NOAA Technical Memorandum NMFS-NWFSC-143

Economic Performance Metrics:

An Overview of Metrics and the Use of Web Applications to Disseminate Outcomes in the U.S. West Coast Groundfish Trawl Catch Share Program

https://doi.org/10.25923/a4g5-cq83

September 2018

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

NOAA Technical Memorandum NMFS-NWFSC-143

Economic Performance Metrics:
An Overview of Metrics and the Use of Web Applications to Disseminate Outcomes in the U.S. West Coast Groundfish Trawl Catch Share Program

https://doi.org/10.25923/a4g5-cq83

Melanie Harsch, Lisa Pfeiffer, Erin Steiner, and Marie Guldin

Fishery Resource Analysis and Monitoring Division
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, Washington 98112

September 2018

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center
https://www.nwfsc.noaa.gov/index.cfm

NOAA Technical Memorandum NMFS-NWFSC Series

The Northwest Fisheries Science Center of NOAA's National Marine Fisheries Service uses the NOAA Technical Memorandum NMFS-NWFSC series to issue scientific and technical publications. Manuscripts have been peer-reviewed and edited. Publications in this series can be cited in the scientific and technical literature. Technical editing services at NWFSC are provided by Al Brown.

The Northwest Fisheries Science Center's NOAA Technical Memorandum NMFS-NWFSC series continues the NMFS-F/NWC series established in 1970 by the Northwest and Alaska Fisheries Science Center, which subsequently was divided into the Northwest Fisheries Science Center and the Alaska Fisheries Science Center. The latter uses the NOAA Technical Memorandum NMFS-AFSC series.

NOAA Technical Memorandums NMFS-NWFSC are available at the Northwest Fisheries Science Center website, https://www.nwfsc.noaa.gov/index.cfm.

Reference this document as follows:

Harsch, M., L. Pfeiffer, E. Steiner, and M. Guldin. 2018. Economic Performance Metrics: An Overview of Metrics and the Use of Web Applications to Disseminate Outcomes in the U.S. West Coast Groundfish Trawl Catch Share Program. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-143. https://doi.org/10.25923/a4g5-cq83

Contents

Figures

Tables

Executive Summary

Decision-makers require objective information in useful reporting formats to evaluate fishery management plans in relation to biological, economic, and social goals. Economic performance metrics are useful for assessing a fishery with respect to management objectives related to the economic performance of the fishery and vessels within that fishery. An initial standard set of metrics applicable across diverse catch share programs is outlined in Brinson and Thunberg (2013).

Because some regions or fisheries may have unique data sets, management objectives, or concerns, the development of additional metrics may be helpful. Stakeholders utilize performance metrics in different ways, from directly addressing management needs to using them for research purposes. Adequately meeting all stakeholders' needs is challenging with traditional written or oral reporting mechanisms, especially in the U.S. West Coast groundfish trawl catch share program, which covers multiple species, sectors, gear types, and states. However, working to address stakeholders' needs increases transparency and trust; increases engagement between managers and fishers, scientists, the public, and other key stakeholders; reduces the burden of providing tailored data requests; allows users to quickly answer policy and research questions; and makes research accessible to a broader audience.

Web applications can support data-driven decision-making and comply with government mandates to publish information in searchable, open formats. In web applications, data can be summarized along many different criteria and shared while remaining compliant with any confidentiality restrictions on the data. Providing downloadable, thoughtfully aggregated data can increase trust and transparency. Tools and extensions have been developed that aid scientists in developing web applications. One tool, the Shiny package from RStudio, allows users familiar with R to develop web applications that seamlessly integrate R code for data processing and plotting into the web application. No knowledge of HTML, CSS, or JavaScript is required. Similar tools are available for other programming languages. This type of tool allows scientists to make their data and research more accessible, useful, and engaging.

Introduction

Fisheries management is the process of gathering information, planning, consulting, and implementing regulations that govern fisheries activities (Cochrane 2002). Critical aspects of fishery management plans are the inclusion of objective information to inform and aid decision-makers, the ability to continuously monitor and evaluate the plan in relation to biological, economic, and social goals, and regular communication and consultation with users (Cochrane 2002).

The review of management actions requires tools for evaluating and detecting changes that occurred in the fishery since program management implementation. Performance metrics are one tool that can be used to evaluate the performance of fishery management programs (Anderson et al. 2015). An "economic performance metric" is a statistic used to analyze past economic performance, predict future economic performance, and describe characteristics of a broader economic system. NOAA Fisheries has established a standard set of metrics that use data commonly collected across management plans for evaluating economic performance of catch share programs. These metrics, which are also relevant beyond catch share programs, are detailed in *The Economic Performance of U.S. Catch Share Programs* (Brinson and Thunberg 2013) and online.[1]

Engaging fishery managers and participants in economic analysis requires multiple tools, including both conventional reporting mechanisms (reports and presentations) and novel approaches geared toward meeting stakeholders' needs. Static reports and presentations provide detailed data and analysis pertaining to objectives. Space limitations of the reporting system constrain the number of permutations of the data that can be displayed, especially when the management plan extends across multiple states or species, and economic performance of participants may be affected by activities beyond the fisheries management program under review. An alternative, which enables stakeholders to view the information they need, is to develop interactive web applications. Web applications are a transparent and objective reporting mechanism that enhances the dissemination of complex statistics, improves decision-makers' ability to get the information they need, and potentially increases engagement with fishery participants. Recent computational developments have assuaged several challenges associated with web development, including application development and handling of confidential data. Developing web applications that meet decision-makers' needs, engage stakeholders, and reduce data request burdens is feasible to anyone with basic knowledge of statistical programming languages.

Most performance metrics and reporting tools are developed with simple single- or two-species fishery management programs in mind. However, as management focus shifts to multispecies and ecosystem-based management, additional metrics and new reporting systems should be considered. Here, we use the U.S. West Coast groundfish trawl catch share program to outline performance metrics that are especially relevant to multispecies fisheries, the challenges and limitations inherent in traditional written reports, especially in complex fisheries, and how web applications can overcome these limitations. We detail perceived challenges that have limited the use of web applications in science and management and how new developments can overcome these challenges.

