Data flows are documented.
7. To ensure that the best available, credible science has been used and to confirm that the analysis provides a sound basis for advice, all analyses and methods are peer reviewed by at least two independent reviewers. For recurrent advice, the review is conducted through a benchmark process; for special requests through one-off reviews.
8. Advice is comprehensive, unambiguous and consistent with the synthesized knowledge, while taking the peer review into account. All advice follows advice frameworks and any deviation from the frameworks or related, previous advice is identified and justified.
9. All ICES advice is adopted by the ICES Advisory Committee (ACOM) through consensus, prior to being made available to the requester and simultaneously published on ICES website.
10. ICES provides advice as an impartial response to a request, and does not lobby the requester or any other party to implement its advice.

Compatibility with NOAA Fisheries Science and Technology Policy Directives

As specified by its governing guidelines, the ICES advisory process is open and transparent, generating independent, credible, and peer-reviewed advice based on the work of the ICES scientific community. The ten principles underpinning development of ICES advisory products clarify that ICES advice is based on the best available science and data (including requirements for data and analysis reproducibility) and is produced through multiple layers of peer review. These requirements align closely with those of the NMFS Policy Directives. Where appropriate for use by NOAA, ICES products may be evaluated in light of the limitations and concerns described above, and these evaluations should be described and disclosed within any resource developed by NOAA.

Best Practices for Aquaculture Science Advice

Aquaculture science advice developed within NOAA must ensure compliance with all existing U.S. laws and NOAA policies and processes described in this Handbook. Beyond these requirements, a range of best practices influences the ability of science advice to provide decision support. Below we provide some recommended best practices for aquaculture science advice and refer to guiding resources that provide additional information. These recommendations are derived from Gluckman (2014), ISC and INGSA (2022), and (ICES 2020).

1. ***Early and iterative engagement with end-users of science advice***. Scientists developing science advice products should proactively engage with the appropriate intended end-users of their products in the early project planning phase. Within NOAA, Regional Aquaculture Coordinators can help to ensure identification and coordination with appropriate end-users.

   Early engagement can ensure that products to be developed align with the true information needs of the end-users, timelines are clarified, the format and function of products are clear, resource implications are understood, and the roles and responsibilities of engaged parties are established. Iterative engagement through feedback sessions or review of draft products can ensure that products remain aligned and responsive to end-user decision support needs and that expectations are mutually understood and managed.

2. ***Best available science and quality-assured data are used in development of science advice products***. Within a given discipline, established methods should be applied to the development of science advice products rather than new, emerging, or untested methods. Data must be derived from quality-assured sources, and the flow and sourcing of data must be documented. When differing from established methods, scientists should clearly articulate where and or how new or emerging methods provide greater quality of information.

   The best available science will evolve and grow as the depth of scientific literature and research grows. Scientists should inform end-users of relevant research needs and gaps that should be addressed to advance the best available science.

3. ***The science underpinning advice products should be transparent, reproducible and accessible***. Data and methods used to generate advice products should be made available such that the analysis and results can be independently generated and

evaluated. Ideally, data and products should be made available in a publicly available repository.

4. ***Clear articulation of science-based results and recommendations***. Science advice products should provide clear, unambiguous descriptions of results and findings that are consistent with the empirical data or synthesized knowledge. Such descriptions should seek to reduce uncertainty on the subject matter evaluated to the greatest extent practicable. Any revisions resulting from peer-review should be appropriately incorporated. Interpretation of results towards policy or management recommendations should be clear, and where appropriate, separated from the science-based results. Any caveats and limitations of the science advice product should be clearly stated and acknowledged.

5. ***Science advice products should be appropriately peer-reviewed***. Peer review provides quality assurance for science advice products. Detailed guidance on legal and NOAA policy requirements for peer review are provided elsewhere in this Handbook. Level of peer review should be commensurate with the scope and magnitude of the science advice product.

6. ***Science to inform policy, not make it***. Science advice products, and the scientists involved in their development, should serve as independent, honest brokers of best available science, and not as advocates. Science advice products must be objective, impartial, and reflective of the breadth of peer-reviewed science, incorporating differing science-based viewpoints or interpretations where appropriate.

