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Using online data visualization and analysis to facilitate public involvement in management of catch share programs

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ABSTRACT

This case study examines the experience of the interdisciplinary Measuring the Effects of Catch Shares (MECS) project, a five-year demonstration project designed to explore the opportunities and constraints for third-party acquisition, organization, and communication of government fisheries statistics in order to track the ecological, economic, social, and governance outcomes of catch share programs. Catch share programs, whereby fishery managers allocate to private entities percentages of the total amount of fish that can be caught in a year, have been used to manage some US fisheries since the 1990s. Given the high financial stakes of commercial fisheries and the wide-ranging impacts ascribed to these programs, they are among the most controversial and contentious tools of contemporary fisheries management. The goal of the MECS project was to create an interactive, web-based platform for conveying a set of neutral, scientific indicators based on the best available fisheries data that could be used by fishing industry participants, fishery managers, and other interested parties to supplement and inform their own understanding of catch share program effects. The MECS project focused on the effects of two US catch share programs: the Northeast Multispecies Sector Program implemented in 2010 in the Northeast groundfish fishery and the Shorebased IFQ Program implemented in 2011 in the West Coast groundfish trawl fishery. The MECS project encountered data access challenges but ultimately succeeded in developing a website that has been received by members of the private and public sector alike as a useful tool that brings together and communicates disparate information that is not otherwise readily accessible.

1. Introduction

Catch share programs, whereby fishery managers dedicate a secure share of fish stocks to individual private or public entities for their exclusive right to catch, are among the most controversial and contentious tools of contemporary fisheries management. Given the high financial stakes of commercial fisheries, many individual citizens and private-sector groups are deeply concerned about the potential effects of catch share programs on fish stocks, fishing businesses, and fishing-reliant communities. However, a major challenge in understanding the effects of catch share programs is that most fisheries data are compiled and controlled by government agencies, and public accessibility to these data may be extremely limited. Although fish harvesters, seafood processors, and other private sector entities help contribute key types of fishery data, limited efforts have been made to foster public use of the data. This case study examines the opportunities and constraints for third-party collection, organization, and interpretation of fisheries statistics in order to track the ecological, economic, social, and governance outcomes of catch share programs, and to communicate that information to public audiences using the Internet and interactive media.

Specifically, the case study describes the experience of the Measuring the Effects of Catch Shares (MECS) project, the goal of which was to provide a set of neutral, scientific indicators that can be used by fishing industry participants, fishery managers, and others to determine how catch share programs have affected businesses, communities, public sector entities, and the natural environment. Rather than advocate for or against catch share programs, the MECS project endeavored to help people supplement and inform their own understanding of catch share

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program effects. In addition, the project was among the first to explore how the Internet could be used to display trends in fisheries using an interactive display of the data underlying various catch share program performance indicators. The project was time limited, operating on a five-year grant.

This case study begins with an overview of the national debate over catch share programs and a review of past initiatives to measure the effects of existing programs. The case study then describes the efforts of the MECS project to create an interactive, web-based platform that enables users to explore catch share program impacts. The focus is on the project's successes and setbacks with respect to selecting key questions and metrics, acquiring data, developing a baseline, and constructing and organizing a website to deliver data and findings to fishery stakeholders and other interested parties. The implementation and outcomes of the MECS project provide valuable lessons for promoting and facilitating independent evaluations of the effects of catch share programs specifically, and natural resource management decisions in general.

1.1. Catch shares controversy and calls for periodic program review

"Catch shares" is a general term for a fisheries management strategy in which specific portions of the annual total allowable catch in a particular fishery are allocated to individuals, cooperatives, communities, or other entities. Each recipient of a catch share is directly accountable to stop fishing when its exclusive allocation is reached. The term includes specific programs defined in US federal law such as "limited access privilege" (LAP) and "individual fishing quota" (IFQ) programs (National Marine Fisheries Service 2010). Under Section 303A of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the National Marine Fisheries Service (NMFS) and the eight regional fishery management councils created by the Act may implement catch share programs in any of the dozens of federally managed fisheries.