[1] Performance metrics can be found online at https://www.st.nmfs.noaa.gov/economics/fisheries/commercial/catch-share-program/background-materials/indicators-definition/.

Economic Performance Metrics

The review of catch share programs is mandated by the Magnuson–Stevens Fishery Management and Conservation Act at §303A(c)(G) and through a NOAA Fisheries guidance document (Morrison 2017). Monitoring and evaluating the performance of catch share programs (and other significant management changes) is necessary to assess whether programs are meeting intended biological, economic, and social goals. One method is the use of standardized performance metrics. On their own, metrics such as number of workers, compensation rates, or number of vessels give specific information about particular trends. Taken together, they help portray a broader depiction of the overall performance of the economy. In fisheries, metrics facilitate the examination of changes occurring in the fishery, assess policy performance, motivate more in-depth research, and can help identify tipping points and thresholds (Link et al. 2017). For monitoring economic performance, Brinson and Thunberg (2013) outline several performance metrics that use data collected across management programs and provide a consistent and comparable means to assess program performance with respect to stated objectives. The metrics are intended to provide a basis for understanding changes that have occurred in terms of their effect on interactions with other fisheries and fishing sectors, and on vessel owners, quota share owners, vessel crew members, processing facilities and employees, and communities.

The metrics outlined in Brinson and Thunberg (2013) are broad, but not exhaustive. For complex fisheries that include multiple species, states, and sectors, or programs with provisions to address specific issues, additional metrics may be necessary to fully encompass the distribution of outcomes. For instance, the U.S. West Coast groundfish trawl catch share program comprises four sectors that catch and process U.S. West Coast groundfish: catcher vessels, motherships, catcher–processors, and shorebased processors. It is multispecies in nature, and spans the western coastline from Washington to California (Warlick et al. 2018). Participants in the program are also diverse. Participating vessels often differ considerably with respect to their operational and physical characteristics. To capture more of this complexity, six additional metrics were included in the five-year review of the U.S. West Coast groundfish trawl catch share program (PFMC and NMFS 2017) that are not included in Brinson and Thunberg (Table 1).

The metrics provide greater detail on the income diversification of vessels and how reliant participants are on the catch share fishery. In the U.S. West Coast groundfish trawl fishery, around 62% of vessels in any given year (2011–16) that fished in catch share fisheries also participated in fisheries outside of the catch share program. For the subset of vessels that fished in non-catch share fisheries, activities in non-catch share fisheries can represent a significant portion of revenue (54% of revenue, on average across years and vessels).[2] Metrics such as fishery participation and proportion of revenue from catch share fisheries help in understanding the overall impact of the catch share program and the reliance of fishery participants on the program.

[2] Results calculated using the Performance Metrics module of the Northwest Fishery Science Center's Fisheries Economics Explorer. Available: https://dataexplorer.northwestscience.fisheries.noaa.gov/fisheye/PerformanceMetrics/.

Table 1. Performance metrics that provide detail on the distribution of effort and revenue.

	Metric	Definition
Distribution of effort	Fishery participation or number of species processed	Number of fisheries that vessels participated in or the number of species processed by a processing entity. Changes may indicate specialization or diversification.
	Share of landings by state	Share of landings, in terms of revenue, in each state or at sea.
Distribution of fishery revenue	Exponential Shannon Index	Measures the income diversification of a vessel (processor) across revenue sources. A larger number corresponds to increased diversification. Changes may indicate specialization or diversification.
	Gini coefficient	Measures the degree of catch share revenue concentration among vessels (processors). The value of the Gini coefficient can be affected by fleet (industry) consolidation and specialization.
	Proportion of revenue or production value from catch share fishery	The proportion of a vessel's (processor's) total revenue that comes from fish caught (processed) in the catch share fishery. Measures how reliant vessels (processors) are on revenue from the catch shares fishery.
	Seasonality	The date (day of year, 1 January = 1) on which 50% of the total volume of catch was landed in the fishery. This metric measures broad-scale changes in the seasonality of fishing for catch share fish. It can also indicate changes in total allowable catch (TAC) or annual catch limit (ACL); it may take the fleet longer to catch a higher TAC/ACL.

Other metrics capture the spatial variation in the catch share program. The operational and physical characteristics of vessels can differ considerably between states. For instance, on average (2011–16), 85% of U.S. West Coast revenue came from catch share fisheries for vessels that reported homeports in Washington State, compared to 66% for Oregon and 59% for California (Figure 1). Even within a state, considerable differences may exist between homeports. In California, the average proportion of revenue from 2011–16 for vessels ranged between 29% and 70%, depending upon the homeport. Metrics such as share of landings by state and the ability to subset the data based on city or state in which vessels homeport help to understand the impact of, and reliance of local communities on, the catch share program. These metrics also allow individual council members and fishers to identify how their geographic region or sector has been impacted.

Reporting: Challenges and Solutions

Developing a narrative about the overall performance of a fishery and progress toward the economic and social goals of the fishery management plan requires interpreting multiple metrics together, adding to the complexity of reporting the metrics. This is further complicated when the fishery is complex, spanning multiple species, operations, and states, and when economic performance of participants may be affected by activities beyond the management program under review. For instance, taking into account all the ways to aggregate the U.S. West Coast groundfish trawl catch share performance metrics data (fishery, homeport, fished for or processed whiting, etc.) leads to 4,145 time-series results across the four sectors. Even if multiple time-series were plotted in the same figure, displaying each metric would result in an overly lengthy and burdensome report that would be difficult to interpret. Indeed, despite devoting roughly 200 pages of the U.S. West Coast groundfish trawl catch share program five-year review (PFMC and NMFS 2017) to economic metrics, the complete set of calculated metrics are not shown for all sectors, species targets, states, and communities. This is because there is insufficient space to encompass the complexity of the catch share program within a reasonable length.

