National Oceanic and Atmospheric Administration (NOAA) Response to:

IMPROVING FISH STOCK ASSESSMENTS

A REPORT ON EMERGING STOCK ASSESSMENT TECHNOLOGIES

A report prepared by the

Ecosystem Sciences and Management Working Group

of the NOAA Science Advisory Board

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(DRAFT)

Introduction

As a component of the Two Year NOAA Science Advisory Board (SAB) Work Plan, in late 2018 the SAB asked the Ecosystem Sciences and Management Working Group (ESMWG) to produce a report on Work Plan Topic 9 *"Evaluate fisheries monitoring technologies to improve stock assessments. This evaluation should consider how to optimally balance electronic monitoring, eDNA, and other technologies…"* This task was a response to a request by NOAA to the SAB to consider technologies to increase the efficiency and accuracy of stock assessments, the potential saving of ship and personnel time in stock assessment cruises, and to explore the potential roles of future methods that are under development. We sincerely thank the ESMWG for their thoughtful and insightful report and offer responses below to each of their recommendations.

SAB/ESMWG recommendations and NOAA responses on potential actions related to improving stock assessments and emerging technologies:

Recommendation 1: *Although new technologies may lead to efficiencies in the medium to long-term time frames, they should not be viewed primarily as cost-saving approaches, but rather as a means to improve stock assessments and ecological monitoring moving forward. The investments required to advance and use these techniques are substantial and their application does not appear likely to result in major cost savings in the short term.*

> **NOAA Response:** NOAA Fisheries agrees with this recommendation and the perspective that new technologies for improving assessments and monitoring are an investment at this point, and do not necessarily present a near-term cost-saving opportunity. As these technologies transition to operational use, they will contribute to filling data gaps, reducing uncertainty in the science advisory process, and potentially enable more stock and ecosystem assessments. Over the longer term, technologies that are new to us today (e.g., eDNA, uncrewed systems, electronic monitoring, artificial intelligence, infrared spectroscopy for fish aging, and others) do have the potential to produce efficiencies in data collection and processing, and there are a few select examples where efficiencies are already being realized (e.g., automated image processing in camera-based surveys). However, in the near term, it is a priority for NOAA Fisheries to invest in new technologies in a variety of ways, such as procurement of the platforms, calibration of new systems, development of analytical techniques for incorporating new types of data into assessments, staff training, and establishment of the needed infrastructure and expertise to use and maintain these systems. These investments need to be

incremental and prioritized in accordance with the greatest assessment and management needs. Additionally, many of these technologies are not replacing, but rather augmenting current programs, allowing NOAA Fisheries to better achieve assessment and monitoring objectives. These augmentations to our traditional ship-based surveys are particularly important given climate change induced shifts in species distributions, often outside of current survey domains, but we concur that augmentation of current activities certainly does not presently represent a cost savings.

Recommendation 2: *Before using the data from new technologies in stock assessments, NOAA will need to examine whether and how the new technologies can be linked to current stock assessment models and supporting analyses, and to what degree any new techniques enhance the stock assessments and increase the efficiency and timeliness of their preparation. For example, can these technologies enable more accurate, more rapid, more cost-effective or fundamentally different ways of assessing fishery stocks? These evaluations should consider both improvements to current, single-species stock assessments, as well as potential benefits to multi-species stock assessments, data-poor fisheries, and broader ecosystem-based fisheries management.*

NOAA Response: We agree that the ultimate goal of any data investment strategy needs careful consideration of how the data will be used in stock assessments and other analyses supporting fishery management. NOAA Fisheries' current investments in advanced data collection technologies are aligned with priorities for improving stock assessments and monitoring. However, evaluating the potential for new types of data to be used in stock assessments is complex and somewhat case-specific. Certain new technologies, such as advanced fish-aging techniques, provide the same type of data as traditional methods (albeit at a higher rate of production). In these cases, stock assessments can readily use the data with minimal need for assessment model calibration and testing. Other technologies provide more novel types of data (e.g., eDNA), and for these, substantial research is needed to understand the capabilities, validate the methods, and apply the technologies in an operational setting.

In addition to new data collection technologies, NOAA Fisheries is investing in the development of a modular stock assessment software platform, the Fisheries Integrated Modeling System (FIMS). This initiative will produce a unified approach to fisheries modeling across a range of data availability scenarios, and will accommodate more data-

rich, multispecies approaches to data-limited methods. Development of FIMS will provide a software architecture that allows for more ready assimilation of new research and data streams as they become operational.