Opportunities and Recommendations

While NOAA currently possesses substantial capacity for generating relevant, timely science advice to support aquaculture management, near-term, mid-term, and long-term opportunities exist, and we provide a range of recommendations below.

Near-term, Mid-term, and Long-term Recommendations

Near-Term

- ***Increase use of the Center for Independent Experts*** as an external, independent, and expert peer review body. Use the Center as a resource for peer review of foundational models, tools, advice products, or approaches that serve as the basis for NOAA responses to science advice requests. This could include 2-3 panel reviews per year of foundational advice products, such as environmental models, risk assessments, disease models, etc.

  For example, a Center panel could be established to review a NOAA Technical Memorandum describing the methods for an aquaculture environmental model, providing a sound basis for future model analyses that utilize the reviewed methods. However, Center experts cannot be used to develop, specify, or prioritize science advice products directly.

- ***Create an online, accessible archive of existing NOAA aquaculture science advice products.*** A wide range of existing peer-reviewed publications, NOAA Technical Memoranda, and other tools have been developed across NOAA that provide science advice, but have not yet been curated or organized comprehensively in one location.

  This could be coordinated with NOAA funding programs, such as NOAA Sea Grant and the NOAA Fisheries Saltonstall-Kennedy Grant Program, which have externally funded projects with relevant products.

- ***Further develop guidance, best practices, and/or templates for the development of science advice products at NOAA***, including applying that guidance to address near-term science advice needs.

Mid-Term

- ***Coordinate with regulatory agencies, including the USACE and EPA, to ensure acceptability and use of NOAA aquaculture science advice*** (e.g., establishing Memoranda of Understanding [MOUs] or Interagency Agreements [IAAs] on

NOAA development of aquaculture science advice). As NOAA scientists continue to ramp-up development of aquaculture science advice products, close coordination and discussion with partner federal agencies at multiple levels (i.e., headquarters and regions) is needed to ensure science advice products are acceptable, aligned with needs of regulators, and are ultimately used to support decisions.

- ***Consider establishing a Science Advice Secretariat*** (or National Aquaculture Science Advice Coordinator) within the Office of Aquaculture focused on the science advice process, with duties including how to receive, prioritize, and coordinate requests (e.g., similar to the approach used by the Canadian Science Advisory Secretariat and ICES). Establishing this function would include both designation of a focal point of contact and a formalized advice 'intake' process (e.g., similar to the Canadian Science Advisory Secretariat's annual advice request form). Additionally, the Science Advice Secretariat would identify and define categories of specific science advice products for aquaculture and appropriate processes to develop them (e.g., level of peer review required, etc.). Develop structure and recommendations for advice-specific 'distributed teams' as part of the larger effort.
- ***Explore use of reimbursable agreements*** for using NOAA science assets for generating aquaculture advice needed by other agencies (e.g., DOE, EPA or USACE).
- ***Work with NOAA General Counsel to establish guidance on use of Fisheries and Oceans Canada (i.e., Canadian Science Advisory Secretariat), International Council for Exploration of the Sea, and other compatible external science advice products***. This evaluation should also assess the ability of non-federal scientists to generate or support the development of NOAA science advice products under requirements of the Federal Advisory Committee Act. Concurrent with this NOAA General Counsel assessment could include identification of issues requiring advice that ICES and/or CSAS could support (e.g., utilize Canada-United States bilateral agreement for generation of advice of value to the United States).

Long-Term

- ***Work towards a scalable model*** whereby NOAA develops tools and guidance that can be utilized by the private sector and/or government partners that meet NOAA's or interagency partners' standards (e.g., USACE/EPA/BOEM/etc.). This could include guidelines for siting analysis, use of the Offshore Aquaculture Escapes Genetics Assessment model, baseline environmental surveys, etc.
- ***Establish a formal aquaculture science advice process***, similar to that of the

Canadian Science Advisory Secretariat or ICES, to cover aquaculture advice processes, based on these recommendations. This process could be established through, and supported by, relevant statutory authority, regulatory authority, and/or a NOAA Fisheries Policy Directive, as appropriate.

- ***Explore use of these processes for other non-fisheries ocean governance needs***, such as marine carbon dioxide removal (mCDR) and the renewable energy sector (e.g., wind, marine hydrokinetic).