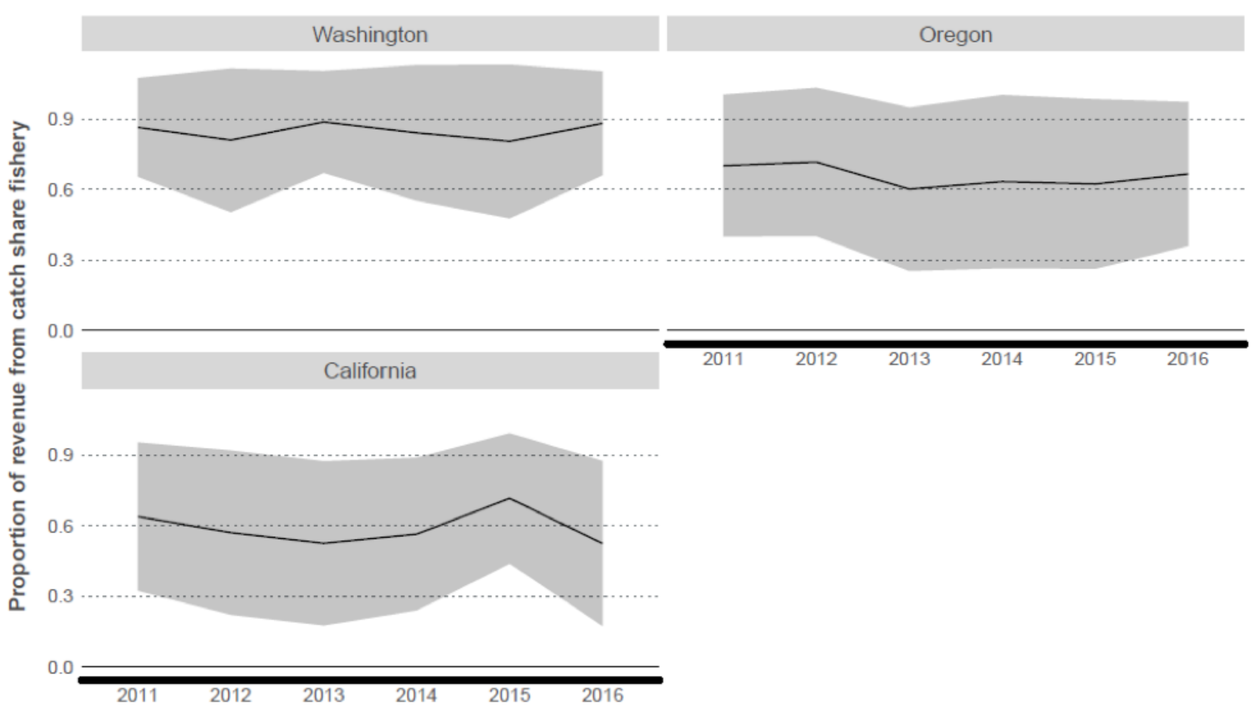

Figure 1. Mean (black line) and standard deviation (gray area) for the proportion of revenue from catch share fisheries for all catcher vessels that participated in the U.S. West Coast groundfish trawl catch share program. The proportion of revenue is the proportion of a vessel's total revenue that comes from fish caught in the catch share fishery divided by the total earnings from fishing off the coasts of Washington, Oregon, and California. Plot output from a query conducted on the FISHEyE Performance Metrics web application, https://dataexplorer.northwestscience.fisheries.noaa.gov/fisheye/PerformanceMetrics/.

The challenges associated with presenting results in the most accessible and usable format are inherent in all reports and fisheries. Even in single-species fisheries, results can vary based on multiple factors, such as homeport or vessel size. Data tables are an efficient means to present lots of similar data. However, detecting trends, correlations, and patterns is more challenging with data tables than with plotted data. Humans are predominantly visual (Few 2014), so providing data in a figure makes data more accessible and quicker to analyze and use for decision-making (McCandless 2010). Figures, however, require more space than tables to portray the same information, and can lead to reports that are difficult to navigate and utilize.

What other avenues of presenting results are available if a comprehensive report is ostensibly cumbersome to use? The first option is to limit the scope of the report—for instance, by showing results for the fishery, rather than species targets, or for the state of the homeport but not the individual homeports. However, aggregating or limiting the scope of the report may have unintended consequences. The report may not address all stakeholders' questions and needs. In addition, stakeholders may feel results are biased and do not reflect the reality of what fishers are experiencing, especially if analysis for their specific subgroup is not included in the report. The result is a feeling that the process is not fair or transparent. Although reasonable for many purposes, parsing and aggregating results may not be the best approach, especially if management decisions have been contentious.

An alternative option is interactive web applications. Web applications overcome the limitations inherent to written reports because space is not limited and reporting is user-driven. Because all metrics are available, web applications can support data-driven decision-making and comply with government mandates to publish information in searchable, open formats. In web applications, data can be shared while remaining compliant with any confidentiality restrictions on the data. Providing all results increases confidence in the unambiguousness of results. Users decide which results are shown and how, thereby transferring the choice of how to reduce the number of results to the users. In addition, users do not have to search the report to find results; they point and click for their own choices. A website is accessible to anyone with access to the internet and allows managers to look for results that they need to make decisions. Thus, web applications are a useful tool to store and display data, plot results, and provide explanatory text.

Interactive Web Applications

Web applications can serve multiple purposes. They can serve as a dynamic reporting tool for data exploration and sharing. They are a tool to share mathematical or statistical models. Web applications allow users to interact with models and results from computationally intensive data analyses. Web applications can be used for data analysis or for collaborating between disparately located groups. Finally, web applications can be used to collect data, can serve as a data warehouse, or can be designed as a survey-based data collection tool.