The anticipated benefits of catch share programs are rooted in economic theory, which asserts that when exclusive allocations exist, a fishery will become more economically efficient because there is no incentive for a fishing operation to select anything but the least cost combination and deployment of fishing inputs [1,2]. If a catch share program allows transfers of allocations across fishing operations, redundant capital is further removed from the fishery as more efficient fishing operations purchase the allocations of less efficient operations [3]. By affording fishing operations increased flexibility in choosing when to fish, exclusive allocations have the added advantage of allowing fishing operations to search out fish of optimal size, improve catch quality, optimize catch mix to market conditions, and avoid fishing in dangerous weather or locations [4]. Moreover, allocating a secure privilege to harvest a specific percentage of a fishery's total catch has the potential to create incentives for long-term stewardship of the resource by fishing industry participants [5].

Despite empirical evidence that adoption of catch share programs can generate substantial economic gains and other benefits, this fisheries management approach can be highly controversial and divisive [6]. Critiques of catch share programs note that besides essentially privatizing a shared public resource, these programs have the potential, depending on their design, to result in inequitable windfalls of fishing privileges; push smaller fishing operations out of business; reduce crew employment and compensation; require high monitoring and enforcement costs to prevent "high-grading" (i.e., discarding fish of lesser quality) and "quota busting" (i.e., landing a larger amount of fish than an individual allocation allows); produce "armchair fishermen" (i.e., individuals who earn income from leasing their allocations rather than fishing the allocations themselves); and lead to extensive non-local ownership of allocations [7–10]. According to catch share program critics, the overall result can be devastating to some fishing industry participants and fishing communities.

Notwithstanding this controversy, the end of the twentieth century and beginning of the twenty-first century saw widespread implementation of catch share programs. It is estimated that there are 500 species of fish managed by 200 catch share programs in 40 countries [11]. In the United States the history of catch share programs is one of fits and starts. The first program in the country was implemented in 1990 in the federally managed Mid-Atlantic surf clam and ocean quahog fishery. By the mid-1990s, three more programs were in place in fisheries occurring in the US exclusive economic zone.

However, growing apprehension within the US fishing industry about the potential negative effects of catch share programs eventually led to political opposition. In 1996, the US Congress enacted a moratorium on the creation of any new IFQ program as part of the Sustainable Fisheries Act amendments to the MSA. At the same time, Congress asked the National Academy of Sciences to study a wide range of questions concerning the social, economic, and biological effects of IFQ programs and to make recommendations about existing and future programs.

Published in 1999, the National Academy of Sciences' study acknowledged the contentious nature of IFQ programs. The study determined that a key to maintaining the stability of and support for these programs was to carefully monitor the performance of each one:

> The Secretary of Commerce should ensure that each fishery management plan that incorporates IFQs include[*s*] enforceable provisions for the regular review and evaluation of the performance of IFQ programs, including a clear timetable, criteria to be used in evaluation, and steps to be taken if the programs do not meet these criteria. Provisions should be made for the collection and evaluation of data required for this assessment. The process could include *review by external, independent review bodies* [emphasis added] [12].

On September 30, 2002, the federal moratorium on catch share programs expired. Congress, in its 2007 reauthorization of the MSA, included several new provisions that elaborated the criteria and guidance for authorizing a catch share program. One of these provisions was based on the recommendation that the Secretary of Commerce conducts periodic assessments of the performance of each program.

In 2017, NMFS published guidelines to help ensure that catch share program reviews conducted by the agency and regional fishery management councils were comprehensive and targeted at meeting statutory requirements; coordinated with stakeholders; carried out in a transparent, efficient, and effective manner; and conducted by applying consistent standards across the country while allowing regional flexibility [13]. However, less attention has been given to the role of independent catch share program reviews, especially ones that not only are readily accessible by a general audience but also offer opportunities for the members of the public to evaluate a program themselves using the best available data.

