Improving the Usability and Effectiveness of FishPath, a Web-Based Decision Support Tool for Data-Limited Fisheries Management

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A thesis

Submitted in partial fulfillment of the

Requirements for the degree of

Master of Marine Affairs

University of Washington

2017

Committee:

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Program Authorized to Offer Degree:

School of Marine and Environmental Affairs

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Abstract

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FishPath is a recently created, web-based, decision support tool for data-limited fishery managers. Throughout 2016-17, it has been beta tested at workshops around the world. Feedback from these workshops has expressed the view that while the content of FishPath is good, users have routinely expressed frustration at the lack of usability and difficulty of synthesizing the results into decision support. This project designed and developed software features for FishPath that will address these concerns. The new features allow for user interaction with the results in order to perform and document the decision making process within FishPath itself. To facilitate easier dissemination of results, a reporting function has also been added. This includes two summary report formats, as well as provides a framework within the software for the creation of additional reports.

Chapter 1: Introduction

Status of Data-Limited Fisheries Around the World

Data-limited fisheries are of great importance around the world. Over 50% of fish caught globally come from unassessed fisheries(Costello et al., 2016). Small scale fisheries, which employ >95% of people in the industry and 90% of which occur in developing countries (FAO, 2007), also tend to be data-limited (Worm et al., 2009). These smaller stocks can be of high importance for biodiversity and food security (Costello et al., 2012).

For the purposes of this paper, the meaning of data-limited extends beyond just having a dearth of data. This follows the paradigm used by FishPath (Dowling et al., 2016). Data-limited fisheries also refers to fisheries management systems that are limited in their capacity or ability to implement harvest strategies in some form (Orensanz et al., 2005, Dowling et al., 2016). Therefore, by definition, the number of fisheries considered data-limited will actually be greater than the number of unassessed fisheries. For example, a fishery might have all the needed data to perform a harvest control rule, however if the capacity to enforce the control rule does not exist, then this fishery would be considered data-limited in this context.

Data-limited fisheries are more often trending towards collapse when compared to assessed fisheries, which in general have started to return towards sustainable levels (Costello et al., 2012, Worm and Branch, 2012). Almost two-thirds of unassessed stocks would have an increased harvest if they were managed at sustainable levels (Costello et al., 2012). Worm and Branch (2012) suggest that there is an "urgent need to direct priorities towards 'fisheries-conservation hotspots' of increasing exploitation rates, high biodiversity, and poor management

capacity, and conclude that the future of fish depends, at least in part, on redoubling science, co-management and conservation efforts in those regions" (p.1).

There have been numerous documented cases of successfully managing data-limited fisheries (Gutiérrez et al., 2011, McClanahan et al., 2009). However, these typically occur at a local scale, through solutions that have been created or tailored for the particular situation, and through bottom-up community driven approaches (Worm and Branch 2012). Unfortunately, the lack of data or management capacity often results in management action being delayed until the fishery is already collapsing (McClanahan et al., 2009, Worm et al., 2009, Dowling et al., 2016).

Overview of FishPath

There has been an increasing number of management approaches being designed for data limited fisheries (Dowling et al., 2016). The number, complexity and some general guidelines for choosing between approaches have been outlined in Dowling et al. (2014 a,b) and Fujita et al. (2014). However, deciphering among choices of approaches and selecting harvest strategies for the characteristics of a unique fishery or fisheries remains challenging. This is especially so when considering that these fisheries management systems are often capacity-limited by definition and might not have access to highly-trained fishery scientists to help interpret and compare approaches.

FishPath is a web-based tool designed to aid managers and stakeholders in this process of choosing harvest strategy components most relevant to a particular fishery or fisheries. FishPath is "an interactive, process-oriented software tool that guides users through the selection of appropriate techniques and tools for assessing and managing data- and capacity-limited fisheries" (Dowling et al., 2016). FishPath uses a web based questionnaire to collect information

on the following five categories to define the fishery characteristics: i) data availability, ii) stock life history attributes, iii) fishery operation characteristics, iv) socioeconomic characteristics and v) governance context (Dowling et al., 2016). The tool compares the answers of the questionnaire against all the possible management "options" for the harvest strategy components (monitoring, assessment and harvest control rules) that are contained within FishPath. Using the answers to the questionnaire, FishPath determines if each option can be used for that fishery. It also lists any reasons why an option would work well and any warnings to know about when using the option in the context of this particular fishery. These are called "caveats" in FishPath. For example, if users answer a question stating that a species cannot be sexed without causing the death of the animal, then any sex-based management option would have a caveat, or strong warning, associated with it stating that it will not be effective.