Numerous perceived challenges exist with designing and developing web applications. These challenges include not knowing web development languages, uncertainty on how to begin developing the web application, finding the time and resources to develop and maintain the page, and deciding how to deal with confidential data. We argue that developing and maintaining web applications is feasible for anyone with basic skills in programming languages such as R, SAS, or MATLAB, and that deploying a web application can be affordable.

The first hurdle for developing web applications is knowledge of CSS, HTML, and JavaScript. A few cloud-based tools have been developed to overcome this limitation. There are also extensions to programming languages such as R and SAS that allow you to use the programming language you know to build the web application. Options for SAS are outlined in Fan and Ushveridze (2008) and Faulkner and Sealy (2011). MATLAB users can use MATLAB App Designer. Tutorials have been written for building web applications in Python,[3] but require more knowledge of CSS, HTML, or JavaScript than is required for other programming languages. Stata[4] can be integrated with web applications (Zlotnik 2015) but, at the time this report was written, no tutorials or extensions existed to aid in web development. Currently, one of the simplest options, with the most tutorials and online help, is the Shiny package by RStudio (Chang et al. 2017, R Core Team 2017). The remainder of this paper focuses on building web applications using the Shiny package. Shiny has the additional advantage of being open-sourced.

The second hurdle is deciding the layout of the website. In Shiny, web applications are defined by two files, a user interface file, which defines the appearance of the web application, and a server file, which defines the functionality of the website and includes R code to analyze and plot the data. In Shiny, the CSS, HTML, or JavaScript code needed to determine the web application layout are wrapped in R functions and called in the user interface file. These functions allow users familiar with R to define the layout and functionality of the web application with short lines of code and without knowledge of web development languages. Analyses, figures, and tables developed in R can be integrated into the web application. This code is placed in the server file. The benefits of Shiny, and similar packages designed for other programming languages, also extend to maintenance of the web application, which should be considered if the web application is going to be active for an extended period. Because numerous tutorials and examples are available online,[5] we do not go into details of the Shiny package here.

[3] For one example of a tutorial, see: https://realpython.com/python-web-applications/.
[4] https://www.stata.com
[5] https://shiny.rstudio.com

The third hurdle is cost and time. The main costs associated with developing a web application are the developer and hosting the web application. The costs of employing a web developer may be significantly reduced by using packages such as Shiny because 1) no web developers are needed, and 2) time in meetings and coordinating work is reduced because an external web developer is not needed. The cost to host the web application is variable, depending upon needs.[6] Time requirements depend upon the complexity of the application needed and how much customization is desired. Simple web applications can be developed quickly if they use standard functions, have few user-defined inputs, and pull from a single flat file. Few applications are this simple, however, and adding complexity and customizing appearance will require more time. Tutorials and examples are available online.

Customizing the web application involves embedding HTML, CSS, or JavaScript code into the Shiny functions. Adding HTML tags is useful to customize part of the web application, such as adding hyperlinks or changing font color. CSS is used to make aesthetic changes across the web application, rather than a single point or section of the web application. JavaScript operations in Shiny apps include error or warning messages, hiding an element, and delaying code execution for a few seconds. The *shinyjs* package is a good starting point for adding JavaScript operations without learning JavaScript (Atalli 2018).

The final major hurdle is how to handle data. Economic and social science data used in performance metrics are generally subject to confidentiality rules. Section 402(b) of the Magnuson–Stevens Act provides that the "Secretary shall, by regulation, prescribe such procedures as may be necessary to preserve the confidentiality of information submitted in compliance with any requirements or regulations under this Act…." In written reports and web applications, confidentiality rules, such as minimum sample size, must be applied to every result reported. Developers must consider all potential means by which confidential data could be derived from reported metrics. For instance, consider the situation in which there are five vessels in the fishery, four of which fish exclusively in the managed fishery and one which fishes in both managed and nonmanaged fisheries. If total revenue is reported for the five vessels and then for only the four vessels that participate solely in the managed fishery, the revenue of the vessel that participates in the nonmanaged fishery could be derived by subtracting the two total revenue values. In this case, confidential data could be derived. In written reports, confidentiality rules are applied only to results presented. This creates a vulnerability because all written reports must be checked against each other to ensure that confidential data cannot be derived. With web applications, all possible conflicts are assessed prior to publishing so that confidential data cannot be derived with subsequent analysis. The code to check for ensuring that confidential data cannot be derived is included in the code to generate the data. This ensures that every time the data are updated or new parameters are added, confidentiality requirements are checked.

[6] https://www.rstudio.com/pricing3/#Comparison

Another data concern is security. Server and database security are beyond the scope of this article, but a few guiding principles can assist decision-making about whether confidential data can be stored on a public server. Loading data that have not yet been subject to confidentiality rules onto a server requires ensuring that the server is secure and that the code to process the data is not subject to hacking. Web application vulnerabilities can be exploited by attackers inserting malicious codes (injection flaws) that can obtain, corrupt, or destroy database contents (Owasp Foundation 2017). If the server is secure and code is checked for potential code injections, then preaggregated data could be housed on the server. Analyses, data aggregation, and confidentiality checks would then be done on the server, in R or another programming language, after a request is made on the web application. The other option is to load postaggregated data on the server. In this option, all analyses, aggregations, and confidentiality checks are done on the local computer, and only a table of results that can be subset is loaded on the server (Table 2). The second approach is more conservative; if the web application is hacked, no confidential data can be obtained. It is also easier to check for the potential ability to derive confidential data. However, the approach requires more time in development. Ease of maintenance may also be a factor in the choice between pre- and postaggregated data, regardless of the web tool's implementation framework (Shiny or otherwise). Updating a preaggregated data set is often simpler than updating a postaggregated dataset, especially when extensive quality control measures are required.

Table 2. Example of data held in the Northwest Fisheries Science Center's Fisheries Economics Explorer (FISHEyE). FISHEyE subsets the data table based on user selections and displays the output. Key: *ESI* = Exponential Shannon Index, *CSF* = catch share fisheries, *W* = whiting vessels, *NW* = nonwhiting vessels.