After the moratorium was lifted, federal fishery managers implemented a spate of new catch share programs across the country. By 2015, there were 17 federal catch share programs in operation, with six of the eight regional fishery management councils implementing at least one program [14]. However, the legislative requirements for program review did little to quell the criticism of the new round of catch share programs. Among some fishing industry representatives there were calls for Congress to consider another moratorium on new catch share programs as well as require independent review of existing programs [15].

2. Design and implementation of the Measuring the Effects of Catch Shares (MECS) Project

The MECS project was initiated in 2014 through multi-year private funding to MRAG Americas, Inc. (MRAG), a private consulting firm. The purpose of the project was to make the best available scientific data readily accessible to everyone with an interest in catch share management, and to offer unprecedented ways of exploring and interacting with those data. The result, it was hoped, would be fishery stakeholders who

were better informed and could more effectively engage in the regional fishery management council process, a bottom-up fisheries management approach emphasizing public participation and involvement [16,17]. The project did not advocate for or against catch share programs. Rather, it sought to provide reliable, neutral information that people could use to answer their own questions and inform their own decisions about them. The MECS project was designed to be a demonstration project that would end after five years. However, the project website was still live at the time of publication of this article and could be accessed at www.catchshareindicators.org.

The MECS project focused on the effects of two US catch share programs: the Northeast Multispecies Sector Program implemented in 2010 in the Northeast groundfish fishery and the Shorebased IFQ Program implemented in 2011 in the West Coast groundfish trawl fishery. These two catch share programs were selected because they were established in federally managed fisheries of high economic, social, political, and ecological importance. Both programs were implemented in multispecies groundfish fisheries in which some species or stocks had been declared overfished under the MSA. However, the programs differ substantially in their design. Each unique catch share program was the outcome of its own extensive public participation process. Stakeholder engagement continued after program implementation during program reviews and amendments initiated by NMFS and the regional fishery management councils.

2.1. Selection of performance indicators and metrics

MRAG engaged several outside consultants to help design and implement the MECS project, which, from the outset, adopted an interdisciplinary approach to address the complex effects of catch share programs holistically. The improved understanding acquired from integrating different disciplinary perspectives and different types of data can engender a situation where the outcome of research is greater than the sum of its (disciplinary) parts [18].

The benefits of an interdisciplinary approach are especially relevant to the evaluation of a catch share program because of the interactions between a program's biological and human effects. Nearly all program outcomes include ecological, economic, social, and governance elements, and these elements are often interrelated. An interdisciplinary approach helps ensure that the data describing these elements are collected and analyzed in a coordinated and complementary manner and delivered effectively to fishery stakeholders.

MRAG announced an open call for letters of interest and selected team members based on their disciplinary knowledge and experience, together with a willingness to try a novel approach to integrating and distilling scientific information in order to make it accessible and useful to the general public. The team included ecologists, economists, anthropologists, and resource policy experts, together with a scientific communications specialist. Some of these individuals were affiliated with academic institutions, while others worked for private consulting firms. Frequent communication among team members was encouraged to promote integration of disciplinary perspectives.

In the first phase of the MECS project, the project team reviewed available literature on the evaluation of catch share programs. Especially informative was the national set of catch share program performance indicators developed by the NMFS Office of Science and Technology [19]. In addition, the team convened workshops and one-on-one interviews with fishing industry representatives, fishery scientists, and fishery managers to identify the main concerns that people have about catch share programs with respect to their effects on fish stocks, fishing operations, fishery shoreside support businesses, and fishing communities. From the beginning, the project team recognized that some important catch share program impacts could not be addressed because of factors such as time and funding constraints and the limited amount of data that could be routinely collected and updated for the two catch share programs. Moreover, there were evaluation questions, such as impacts on quality of life, community stability, and preservation of cultural values and traditions, that while clearly important, were challenging to address because of the difficulty of translating the impact into one or more performance indicators that could be measured quantitatively in a reliable and valid way. Within the confines of these constraints, the project team distilled the published performance measures, together with the elicited concerns from the workshops and interviews, into a set of key questions organized by discipline (Table 1). These key questions served as the performance indicators for evaluating the ecological, economic, social, and governance effects of the two catch share programs.