After completing the questionnaire, users are presented with these results. FishPath displays a list for each harvest strategy component that contains all options with their associated caveats (Figure 1). Users use this information to shorten the list of all possible options to a subset most suitable for management objectives. The ultimate objective of the FishPath process is to determine this subset so that these options can then be subjected to more formal evaluations. An in depth discussion about how the FishPath was created and the underlying mechanisms for how the answers of the questionnaire are used to determine the results can be found in Dowling et al. 2016.

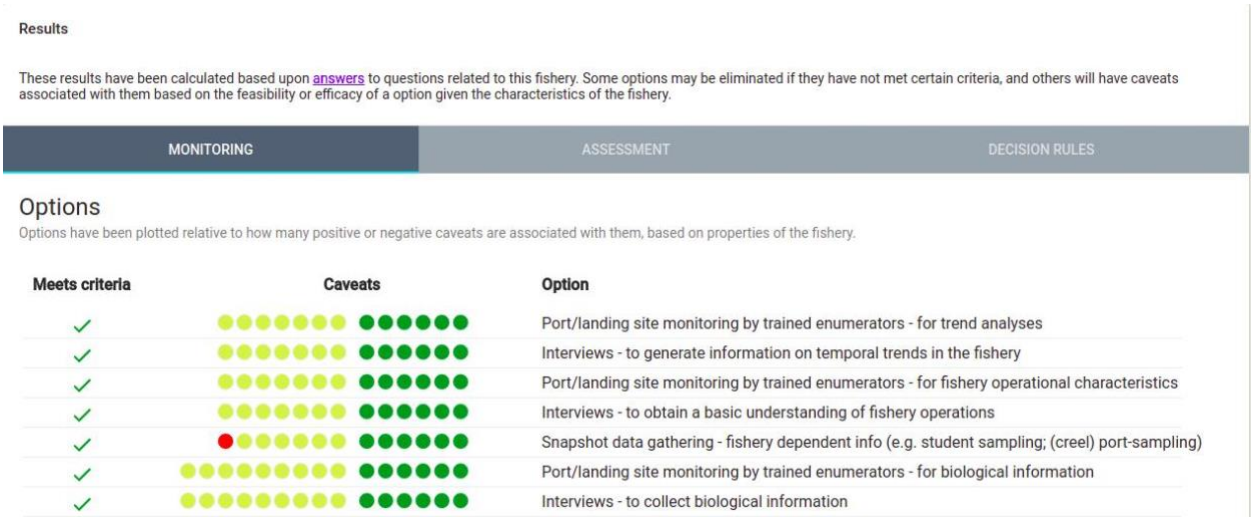

Figure 1. Partial results list for the original FishPath. Caveats are displayed as circles with a color representing the severity of the warning (yellow, orange, or red) or a desirable characteristic (green). Details about the option and its caveats can be accessed by clicking on an option (Figure 3). Users can toggle between the lists for each harvest strategy component by clicking on the component in the list across the top.

Currently, FishPath is primarily used in a workshop setting. A group of FishPath experts will walk through the process to use FishPath with managers and scientists that know the fishery (Dowling et al., 2016). The FishPath experts work with the stakeholders to answer the questionnaire. Then the experts guide the managers and scientists through the process of narrowing down the results to the list subset of most suitable options. This process is described in Chapter 2.

Chapter 2: Need for Improvements to FishPath

Limitations of FishPath

The FishPath tool is a major first step in providing support for managers looking to understand available options and begin or improve the management of their data-limited fisheries. However, feedback from the guided workshops around the world has made it clear that,

in its original form, FishPath needed specific improvements to improve the user experience. The main concerns focus around users' ability to explore the copious results (Figure 1), narrow the results to desired options, and disseminate the information (FishPath Core Team, personal communication, March 1, 2017). This was common feedback given at workshops in Jamaica, Mexico, Bahamas, Australia and elsewhere (FishPath Core Team, personal communication, March 1, 2017).

The concern about the results fell into two categories. First, users need guidance on how to narrow the outputted results. There are at least 40 options available for each harvest strategy component which means there is a lot of information through which to sort. To ease this burden, N. Dowling (CSIRO) has created a fifteen step process (Table 1) to narrow the results of FishPath (N. Dowling, personal communication, June 15, 2017). This provides formal guidance for users to narrow the results to the best options for each component.