Metric	**Variable**	**Year**	**Statistic**	**Category**	**Vessels**	**Value**	**Variance**	***n***
ESI	All CSF	2009	Median	Fisheries	W	1.8	0.3	41
ESI	All CSF	2009	Total	Fisheries	W	74.3	—	41
ESI	All non-CSF	2009	Median	Fisheries	NW	1.3	0.4	93
ESI	All non-CSF	2009	Total	Fisheries	NW	127.8	—	93
Revenue	All CSF	2009	Median per vessel	Fisheries	W	503835.6	188406.5	41

FISHEyE

Interactive data visualization tools are most compelling when they address specific scientific questions with dedicated analysis. The Fisheries Economics Explorer (FISHEyE) is an interactive tool developed for the exploration of the economic effects of the U.S. West Coast groundfish trawl catch share program on participants and regional economies. The tool consists of three applications: the net revenue explorer, the performance metrics explorer, and the costs explorer. These applications were designed with specific management applications in mind: managers had a set of questions related to the economic outcomes after this significant change in management institutions, and the three applications provided information to address these questions along requested dimensions of data disaggregation. FISHEyE serves as a case study of issues, statistical considerations, and web-design factors that arose and were considered during development.

Economic data collected as part of the U.S. West Coast groundfish trawl catch share program can be viewed, downloaded, and explored using the NWFSC's FISHEyE web application (Figure 2). The web application was built using the Shiny package and RStudio, with the goals of 1) engaging fishery managers, scientists, the public, and key stakeholders, 2) making research accessible to a wider audience, 3) allowing users to quickly answer policy and research questions, and 4) allowing researchers at NWFSC to provide timely analysis to current policy questions. Based on feedback received through a variety of interactions with the Pacific Fishery Management Council and advisory bodies, FISHEyE has achieved each of these objectives along with increasing transparency and trust.

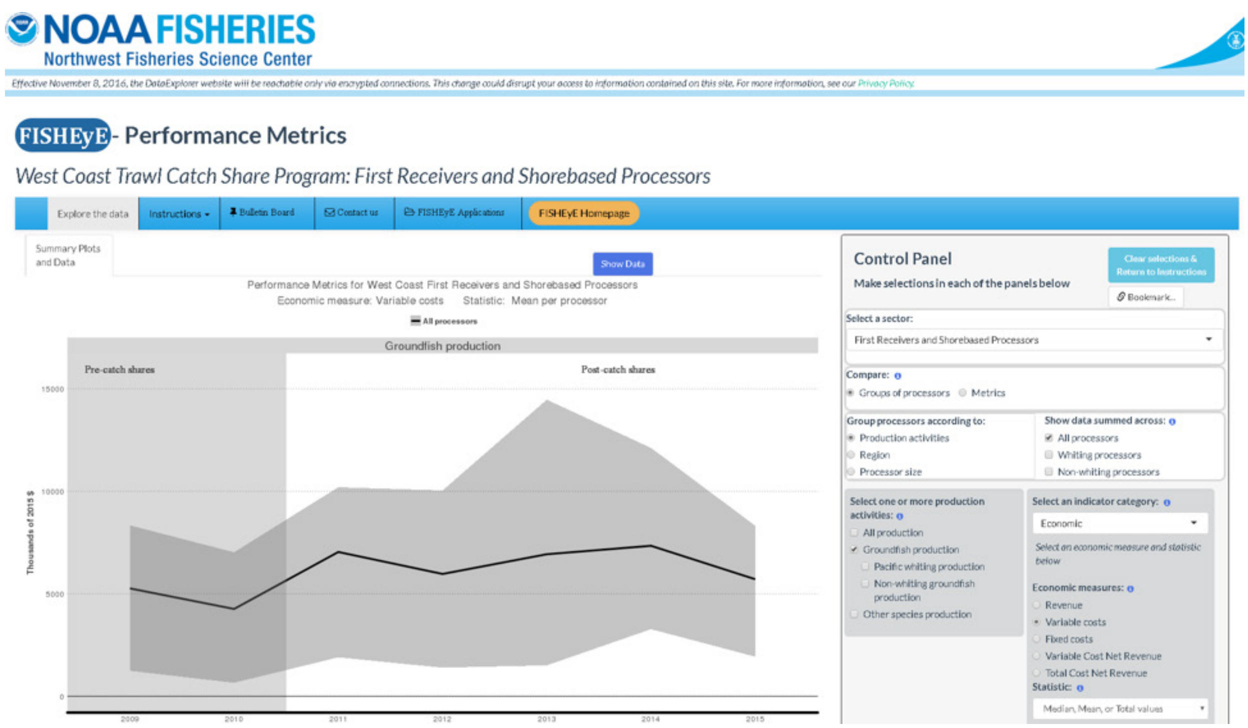

Figure 2. Plot output from a query conducted on the FISHEyE Performance Metrics web application. Visit https://dataexplorer.northwestscience.fisheries.noaa.gov/fisheye/.

Generating a web application removes the necessity of selecting which figures and results to share. Data can be summarized along several variables: target fishery group or production activity, vessel or processor size, homeport, and state of homeport or region. In addition to selecting which variables to display, users select the metric of interest, whether to display average, median, or fleetwide values, and whether to split the data by participation in the whiting fishery, which is a high-volume fishery with the potential to overwhelm other results (Figure 3). This helps to ensure that stakeholders can find the results they need. Results are displayed on the web application as plots or tables, and can be downloaded in either format (Figure 2). Further, the web application allows users to download the summarized data, thereby reducing burden on staff to fulfill data requests.