Based on the review of studies on the evaluation of catch share program performance, together with the information garnered from the interviews and workshops, the project team chose a set of metrics designed to answer one or more key questions. These metrics were the focus of the MECS project's data collection and reporting. The metrics

Table 1
MECS project key questions and metrics to measure ecological, economic, social and governance impacts of catch share programs.

Key question	Metrics
Ecological	
Has the status of fish stocks changed?	biomass; fishing mortality
Have fleetwide catches stayed within quotas?	ratio of catch to quota
Has the quality of fishery data changed with changes in observer coverage?	observer coverage levels
Have discarding practices changed?	discards of harvested species
Has the level of bycatch and interactions with protected species changed?	interactions with protected species (marine mammals, seabirds, and sea turtles)
Has the level of fishing effort changed in amount or location?	total amount of tows by vessels participating in the groundfish fishery; location of fishing effort
Have fishing impacts on seafloor habitats changed?	contact of fishing gear with seafloor habitats
Economic	
Has the financial viability of the fishery changed?	amount and value of groundfish landings by species/species group
Has the number of active vessels in the fishery changed?	number of vessels participating in the groundfish fishery
Have opportunities or barriers to entering the fishery changed?	distribution of catch allocations across groundfish vessels; number and volume of transfers of catch allocations among vessels by species
Are fishing vessels participating in a different mix of fisheries?	number of groundfish vessels participating in non-groundfish fisheries; amount and value of non-groundfish landings
Has the cost of fishery management to the private sector changed?	fishery management costs incurred by industry
Social	
Have fishery landings and revenues changed across states and ports?	amount and value of groundfish landings by state and port
Has fishing vessel activity changed across states and ports?	number of vessels participating in the groundfish fishery by state and port
Has fishing vessel safety changed?	number of fatalities and safety-related incidents reported in fishing fleet
How has crew employment and compensation changed?	number of crew positions; amount of crew compensation
Has fishing support service employment changed?	number of shoreside businesses dependent on the fishery by state and port
Has seafood processor employment changed?	number of seafood dealers purchasing and processing groundfish
Governance	
Has the public cost of fishery management changed?	catch share management costs incurred by regional fishery management councils and NMFS
Has the efficiency of fishery management changed?	time spent by regional fishery management councils and fishery stakeholders in fishery management decision-making; annual catch limits by species/species group
How has litigation shaped the design of the catch share programs?	level of fishery-related litigation

for some key questions varied between the two catch share programs due to differences in data availability.

2.2. Data acquisition

Tracking the performance indicators of the catch share programs relied heavily on publicly available data. Most of the available data for federally managed marine fisheries are collected by NMFS in cooperation with state and interstate agencies. In the case of the two fisheries of interest to the MECS project, the data collection programs differ, but both programs generate detailed catch and effort statistics for all fishing trips taken by each participating vessel. These data are used to ensure compliance with catch limits and are also a key component of scientific assessments of the status of the stocks. For the Northeast groundfish fishery, NMFS collects catch and effort information by two primary means: (1) vessel operators permitted by the NMFS Greater Atlantic Regional Fisheries Office (GARFO) must submit a vessel trip report for every fishing trip, and (2) seafood dealers permitted by GARFO must report all purchases and receipt of fish. Additional data are obtained from the industry organizations responsible for quota management. All this information is managed by GARFO's Analysis and Program Support Division.

For the West Coast groundfish fishery, state fisheries agencies in California, Oregon, and Washington collect catch and effort information from vessel operators by means of mandatory vessel logbooks and state-issued landing receipts (also called fish tickets). This information is submitted to Pacific Fishery Information Network (PacFIN), a joint federal and state fisheries data network maintained by the Pacific States Marine Fisheries Commission (PSMFC) and funded by NMFS [20].

In both fisheries, at-sea observer programs administered by NMFS play an important role in determining the amount of a vessel's catch that is discarded at sea. However, the observer coverage levels vary between the fisheries and across the timeframe of the MECS project.