Recommendations for a Structured Science Advice Process

While NOAA produces meaningful scientific research in aquaculture, there are three main gaps that limit our capacity to scale-up aquaculture science advice, a growing need in light of mounting interest in industry growth and expansion. These gaps include:

1. A clear pathway for accepting, prioritizing, and matching advice requests with an appropriate science advice product
2. Clear processes, timelines, and standards regarding development and peer-review of science advice products
3. A clear process for matching an appropriate level of peer review for various advice products

The recommendations and suggested process that follow later in this section could be established through and supported by appropriate statutory and regulatory authorities and/or agency Policy Directives.

A Clear Pathway for Science Advice Requests

Operationally, requests for scientific advice to support regulatory decisions for aquaculture (e.g., USACE, EPA, NMFS) have been received and managed in an ad hoc manner. Largely, these requests have been funneled through the National Marine Fisheries Service Office of Aquaculture, the NMFS Science Centers, or the Coastal Aquaculture Siting and Sustainability Program of the National Ocean Service National Centers for Coastal Ocean Science.

Products undergo review processes established for scientific publications analogous to peer-reviewed journals–processes that are compatible with NMFS Policy Directive 04-113: Policy on the Internal Review and Approval of Fundamental Research Communications. NOAA does not currently have a process to focus resources on specific questions or needs, nor a formalized way to specify a type of product or prioritize science advice products for aquaculture regulatory needs.

Clear Processes, Timelines, and Standards for Developing Science Advice Products

As NOAA responses to aquaculture science advice requests are currently addressed on an ad hoc basis, there are no established standard operating procedures, timelines, or standards (e.g., formatting, review) for science advice products. There exist valuable examples of established processes to receive and prioritize advice requests, and to generate science advice products that are responsive to advice needs and that meet varied, rigorous scientific information quality standards (e.g., processes under the

Magnuson-Stevens Fishery Conservation and Management Act, National Academies of Sciences, Canadian Science Advisory Secretariat).

Importantly, any new process must be capable of differentiating fast-paced advice needs (e.g., where a response is relatively simple and existing literature or tools can address it) versus longer-term, more involved advice needs (e.g., where a response requires a new model, etc.). Improved organization of resultant science advice products (e.g., active management of the process with an online database) would improve quality, transparency, and efficiency of application for future advice requests. In turn, having a robust and transparent process will improve public and industry confidence in NOAA's science to support regulatory decision-making.

Rigorous Peer Review of Foundational Advice Products

All Fundamental Research Communications (i.e., documents or resources with broad external dissemination) developed at NOAA are subject to peer-review requirements. Thus, opportunities exist to increase the quality and efficiency of review and dissemination of foundational science advice products (e.g., models, tools). For example, use of the Center for Independent Experts for expert desktop-based or panel reviews of foundational science advice products would provide a firm foundation for subsequent iterative use of these products to address advice requests.

At the same time, not all science used for governmental decision-making requires this level of review. At present, we lack a systematic process for matching information needs with science product types and the degree of review necessary.

Draft Aquaculture Science Advice Process

In this section, we present a draft process to develop NOAA aquaculture science advice with detailed recommendations in the flowchart (Figure 4) and outline below.