When developing a web application, it is important to keep the user in mind: How will the user interact with the site and find necessary information? Can data and plots be saved? (See Table 3). The users of FISHEyE were expected to be diverse in age, education, and experience. As such, the site was designed to be easily navigated by scientists, fishery council members, staff of nongovernmental organizations, and fishery participants alike. We kept this broad group of potential users in mind when designing FISHEyE, and made the web application so that it guides users through selections, engages users through dynamic and colorful plots, and is as simple as possible. Users make selections using the dynamic Control Panel on the right of the web application (Figure 3). Making the control panel dynamic and ordering the selections guides the user through the process of deciding which results to show.

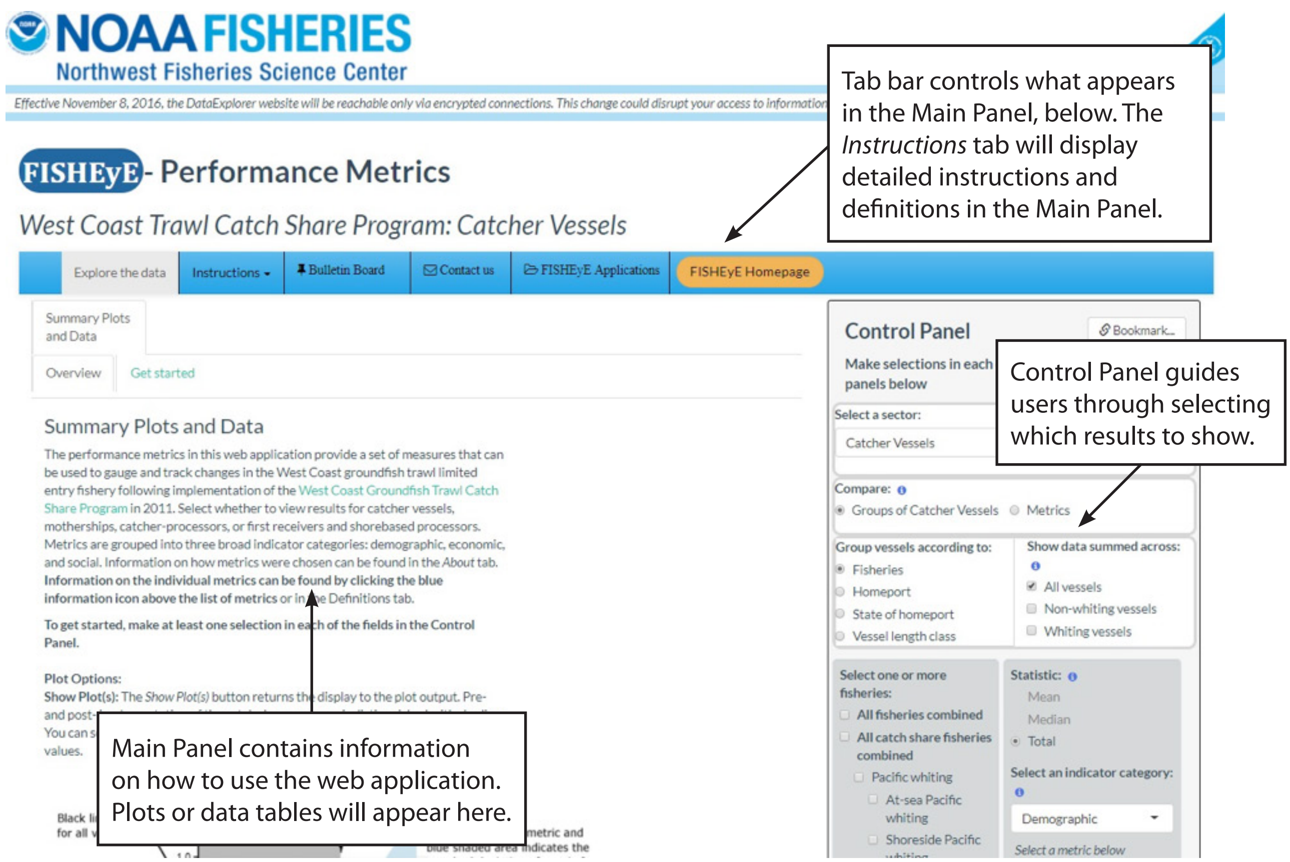

Figure 3. FISHEyE Performance Metrics landing page. Arrows indicate key components of the web application. Visit https://dataexplorer.northwestscience.fisheries.noaa.gov/fisheye/.

Table 3. Web application attributes and best practices.

Attributes	Best practices
Designed for the user	Easy to navigate. Dynamic and colorful. Visuals lack complexity. Minimally processed.
Downloadable	Button to download data or figures provided.
Informative	Information and instructions provided at multiple locations. Contact link provided.
Interactive	User selections and subsequent output developed with end user in mind. Fast response times.* Simple data processing and analysis.

* Studies have shown that users respond negatively to slow websites, including decreased further engagement and return visits.

An important aspect of many web applications is the display of data and results. Plots and tables can be developed in R using any method (base package, ggplot, etc.) and then displayed on the web application with a call to the Shiny function to render the plot. In web applications, plotting figures is dynamic. Users can decide which parameters are plotted and how much complexity is included, such as which performance metrics are displayed. Users can also choose the perspective. For instance, are users interested in the ex-vessel revenue earned from fishing a specific species, or are they interested in the ex-vessel revenue from fishing this species relative to the entire fishery? When developing the code to plot figures, it is also important to consider the end output. If plots are to be downloaded, choose colors that work well when printed in color or black-and-white. Always consider color blindness. Ultimately, the goal is to build plots that are unambiguous and allow the users to easily and accurately interpret the results.

A final consideration is statistics. The appropriate statistics to display will depend upon the data and the objectives of the web application. FISHEyE is primarily a data exploration tool and, therefore, focuses on summary statistics: totals, means, and medians. The choice between summary statistics is important and depends upon the metric and the data. For instance, one may want to know about the economic performance (i.e., revenue) of the fleet as a whole (total) or of a representative vessel (median or mean). In other cases, it may not be appropriate to display results for all summary statistics. For example, the Gini coefficient is an index, so a median and mean value could not be provided. Similarly, in the performance metrics modules of FISHEyE, total vessel length across the fleet was not informative, and is not an available choice. The data in FISHEyE are highly variable and often skewed. If the data are variable and skewed in a particular direction (Figure 4A), which is common in economic and social data, then the median may be a better representation of a typical vessel than the mean. If the data are not heavily skewed, then the median and mean should be similar, and either statistical measure would be useful. Adding measures of variances such as quartiles (for median) and standard deviation (for mean) aids in understanding the distribution of the data.