Whether changes are being made to data sources or analytical methods, new approaches need to be evaluated at a level commensurate with their degree of novelty, and within a consistent framework to ensure that management decisions are based on the best scientific information available (BSIA). NOAA Fisheries has described a general BSIA framework, which provides a structure for conducting these evaluations. The BSIA framework mitigates against haphazard changes to data and methods by establishing a systematic approach that evaluates the validity and benefits associated with proposed changes before they are used as a basis for management decisions.

Recommendation 3: *New technologies can be advanced by holding workshops with diverse experts to develop ideas for how to apply these new technologies to stock assessment. It is likely that some adjustments with the technologies and stock assessment analyses will be needed to ensure effective use of the new data. Further, the workshops could explore how these methods may provide innovative insights to benefit NOAA's fishery management and overall science mission.*

NOAA Response: NOAA Fisheries concurs and strongly supports this approach to readying new technologies for stock assessment applications. The external community has great expertise and innovation, but is unfocused on NOAA's needs. NOAA can take the lead by facilitating a research-to-operations pathway. An example illustrates the merits of this approach and NOAA Fisheries' commitment to it. In the early 2010's NOAA Fisheries saw the need for automated imaging processing in order to speed access to optical data from fishery surveys and fishery observer programs, but our approach had been piecemeal across our Science Centers. We commissioned a workshop, organized in 2014 by the National Academy of Sciences, to explore the potential for this technology. This highly informative workshop gathered examples from diverse commercial, military, and research fields and provided the insight needed for NOAA Fisheries to commission a national Strategic Initiative that created a partnership with an external entity to implement an automated image processing system. That system is functional today and processes images for highly important assessment surveys, such as the camera sled survey for sea scallops off the Northeast coast.

More recently, there has been great interest in improving the survey methodology for red snapper, a highly important fish stock in the Gulf of Mexico. A NOAA grant funded an external project to design and conduct a new survey, independent of existing surveys conducted by NOAA and its regional partners. This externally-led project employed various advanced and conventional technologies. started with scoping workshops involving NOAA Fisheries to assure that the results would be suitable for subsequent inclusion in the red snapper stock assessment. This project is poised for completion in early 2021.

Recommendation 4: *Side-by-side dedicated comparisons between new technologies and ongoing stock assessment analyses will be needed to advance these new techniques. These comparisons will need to consider NOAA activities on-shore and at-sea. To account for environmental variability, multiple years of comparative field work and associated exploratory analyses will be required to successfully add the information generated by these new technologies to current assessment methods, while ensuring there is no disruption of the integrity, reliability and credibility of the stock assessments.*

NOAA Response: NOAA concurs with and supports this recommendation. Stock assessments build on sustained time series of our target populations' distribution, abundance, biological traits (e.g., population's age structure, individuals' condition), etc., and the relation of the populations to environmental variability. In recent years, NOAA Fisheries has begun such side-by-side data collection of traditional acoustic-trawl surveys and uncrewed systems, e.g., Wordy et al. (2017), as well we traditional surveys, uncrewed systems, and eDNA.

We similarly concur with the recommendation that there are multiple changes that need to be considered in future stock assessments. In addition to changes in technologies (requiring the above-mentioned side-by-sides), rapid changes in environment that affect target populations, and the ecosystem more broadly, e.g., feeding environment, and species' composition, also similar side-by-side approaches in the single- versus multi-species stock assessments, e.g., Holman et al. (2018) as well as evolving Ecosystem Based Fisheries Management approaches, e.g., Barbeaux et al. (2020). NOAA concurs that continued planning is paramount to ensure quantitative incorporation of new types of data as well as changes in the environment and supporting ecosystems. [Please also seethe response to *Recommendation #2* above and the Fisheries Integrated Modeling System (FIMS).]

Recommendation 5: *NOAA will need to invest in laboratory and field testing of these methods, as appropriate for the Agency's potential (present and future) applications. While basic development of molecular tools to identify DNA is mostly supported through the medical fields, studies on the application of these tools to stock assessment require NOAA support. NOAA should consider Public-Private-Partnerships (P3) to develop support for these methods in areas where the agency does not have primary responsibility or does not have sufficient in-house resources.*

NOAA Response: NOAA Fisheries agrees with the need for laboratory and field testing of new methods, including Public-Private-Partnerships. This is a necessary step, especially when the outcomes of the work will be used as scientific support for regulatory programs. Oftentimes, it is difficult to conduct such studies with the same staff, ships and resources that are needed to maintain the existing time series. Our work on advanced technologies has always focused on adaption of new technologies to our needs while relying principally on the external community for basic research and development, but in many cases a natural, although informal partnership has evolved and our staff have contributed to basic research as well. In some cases we have used Small Business Innovation Research (SBIR) grants to reach out to the external community for development on specific topics.