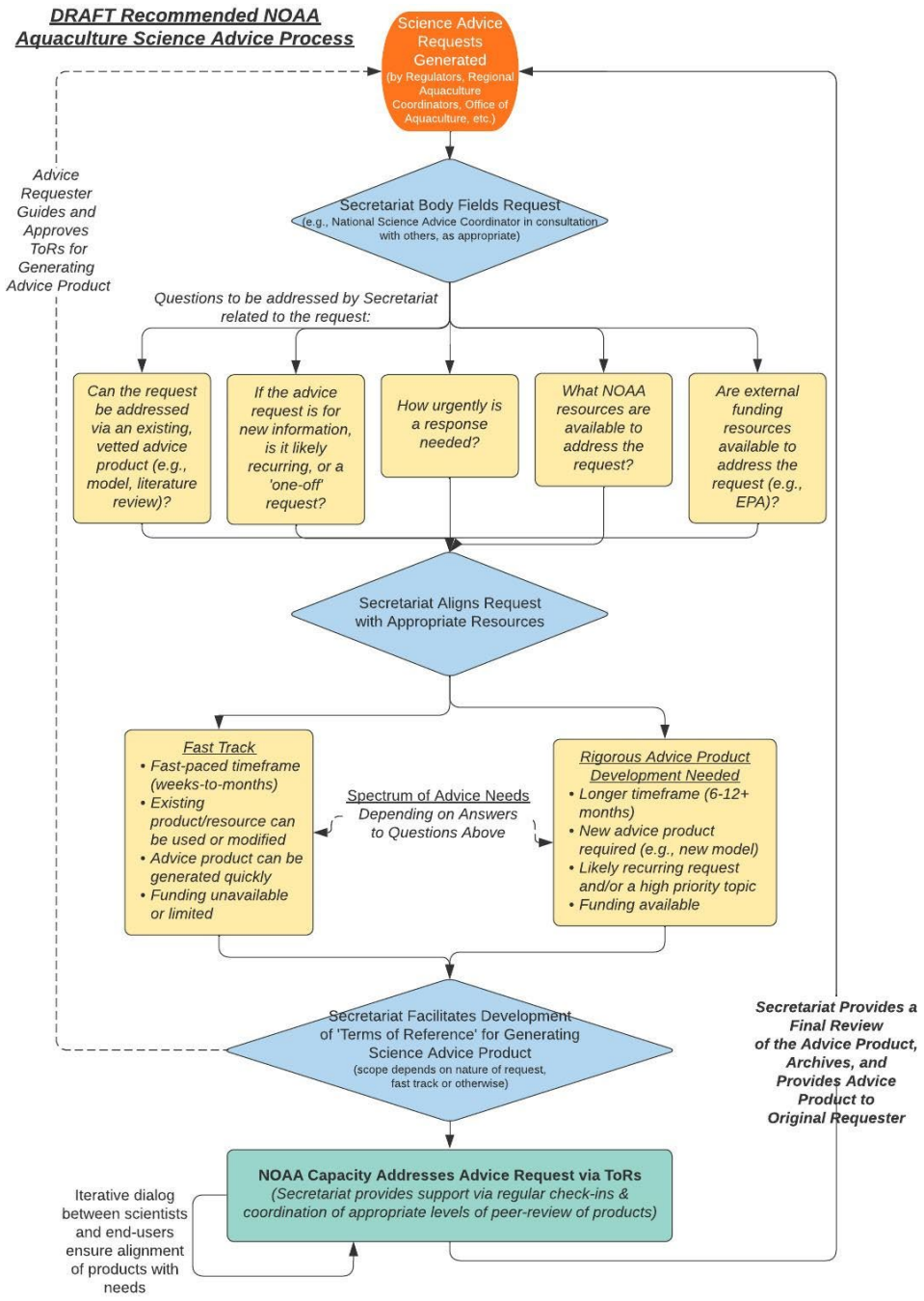

Figure 4. Draft recommended process for NOAA aquaculture science advice.

1. Science Advice is Requested

Science advice requests are generated by decision makers at NMFS Offices such as the Offices of Habitat Conservation, Protected Resources, and Sustainable Fisheries, or NMFS Regional Offices. Requests may originate from other federal agencies, such as the EPA or USACE, or from a NMFS Regional Aquaculture Coordinator or the Office of Aquaculture. Requests are in the form of specific, pointed questions related to a proposed aquaculture project or higher-level planning exercise, such as a programmatic document under the National Environmental Policy Act.

a. Requests are received via a standardized form similar to that used by the Canadian Science Advisory Secretariat (Appendix Figure 1). Alternatively, an intake process is developed to outline specific elements of the request that must be described, such as timeline and geographic scope (local, regional, or national). The advice request must be adequately specific. For example, is the advice request related to siting, benthic or water quality impacts, habitat, genetic interactions, etc.

b. Information from the request should allow for appropriate assessment of its scope and the requirements for a responsive science advice product, such as:

    i. Whether the advice will require generation of new research or information.
    ii. Whether the need for advice is urgent.
    iii. Whether the advice can be based on the best information currently available.

c. Requests could be solicited during an annual call or received on a continuous basis.

d. In developing and rolling out this process, attention should be paid to how this national-level process would be implemented where existing relationships exist between Regional Offices and Science Centers, etc. Effective communication amongst all involved parties can help proactively address challenges.