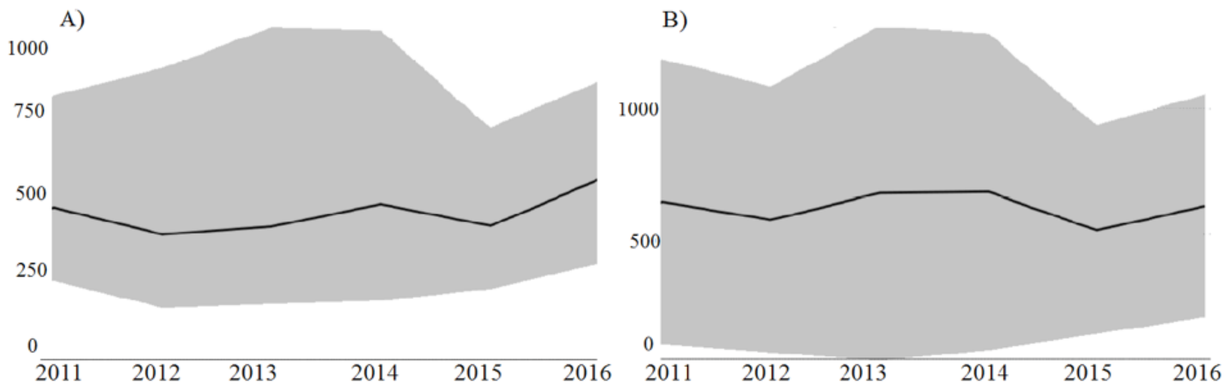

Figure 4. Ex-vessel revenue for catcher vessels from all activities in the U.S. West Coast groundfish trawl catch share fishery from 2011–16. Solid line and dark shaded area around the line are the (A) median and 25th and 75th percentiles and (B) mean and one standard deviation.

FISHEyE provides numerous avenues to find information on the U.S. West Coast groundfish trawl catch share program, and the features and functionality of the web application. When the web application first opens, the most essential information for understanding how to use the tool is shown (Figure 3). This information disappears when selections are made in the control panel, but can be downloaded. Information on the individual choices in the control panel is available by clicking on information icons next to the selection titles. Tabs at the top of the web application allow users to find more information on how to use the web application and more information about each of the choices in the control panel. Finally, many options exist for how to send feedback or ask questions. The simplest choice is to provide an email address.

Conclusions

Informed and appropriate performance measures are important for monitoring and evaluating fisheries management plans. Selected metrics should reflect the complexity of the fishery and, if appropriate, community-level statistics and revenue, along with reliance on fisheries. As shown through the U.S. West Coast groundfish trawl catch share program, interactive web applications provide a transparent and fun way to engage and meet a wide variety of stakeholder needs. Web applications are user-driven, which improves NWFSC's ability to address the questions and concerns of stakeholders. They also allow the addition of new metrics or different aggregations of data as new questions come up, and meet both confidentiality rules and requirements to make data publicly available. Interactive data visualization tools such as FISHEyE are most powerful when coupled with dedicated analysis of specific management questions. Although there are many perceived challenges to this reporting format, development of new tools and packages, such as the Shiny package by RStudio, has made development of web applications feasible for anyone with basic programming knowledge.

References

Anderson, J. L., C. M. Anderson, J. Chu, J. Meredith, F. Asche, G. Sylvia, M. D. Smith, D. Anggraeni, R. Arthur, A. Guttormsen, J. K. McCluney, T. Ward, W. Akpalu, H. Eggert, J. Flores, M. A. Freeman, D. S. Holland, G. Knapp, M. Kobayashi, S. Larkin, K. MacLauchlin, K. Schnier, M. Soboil, S. Tveteras, H. Uchida, and D. Valderrama. 2015. The Fishery Performance Indicators: A Management Tool for Triple Bottom Line Outcomes. PLoS ONE 10(5):e0122809. DOI: 10.1371/journal.pone.0122809

Attali, D. 2018. shinyjs: Easily improve the user experience of your Shiny apps in seconds. Available: deanattali.com/shinyjs. (September 2018).

Bonzon, K., K. McIlwain, C. K. Strauss, and T. Van Leuvan. 2013. Catch Share Design Manual, volume 1: A Guide for Managers and Fishermen, 2nd edition. Environmental Defense Fund, New York.

Brinson, A. A., and E. M. Thunberg. 2013. The Economic Performance of U.S. Catch Share Programs. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-133a.

Chang, W., J. Cheng, J. J. Allaire, Y. Xie, and J. McPherson. 2017. shiny: Web Application Framework for R. R package version 1.0.5. Available: CRAN.R-project.org/package=shiny. (September 2018).

Cochrane, K. L., editor. 2002. A Fishery Manager's Guidebook – Management Measures and Their Application. Food and Agriculture Organization of the United Nations, Rome. Fisheries Technical Paper 424.

Fan, C., and A. Ushveridze. 2008. Creating interactive web-based reports with SAS®. SAS Global Forum 2008 Paper 266-2008. SAS Institute Inc., Cary, North Carolina.

Faulkner, B. and Sealy, V. 2011. Creating Custom Web Applications with SAS® 9.3 Stored Processes Using SAS® AppDev Studio™. SAS Global Forum 2011 Paper 013-2011. SAS Institute Inc., Cary, North Carolina.

Few, S. 2014. Why Do We Visualize Quantitative Data? Available: www.perceptualedge.com/blog/?p=1897.