Recommendation 6: *NOAA should explore the potential for workforce development, cooperative institutes, postdoctoral programs and training classes to provide current and prospective NOAA scientists training for these methods. Efforts such as these are necessary to build a future workforce with expertise in these new technologies.*

NOAA Response: NOAA agrees with the need to develop both a current internal and external future workforce with experience in advanced technologies including machine learning, data science, 'Omics, and autonomous sampling systems. NOAA is exploring the use of new internal programs such as LANTERN and a proposed advanced tech bootcamp to rapidly develop its existing workforce through targeted training and structured activities. NOAA can also continue to take advantage of existing partnering and cooperative education programs (e.g., the NOAA Living Marine Resources Cooperative Science Center, LMRCSC) to sponsor undergraduate and graduate students in specialized fields of study alongside internal development of NOAA staff to improve existing talent and recruit new talent in these new methods.

Recommendation 7: *New technologies will generate large amounts of data that will need to be organized, analyzed and interpreted. NOAA should consider how artificial intelligence, cloud computing and other approaches can be applied to process the large volumes of data that will be generated. NOAA will also need to consider provisions for (and implications of) data ownership and access, particularly when new technologies are implemented by public- private partnerships or are processed (or stored) on the cloud.*

NOAA Response: NOAA's operations and science products are rapidly becoming more dependent on big data observations and the new technologies and approaches that can generate petabytes of environmental video, acoustic, genetics, and 'omics data, and model output. These systems – existing and in development – deliver data critical to building our scientific understanding and making management decisions, provided we can adequately acquire, log, store, process, and archive the high volumes of data they generate.

NOAA and the Federal government recognize this new opportunity. The NOAA Big Data Program provides cloud storage and sharing capacity. NOAA's S&T Focus Area Strategies – notably Uncrewed Systems, Artificial Intelligence, 'Omics, and Cloud - will expand NOAA's capability to use emerging technologies and revolutionize the agency's high-volume observations, predictions, and understanding of the environment.

A comprehensive plan for managing these data through their full lifecycle is a critical step. As part of their Fisheries Information Management Modernization efforts, NOAA Fisheries will bring together a high-level team of data owners, managers, and users to evaluate the current and future NOAA Fisheries high-volume data acquisition, processing, and management requirements. The team will design and evaluate a program that builds upon the existing technologies, governance, policies, and procedures of high-volume data systems in NOAA Fisheries and other NOAA line offices, and private partners, to learn from their data engineering decisions and look for areas of cooperation. As appropriate, NOAA Fisheries will identify drivers, scope out requirements, determine existing resources, capabilities, and parallel activities, and develop implementation plans. Planning and implementation will be done is close collaboration with our partners within and outside of the government.

The ultimate outcome of these efforts will be policy and guidance for data providers, processors, users, and stewards to locate, transport, process, and archive high-volume

data sets and their metadata consistent with NOAA, DOC, and Federal requirements. These actions will help NOAA build and manage end-to-end systems to acquire and store video, acoustic, genomics, and other high-volume data. They will consider the application of artificial intelligence and incorporate machine-learning capabilities to streamline the packaging, transporting, and processing of these data, creating metadata, and accessing and extracting specific data and information for further analysis and decision making. These actions will ensure adequate data storage services using cloud and on-premise servers and high-speed networks using public-private partnerships. These high- volume information management systems and policies will be consistent with and responsive to NOAA Focus Areas and IM legislation and orders, and use systems and tools already in place where possible.

NOAA Fisheries is establishing a High-Volume Data (HVD) Team to:

- evaluate current and future NMFS high-volume data producers and management requirements;
- build upon the existing technologies, governance, policies, and procedures of high-volume data systems in NOAA Fisheries and other NOAA line offices, and private partners, to learn from their data engineering decisions and look for areas of cooperation.
- identify drivers, scope out requirements, determine existing resources, capabilities, and parallel activities, and develop implementation plans; and,
- implement updated plans for shipboard data acquisition, regional electronic monitoring and reporting, artificial intelligence technologies, and cloud services.

Concluding remarks

NOAA again wishes to thank the valuable input and recommendations of the SAB and the ESMWG. We support and concur with the report's recommendations, and in certain cases as indicated above, NOAA is making investments in some of the identified approaches, with different stages of R2O (research-to-operations) in place. We look forward to continued collaboration with the SAB and the ESMWG.