2. Secretariat Fields Requests

A Secretariat could be established and headed by a National Science Advice Coordinator. Such a position is not currently funded, but is potentially an appropriate function of the Office of Aquaculture Regulatory Science Coordinator. The Coordinator would consult, as appropriate, with Regional Aquaculture Coordinators, regulatory and policy branches of the Office Aquaculture, National Centers for Coastal Ocean Science, NMFS Science Centers, and others as appropriate. These consultations would provide internal answers to relevant questions about the request and response, such as:

a. *Can the request be addressed via an existing vetted model, tool, advice product or approach?* This could include existing NOAA products, or those of compatible partners (e.g., ICES, Canadian Science Advisory Secretariat).

b. If this is an advice request for novel information, is it likely to represent a recurring need or a "one-off" request?

c. How urgently is a response needed, and what depth of response is required (e.g., descriptive, quantitative/analysis-based)?

d. What NOAA resources (e.g., funding, human resources) are available to address the request? (NMFS Office of Aquaculture, Habitat Conservation, or Protected Resources)

e. Are external funding resources available to address the request? (EPA, USACE)

3. Secretariat Aligns Request with Appropriate Resources

a. The National Science Advice Coordinator, in consultation with other members of the Secretariat, would evaluate the landscape of existing vetted science advice products and capacities existing within NOAA that could address the request.

   i. An essential component of this alignment process is determination of whether a request necessitates a "fast track" (weeks-to-months timeline), or if the request requires more rigorous advice product development (6-12+ months).

   ii. Where internal capacity is limited or an advice request is multifaceted, advice teams involving relevant experts may be established to address the request. ***Note:*** The ability of non-federal scientists to generate or support development of NOAA science advice products merits further review by NOAA General Counsel under requirements of the Federal Advisory Committee Act.

   iii. Where relevant non-NOAA advice products exist, such as those generated by ICES or the Canadian Science Advisory Secretariat, the Secretariat can request a review by relevant subject matter expert(s) within NOAA. This review would ensure compliance with NMFS Policy Directives regarding information quality (e.g., an established review and quality check form), and would generate a synthesis of the external advice product that is responsive to the advice request.

b. The Secretariat would coordinate with NOAA subject matter experts, the requester, and others, as necessary, to establish terms of reference for generating the advice product.

   i. The scope of terms of reference will be adjusted based on relevant factors, such as depth of the request, timeline, availability of relevant capacity, and availability of funding resources to support the request.

   ii. For "fast track" requests, terms of reference should be developed quickly and

with limited scope. In these cases, terms of reference should define development of an advice product akin to a brief document based on a descriptive or simplified analysis (similar to a Canadian Science Advisory Secretariat Science Response Document).

iii. For requests requiring more rigorous advice product development, terms of reference should be carefully articulated to define the question to be addressed, ideally developing a resource that would provide value for addressing the current and future related concerns (similar to a Canadian Science Advisory Secretariat Research Document).

iv. Level of peer-review required for an advice product would also be defined in the terms of reference(e.g., standard NOAA peer review, Center for Independent Experts review). Peer review would be coordinated by the Secretariat.

4. Advice Request is Addressed via Terms of Reference

a. Based upon the established terms of reference for the advice request, NOAA subject-matter experts generate the required advice product(s).

b. The Secretariat checks in regularly with subject-matter experts producing science advice and coordinates progress and status with the original advice requestor. This could include iterative dialog between scientists and end-users to ensure the alignment of products with needs.

c. The Secretariat coordinates and confirms peer-review of the advice products based on the process defined in the terms of reference.

5. Secretariat Provides a Final Review

The Secretariat provides a final review of all advice products to confirm that they are responsive to the original request and then ***provides the advice product*** to the original requester. Science advice products are published and archived in a searchable, publicly available database hosted online. Advice products would be subject to any applicable limitations, for example, those based on confidentiality or an applicable privilege. This would improve efficiency by allowing advice products to be accessible and available for use in other potential situations and scenarios where similar advice is needed, or to serve as the basis for future requests.