Although NMFS and PSMFC provide websites that allow users to download commercial fisheries data, the information provided is in a predetermined format that often inhibits the ability to conduct comprehensive analyses. In general, members of the public who desire access to more detailed fisheries information must sign a non-disclosure agreement and fill out a database access request form that must be approved by an agency database official. However, obtaining information useful to the MECS project through a data request proved challenging.

The data access issues encountered by the MECS project underscore the presence of competing provisions within the MSA. On the one hand, a stated policy of the Act is that regional fishery management councils "enable the States, the fishing Industry, consumer and environmental organizations, and other interested persons to participate in, and advise on, the establishment and administration of … [fishery management] plans" (Section 2(b)(3)(b)(5)(A)). This public participation in the development of fishery management plans has been referred to as the "cornerstone" of the MSA [17]. Court cases have determined that to effectuate this policy of stakeholder involvement in the decision-making process, interested parties must be supplied with an adequate amount of information so that they might be able to scrutinize and comment upon regulatory decisions [21].

On the other hand, the MSA also requires that any statistics submitted to NMFS, a state fishery management agency, or a marine fisheries commission by any person in compliance with the Act must be kept confidential. Section 402(b)(3) of the Act provides that NMFS "shall, by regulation, prescribe such procedures as may be necessary to preserve the confidentiality of information submitted in compliance with any requirement or regulation under this Act." Accordingly, NMFS has promulgated confidentiality regulations, which are set forth at 50 CFR part 600, subpart E. From NMFS' perspective, protecting the confidentiality of proprietary data is not only required by federal statute and regulation, it is critical to the agency's efforts to obtain the data required to meet its fishery conservation and management responsibilities [22]. There is no sunset clause on data confidentiality; data are confidential in perpetuity [23].

Section 402(b)(3) does also authorize NMFS to release to the public statistics subject to the Act's confidentiality requirements "in any aggregate or summary form which does not directly or indirectly disclose the identity or business of any person who submits such statistics." However, aggregation of data can limit the ability to use the data to readily answer questions that arise across data sets, and over a variety of scales within data sets. For example, aggregated data make it difficult to determine the community-level effects of catch share programs in terms of changes in local fishery landings, revenue, and jobs. It is often these finer-grain data that are needed to effectively engage stakeholders in the fishery management process because they allow individuals to see how their own communities could be directly affected by management measures.

A report on the collection, management, and use of marine fisheries data in the US prepared by the National Research Council [23] in 2000 acknowledged that some level of confidentiality may be necessary to allow fishing industry participants to maintain their businesses and to promote reporting of high-quality information about location, landings, and bycatch in some fisheries. However, the report concluded that, "Confidentiality of fisheries data is restrictive to the point of hindering both research and management. State and federal restrictions to free access to data neglect the rights of the public to have greater information about the use of [fishery] public-trust resources." The report further asserted that, "It is important for [fishery] scientists and managers to improve their communication of the data available and to make such data available to stakeholders more readily and in a user-friendly form. When this is not achieved, a lack of trust develops between those who control access to data and those who cannot gain access."

Little has changed since publication of the National Research Council's report. Efforts by public-private collaborations such as the Fishing Data Innovation Task Force [24,25] to find options that protect confidentiality but provide access to data have been the subject of workshops, task forces, and publications. However, various third parties continue to lament the difficulty of securing access to federal fisheries data for research purposes [26,27].

In the case of the MECS project, team members spent considerable time meeting with NMFS regional staff to ensure that data requests were submitted in accordance with agency guidelines. In addition, these meetings provided an opportunity for the project team to assure NMFS staff that the intention of the project was to build upon rather than duplicate the agency's own efforts to analyze the effects of the two catch share programs. After a substantial delay from the time the project team submitted its data requests, NMFS and PSMFC provided the team with an extensive amount of fisheries data, albeit in a filtered and aggregated form. Given the confidentiality restrictions, the data were not sufficiently detailed to fully track the performance indicators developed by the MECS project at the desired level of granularity. It was necessary for project team members to draw on additional sources of information, the major ones of which are described below.