Table 1. The steps of a process designed by Dowling to guide users through the narrowing process of the FishPath results (N. Dowling, personal communication, June 15, 2017).

Step	**Action**
1	Discard illegal options
2	Discard obviously bad options
3	Analyze the caveats for remaining options; if a caveat cannot be overcome, then discard; if it can, then list how and remove caveat
4	Reinstate options inappropriately flagged by FishPath
5	Broadly compare remaining options; highlight standouts
6	For assessment component: if caveats are similar, favor more rigorous, data-rich options
7	For monitoring component: if caveats similar, favor more comprehensive data collection

8	Identify other standout options that are either consistent with current practice or previously identified as possible before FishPath results
9	Analyze remaining caveats in detail to broadly weight options (not a formal analysis); explicitly note how each caveat would be overcome
10	Alternate to 9: give qualitative difficulty to overcome score to each caveat, then sum scores to give each option an overall score that can be used to compare remaining options
11	For each remaining option, identify key limiters such as cost, capacity, time, long-term feasibility
12	Consider cost-benefit interactions for options across components (e.g.: Does an investment in a monitoring option provide a large benefit in assessment?)
13	If still a large number of options: create a subset of options with representatives from the range of remaining options (i.e. from low cost/capacity to sophisticated/robust)
14	Based on above, identify the top 3-5 options for each component
15	Begin process of formal evaluation of top options

This leads to the second category. There is no way to interact with the results in the current version of FishPath such as being able to rearrange the order of the options. Whether using the fifteen steps or another prioritization method, the users had to export the results to a spreadsheet (using a comma-separated values (CSV) file generated by FishPath) in order to interact with the results (Figure 2). The spreadsheet only contained a list of the options with an overview of the information for each option. This overview information consisted of whether the option was eliminated and the number of each color of caveat. It did not contain any of the detailed information about the option or what the associated caveats were. This would force the users to continually reference the FishPath application while making changes to the spreadsheet. Besides being a possible point of frustration, it also increases the chance of errors. When deciding on what actions to take for an option, users would have to find the option of interest in FishPath to explore its details. As many of the option titles are similar, the users needed to use

caution to make sure that the option details they were viewing corresponded to the option they were editing in the spreadsheet. If looking at the incorrect option in FishPath, then this could result in the users making management decisions based on incorrect information. Since edits to the spreadsheet obviously would not update the results page in FishPath, the more edits that were made to the spreadsheet, the more this became a problem. Feedback from the workshops has made it apparent that there needs to be better mechanisms for working with the results of FishPath.

	A	B	C	D	E	F	G	H	I
1	Section	Category	Option	Eliminated	# red caveats	# orange caveats	# yellow caveats	# grey caveats	# green caveats
2	Monitoring	Fishery (basic understanding of how fi	Market surveys - for fishery operational chara	FALSE	0	0	4	0	3
3	Monitoring	Sustainability (trend analysis) - e.g. m	Market surveys - for trend analyses	FALSE	0	0	4	0	3
4	Monitoring	Biological information - leads to analy	Market surveys - for biological information	FALSE	0	0	6	0	3
5	Monitoring	Reference points/stock status	Market surveys - for reference points/stock st	FALSE	0	2	3	0	3
6	Monitoring	Fishery (basic understanding of how fi	Port/landing site monitoring by trained enume	FALSE	0	0	7	0	6

Figure 2. Example of the first few lines of the CSV export.

Another frustration highlighted, is the cumbersome nature of accessing the information about each option during the decision making process. Each option has a detail view that opens when clicked upon (Figure 3), but there is no way to search the options based on keywords, caveats or any other method. This makes it time consuming and frustrating to make broad decisions based on criteria. For example, if the fishery is open access and that in unlikely to change, then the decision makers might decide to remove any option that has negative caveats due to being an open access fishery. Currently, users must open each option and search through the caveat list to determine if there is one associated with open access. Users are also not able to have the information screen of two options open at the same time. When comparing options, users must flip between the two information screens of those options. Because the results screen is static, these options might be far away from each other in the list and as before, it is not always easy to distinguish between the options.