Link, J. S., O. Thébaud, D. C. Smith, A. D. M. Smith, J. Schmidt, J. Rice, J. J. Poos, C. Pita, D. Lipton, M. Kraan, S. Frusher, L. Doyen, A. Cudennec, K. Criddle, and D. Bailly. 2017. Keeping Humans in the Ecosystem. ICES Journal of Marine Science 74(7):1947–1956. DOI: 10.1093/icesjms/fsx130

McCandless, D. 2010. The beauty of data visualization. Available: www.ted.com/talks/david_mccandless_the_beauty_of_data_visualization. (September 2018).

Morrison, W. 2017. Catch Share Policy. U.S. Department of Commerce, National Marine Fisheries Service Policy Directive 01-121. Available: www.fisheries.noaa.gov/national/laws-and-policies/fisheries-management-policy-directives. (September 2018).

Owasp Foundation. 2017. OWASP Top 10 – 2017: The Ten Most Critical Web Application Security Risks. Available: www.owasp.org/images/7/72/OWASP_Top_10-2017_%28en%29.pdf.pdf. (September 2018).

PFMC and NMFS (Pacific Fishery Management Council and National Marine Fisheries Service). 2017. West Coast Groundfish Trawl Catch Share Program: Five-year Review. Approved by the Pacific Fishery Management Council, 16 November 2017, Costa Mesa, California.

R Core Team. 2017. The R Project for Statistical Computing. R Foundation for Statistical Computing, Vienna. Available: www.R-project.org. (September 2018).

Warlick, A., E. Steiner, and M. Guldin. 2018. History of the West Coast groundfish trawl fishery: Tracking socioeconomic characteristics across different management policies in a multispecies fishery. Marine Policy 93:9–21. DOI: 10.1016/j.marpol.2018.03.014

Zlotnik, A. 2015. Stata for internet applications: a web interface for Stata user-written commands. United Kingdom Stata User's Group Meetings 2015: 16. Available: ideas.repec.org/p/boc/usug15/16.html. (September 2018).

Recently published by the Northwest Fisheries Science Center

NOAA Technical Memorandum NMFS-NWFSC-

142 **Jannot, J. E., T. Good, V. Tuttle, A. M. Eich, and S. Fitzgerald, editors. 2018.** U.S. West Coast and Alaska Trawl Fisheries Seabird Cable Strike Mitigation Workshop, November 2017: Summary Report. U.S. Department of Commerce, NOAA Technical Memorandum NMFSNWFSC-142. NTIS number PB2018-101082. https://doi.org/10.7289/V5/TM-NWFSC-142

141 **McClure, M., J. Anderson, G. Pess, T. Cooney, R. Carmichael, C. Baldwin, J. Hesse, L. Weitkamp, D. Holzer, M. Sheer, and S. Lindley. 2018.** Anadromous Salmonid Reintroductions: General Planning Principles for Long-Term Viability and Recovery. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-141. NTIS number PB2018-101081. https://doi.org/10.7289/V5/TM-NWFSC-141

140 **Buhle, E. R., M. D. Scheuerell, T. D. Cooney, M. J. Ford, R. W. Zabel, and J. T. Thorson. 2018.** Using Integrated Population Models to Evaluate Fishery and Environmental Impacts on Pacific Salmon Viability. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-140. NTIS number PB2018-101080. https://doi.org/10.7289/V5/TM-NWFSC-140

139 **Harvey, C., N. Garfield, G. Williams, K. Andrews, C. Barceló, K. Barnas, S. Bograd, R. Brodeur, B. Burke, J. Cope, L. deWitt, J. Field, J. Fisher, C. Greene, T. Good, E. Hazen, D. Holland, M. Jacox, S. Kasperski, S. Kim, A. Leising, S. Melin, C. Morgan, S. Munsch, K. Norman, W. T. Peterson, M. Poe, J. Samhouri, I. Schroeder, W. Sydeman, J. Thayer, A. Thompson, N. Tolimieri, A. Varney, B. Wells, T. Williams, and J. Zamon. 2017.** Ecosystem Status Report of the California Current for 2017: A Summary of Ecosystem Indicators Compiled by the California Current Integrated Ecosystem Assessment Team (CCIEA). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-139. NTIS number PB2018-100477. https://doi.org/10.7289/V5/TM-NWFSC-139

138 **Kamikawa, D. J. 2017.** Survey Fishes: An Illustrated List of the Fishes Captured during the Northwest Fisheries Science Center's Fishery Resource Analysis and Monitoring Division's West Coast Surveys. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-138. NTIS number PB2018-100308. https://doi.org/10.7289/V5/TM-NWFSC-138

137 **Beechie, T. J., O. Stefankiv, B. Timpane-Padgham, J. E. Hall, G. R. Pess, M. Rowse, M. Liermann, K. Fresh, and M. J. Ford. 2017.** Monitoring Salmon Habitat Status and Trends in Puget Sound: Development of Sample Designs, Monitoring Metrics, and Sampling Protocols for Large River, Floodplain, Delta, and Nearshore Environments. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-137. NTIS number PB2017-102556. https://doi.org/10.7289/V5/TM-NWFSC-137

136 **Keller, A. A., J. R. Wallace, and R. D. Methot. 2017.** The Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey: History, Design, and Description. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-136. NTIS number PB2017-101432. https://doi.org/10.7289/V5/TM-NWFSC-136

135 **Mongillo, T. M., G. M. Ylitalo, L. D. Rhodes, S. M. O'Neill, D. P. Noren, and M. B. Hanson. 2016.** Exposure to a Mixture of Toxic Chemicals: Implications for the Health of Endangered Southern Resident Killer Whales. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-135. NTIS number PB2017-101431. https://doi.org/10.7289/V5/TM-NWFSC-135

NOAA Technical Memorandums NMFS-NWFSC are available at the Northwest Fisheries Science Center website, https://www.nwfsc.noaa.gov/index.cfm.