2.2.1. Supplementary published sources

An important secondary source for the Northeast groundfish fishery was a series of reports that NMFS began to prepare shortly after the fishery's catch share program began [28]. These reports evaluated the economic and social performance of active Northeast groundfish vessels during a given fishing year. Each report contained an extensive set of tables that presented a wide array of metrics. Much of the quantitative information presented was difficult to recreate using publicly available primary data. For example, some of the metrics in the reports are presented at both the individual vessel level and at the affiliated vessel level, where "vessel affiliations" are defined as networks of vessels connected through common owners. Vessel ownership information is not readily available to third parties.

With respect to the West Coast groundfish fishery, the project team was able to draw on information presented in the Pacific Fishery Management Council's five-year review of the catch share program [29]. As with the Northeast groundfish fishery performance reports, the five-year review contained myriad tables of fishery performance metrics derived from information that could not be obtained through data requests. In addition, approximately two years after the MECS project began, the NMFS Northwest Fisheries Science Center launched FISHeries Economics Explorer (FISHEyE), an interactive tool to help members of the public examine the economic impacts of the Shorebased IFQ Program and other components of the West Coast Groundfish Trawl Catch Share Program on participants and regional economies [30,31]. FISHEyE gave the project team and other users the ability to query aggregated fisheries data. However, the website's limited baseline period (three years prior to initiation of the catch share program) reduced its usefulness to the MECS project, which endeavored to place fishery trends subsequent to catch share program implementation in as broad a historical context as possible.

Analyses of ecological impacts in both the West Coast and Northeast groundfish fisheries relied on stock assessment reports and observer program reports prepared by NMFS. Additional data were extracted from environmental reviews generated by the New England Fishery Management Council and Pacific Fishery Management Council in the course of developing fishery management plan amendments.

2.2.2. Personal interviews

Over the course of the project, team members conducted one-on-one and group interviews with stakeholders knowledgeable about the Northeast and West Coast groundfish fisheries, including fishing vessel owners, captains, and crew members; state and federal fishery managers and scientists; seafood buyers and processors; suppliers of shoreside fishing fleet support services; and representatives of fishing and environmental organizations. In total, the team interviewed 45 individuals in seven West Coast communities, and 29 individuals in six Northeast communities. The questions asked during the interviews were derived from the key questions that served as the indicators for evaluating the ecological, economic, social, and governance effects of the two catch share programs.

The approach taken in conducting the interviews was based on the concept of phenomenology, a form of qualitative research centered on investigating "an individual's lived experiences within the world" [32]. As described by Harrison and Loring [33], the goal of this approach "is not to produce a set of findings that are generalizable to the community at large but to learn about the essence of a particular local phenomenon…by seeing [it] through the eyes of multiple participants." The local phenomenon of interest for the MECS project was the impact of a catch share program on fishing businesses and fishing-reliant communities. While the subjective information obtained from interviews deviated from the "let the data tell the story" general approach of the MECS project, the project team felt that the information enriched the project in two ways. First, the project team believed that those stakeholders most involved in the fishery would be able to provide added insight into the trends seen in the quantitative data. Second, the interviews provided additional details as to how people and communities were affected by the catch share programs. These often highly personal perceptions and experiences could not be fully captured in numerical data.

Quotes from the interviews were incorporated into webpages for selected performance indicators by means of an accordion expandable box labeled "In Their Own Words."

2.3. Project implementation

The MECS project team recognized that the project website would be of interest in the work of fishery managers, fishery scientists, fishing industry participants, environmental organizations, and others. Developing an approach that provided scientifically sound and objective information that could be readily understood by these diverse audiences required rigorous attention to data clarity and accessible language. Each step in the implementation process is outlined below.

2.3.1. Selecting a baseline and defining the narrative

A major objective of the MECS project was to allow website users not only to see whether certain catch share program outcomes occurred, but also to understand whether changes observed in the fisheries after program implementation were attributable to the programs. For example, the health of groundfish stocks depends on many factors, some of which are external to a catch share program.