Acknowledgements

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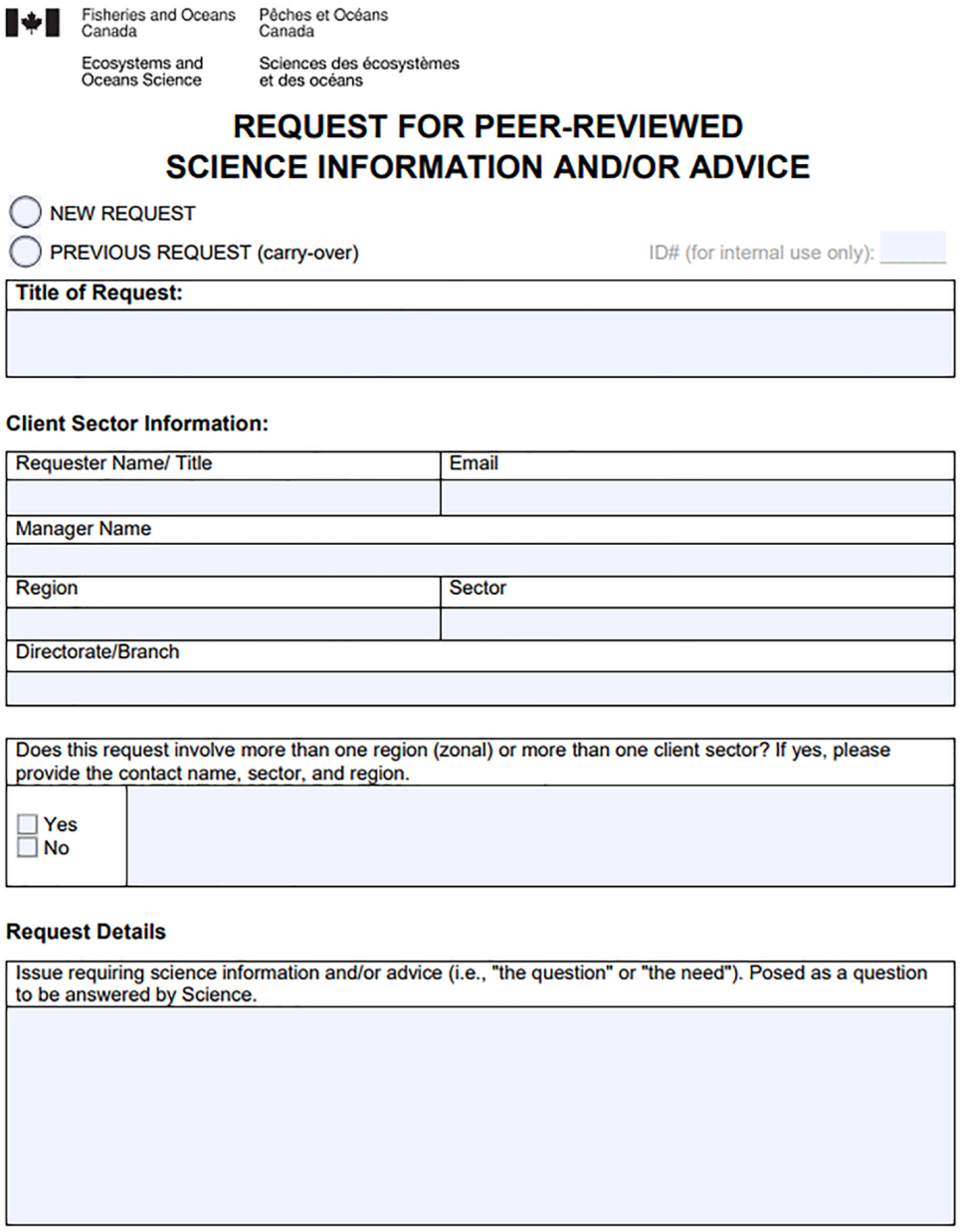
Appendix



Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

REQUEST FOR PEER-REVIEWED SCIENCE INFORMATION AND/OR ADVICE

NEW REQUEST
PREVIOUS REQUEST (carry-over) ID# (for internal use only): _____

Title of Request:

Client Sector Information:

Requester Name/ Title	Email
Manager Name	
Region	Sector
Directorate/Branch	

Does this request involve more than one region (zonal) or more than one client sector? If yes, please provide the contact name, sector, and region.	
Yes No	

Request Details

Issue requiring science information and/or advice (i.e., "the question" or "the need"). Posed as a question to be answered by Science.