Although there is no perfect way to solve this attribution problem, the project team took steps to help website users examine direct cause-and-effect relationships. To identify longer-term trends in the fisheries that pre-date catch share program implementation, data were presented for a baseline period that extended back to 2002 (the year that Congress ended the moratorium on new catch share programs in the US) or further (up to 35 years for some metrics). The long timeframe provided a historical context for understanding changes that occurred in the fisheries after the start of the catch share programs.

To further clarify the historical context, a dedicated webpage was created for each fishery to detail the fishery's biological and economic performance leading up to catch share program development. This overview was accompanied by an interactive timeline that highlighted major events in the fishery's history. Additional webpages were developed to describe the evolution of the management framework for each fishery. Examples include the following background webpages for the Northeast groundfish fishery and its catch share program: Catch Share Program Overview https://www.catchshareindicators.org/northeast/about-the-fishery/fishery-overview/; Fishery Background and Timeline https://www.catchshareindicators.org/northeast/about-the-fishery/history-and-timeline/; and Management Context https://www.catchshareindicators.org/northeast/about-the-fishery/management-framework/.

In addition, the individual webpage for each performance indicator includes a narrative highlighting key patterns and trends in the accompanying data. Where credible evidence was available, the narratives describe the contribution of various factors to these changes in metrics data. The science communications specialist on the MECS project team edited the narratives to ensure that the text would be accessible to a variety of audiences. Technical terms used in the narratives are linked to a glossary provided on the website.

2.3.2. Construction and organization of the website

From the start, the MECS project team intended the interactive website to be an easy-to-use tool for the public, while also serving as a valuable resource for fishery managers and scientists. Early in the project before results were available, an initial "brochure-style" version of the website was launched with information about the project's purpose and approach.

When the first set of interim results were ready for release, the project team redesigned the website to focus on results rather than the project development. The team sought to communicate the findings in ways that would most effectively meet the needs of different users. To help draw in and engage users, the website relied on high-quality photography and graphics, concise text with various levels of detail, and interactive charts in attractively designed page layouts.

Initially, the MECS project team envisioned releasing performance indicator results on the website on an ongoing basis throughout the project's five-year duration. The intention was to empower fishery stakeholders with the most recent data and findings on an annual or semi-annual basis, and then conclude with a final analysis covering the first few years under catch share management. It was hoped that regular website updates would draw increasing numbers of users and build awareness of the project. However, the aforementioned challenges and delays encountered in obtaining data from government sources meant

that it was difficult to provide timely updates that would attract and sustain the intended audience's interest. Data were already somewhat outdated by the time they could be analyzed and posted, which may have diminished the utility of the results for some users. Nevertheless, data continued to be uploaded to the website on a rolling basis when available, with the final upload being completed at the end of 2018.

2.3.3. Dashboards with drilldown capability

For each of the two catch share programs, the website offers an online dashboard consisting of one simple, at-a-glance graph for each ecological, economic, social, and governance performance indicator. The dashboard acts as an entryway to the indicator narrative and interactive graphics. Within the constraints of the aggregated data provided by NMFS and the PSMFC, users can drill down to find the level of detail and nuance they want to answer their questions about the catch share programs.

Selecting an indicator in the dashboard directs the user to a webpage that presents increasingly granular levels of information for the indicator from a high-level overview to more in-depth explanations. These are provided in the following components on each indicator webpage:

- Key Findings—Brief bullet points that highlight the most important takeaway messages from the data analysis
- Interactive Chart Story—One or more interactive charts that illustrate important patterns or trends in the data, with each chart accompanied by brief text highlighting noteworthy patterns
- Metrics—Short explanations of the specific measurements used to determine changes in the indicator
- Analysis—Concise narratives describing the MECS project's findings about the indicator status before and after catch share program implementation
- Information Sources—Each interactive chart cites the source of the charted data, and each indicator webpage lists publications, websites, and other sources of information used in the analysis and narrative.

2.3.4. Interactive charting

The MECS project team sought to provide website users with ways to explore and visualize the data in ways that fit their individual needs and interests. For example, a user might be interested in a specific fishing community or fish stock rather than the fishery as a whole. The data sets for the performance indicators were large and often complex. But the website needed to make it simple for users, including those with limited computer skills, to select components of the data of interest and view automatically generated graphs of the results. The Tableau Desktop® platform (https://www.tableau.com) proved to be an effective solution for building interactive charts with filters that website users can use to select subsets of data to display. These charts were readily embedded into the indicator results pages of the website. This format provides the opportunity to tell the indicator story across a series of chart tabs, with key trends and patterns emerging from each chart's data. The underlying data behind charts were not made accessible to website users because the data were obtained through requests submitted by the MECS project team to NMFS GARFO and PSMFC. However, hovering the cursor over a data point on a chart reveals information on that data point, including its value. In addition, the charts can be shared via social media and downloaded in multiple formats such as PDF and image files.

An example of the website graphics can be seen at https://www.catchshareindicators.org/westcoast/economic/revenues/. This sample webpage addresses the key question of whether the financial viability of the West Coast groundfish fishery changed after implementation of the Shorebased IFQ Program. The primary interactive chart shows the revenue trend in the fishery from 1982 through 2014 by species. Additional charts displaying details about changes in groundfish revenue over time are provided as callouts in the accompanying narrative.

2.3.5. Interconnectedness of performance indicators

Considering relationships among the different performance indicators is important to fully understand the effects of catch share programs on fish stocks, fishing industry participants, and fishing communities. Changes in one performance indicator can help explain changes in other indicators. For instance, a decrease in a fish stock's biomass could lead to a reduction in the annual catch limit, which in turn could result in lower landings and revenues. The web-based reporting platform proved to be an effective tool for highlighting the interconnectedness of the biological, governance, economic, and social performance indicators. The MECS project team called the attention of website users to these connections by inserting hyperlinks in the indicator narratives that connect one indicator webpage to another.

3. Conclusion

For a fisheries management measure as controversial and contentious as a catch share program, it is essential to the program's success that there be opportunities for stakeholder involvement in the decision-making process, and that these stakeholders possess enough information that they can assess program impacts in a way that is meaningful to them. But the ability of third parties to collect and publish data that could enhance stakeholders' understandings of the complex ecological, economic, social, and governance effects of catch share program is hampered by regulations that limit public access to government fisheries data. The MECS project presents an example of adapting to these data acquisition challenges and communicating procured data to a broad audience through an interactive website. While it was difficult to provide timely data updates, the project website provided users with multiple ways to explore and visualize data describing the ecological, economic, social, and governance impacts of two catch share programs.

It is difficult to evaluate the extent to which the MECS project facilitated stakeholder participation in the fisheries management process. There is, however, some indirect evidence that the project website encouraged stakeholder information gathering. From January 2015 to January 2019, 19,697 users accessed the project website a total of 24,915 times. Examples of publications citing the website include law review articles [34,35]; a food blog [36]; an independent policy institute report on federal fisheries management [37]; a planning document for an intergovernmental regional ecosystem indicator monitoring and assessment program [38]; a guidance document in support of California's 1998 Marine Life Management Act [39]; an analysis of the economic viability of a marine construction company [40]; master's theses [41,42]; a fish harvester's blog [43]; a peer-reviewed journal article about tools for evaluating socioeconomic performance of fisheries management [44]; and a Federal Register notice in which NMFS responds to a public comment on a fisheries management regulation by referencing information from the website [45].

In short, during the duration of the MECS project the website was received by fishing industry participants and government agency staff alike as a useful resource that brought together disparate information that was not otherwise readily accessible. In a review of the website, a private institute that focuses on collaborative solutions to global ocean challenges noted that a lack of objective information has made it difficult for supporters and opponents of catch share programs to work from a shared understanding of what changes have actually occurred [46]. The MECS project endeavored to show that a carefully constructed interactive website with enhanced data visualization can help overcome that difficulty.

CRediT authorship contribution statement

Donald Schug served as lead author, with Peter Taylor providing material on the development of the dashboard and its use. Suzanne Iudicello and Jill Swasey contributed discussion of the goals and history of the overall project and the context of stakeholder participation in

fishery management decision making.

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Competing interests

The authors have no competing interests to declare.

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