Appendix Figure 1. Example of the Canadian Science Advisory Secretariat request form for peer-reviewed science information and/or advice. This form is used by the Secretariat to collate advice requests.

Appendix Table 1. Overview of agencies, laws, policies, and processes relevant to aquaculture science advice, including domestic and foreign/international agencies offering advice compatible with NOAA Fisheries Policy Directives. In addition to the agencies listed here, the U.S. Army Corps of Engineers and Environmental Protection Agency also have established requirements for peer-review of various science information products which are generally aligned with those of NOAA Fisheries.

NOAA Fisheries Science and Technology Policy Directives	Magnuson-Stevens Act Processes	Center for Independent Experts	National Academies of Science	Canadian Science Advisory Secretariat	International Council for Exploration of the Sea
Description and use					
Establishes requirements for peer-review of science information products by qualified specialists.	Establishes requirements for use and integration of best available science to inform fishery management.	Conducts peer-review of influential NOAA science used for policy decisions.	Generates science advice for the U.S. (including examples for marine aquaculture via the Ocean Studies Board)	Responds to requests and generates science advice for Canada on fisheries, aquaculture, etc.	Responds to requests and generates marine natural resources science advice for member nations.
Ensure information quality standards are met.	Inform U.S. fishery management.	Ensure rigorous evaluation of information products for fishery policy decisions.	Provide the highest quality science advice for priority concerns in the U.S.	Provide science advice responsive to requests for management decision support.	Provide science advice across all aspects of marine natural resources management.
Statutory authority					
Data Quality Act	Magnuson-Stevens Act	Magnuson-Stevens Act	Congressional Act of Incorporation, Executive Order 12832	Department of Fisheries and Oceans Act	Convention for International Council for the Exploration of the Sea (1964)
Guiding principles					
NOAA Information Quality Guidelines	National Standard 2 - Scientific Information and Guidelines	National Standard 2 - Scientific Information and Guidelines.	Established processes for definition, structure, execution, and publication of advice	Science Advice for Government Effectiveness (SAGE) principles	Guidelines and established framework for developing scientific advice

Appendix Table 1. Continued.

Science and Technology Policy Directives	Magnuson-Stevens Act Processes	Office of Science and Technology Center for Independent Experts	National Academies of Science	Canadian Science Advisory Secretariat	International Council for Exploration of the Sea
Ability to prioritize specific questions or needs					
No, peer-review of developed science information products only.	Yes, formalized process for each Fishery Management Council to focus on specific science advice needs.	No, peer-review of developed science information products only.	Yes, address a breadth of science advice, including marine aquaculture.	Yes, established process and structure to facilitate and prioritize requests.	Yes, formalized process and structure to facilitate and prioritize requests.
Cost/who pays					
Peer-review conducted by volunteer reviewers.	NMFS	NMFS Office of Science and Technology. Aquaculture needs can be addressed within the existing budget (i.e., ~3 reviews/year).	Costs determined based on needs of each project, typically paid by study sponsor.	Costs include peer-review meeting logistics, staff time, translation, etc. paid by DFO .	Costs include meeting logistics, staff time, document production paid by requesting ICES member country.
Time to develop advice products					
Variable, typically <1 month for reviews.	Timeline concurrent with Fishery Management Council stock assessment development process.	Annual data call for scheduling reviews. Reviews conducted within one month.	Variable, typically one to two years for consensus studies.	Annual call for advice requests submitted 1-3 years in advance. Peer reviews take place all year.	Variable, one to multi-year.
Examples of advice products					
	Stock Assessments.		Consensus studies, peer review of documents, and convening activities for informal advice from individual experts.	Science Advisory Reports, Science Responses.	Overviews, Viewpoints, and solicited advice.

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January 2023

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