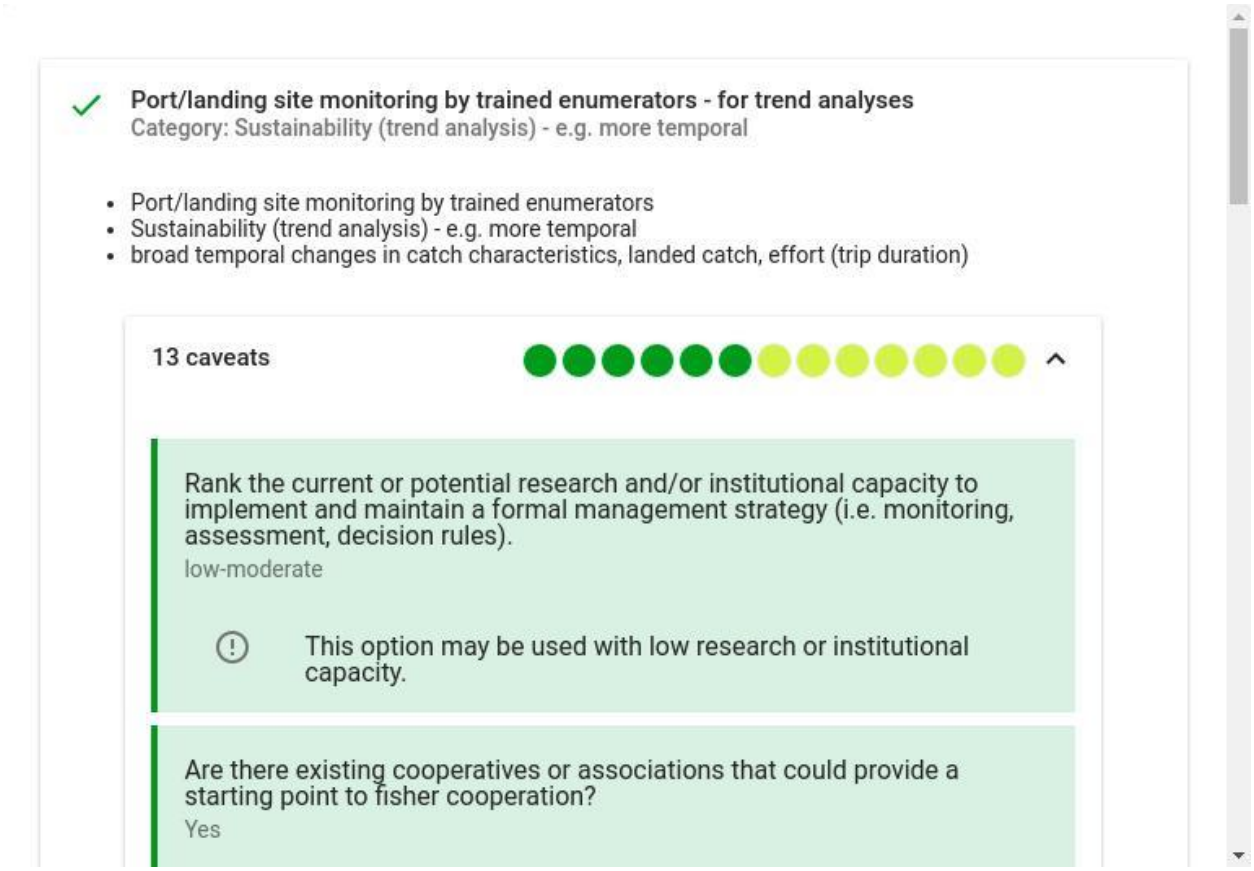

Figure 3. The beginning of the option detail view. It displays more detailed information about the option that is contained within FishPath, followed by information about each caveat.

Finally, the current iteration of FishPath does not have any reporting tools or other ways to disseminate the results beyond the export to a CSV file discussed above. During the Jamaica workshop in February 2017, users expressed a desire to be able to generate reports of their results (FishPath Core Team, personal communication, March 1, 2017). They stated that it would have been useful to bring a report of their end results to the government in order to help fundraise for improved management. FishPath should have a way to be able to report the final results so that they may be disseminated or used in the next step of decision making, in addition to writing reports directly from FishPath output.

Chapter 3: Design Rationale for Features Included in Project

The objective of this thesis project is to design and develop new software features that will address some of these limitations. This chapter focuses on the design process that was used to determine what features would be most effective in addressing the limitations. First is a discussion of possible ways that are available to narrow the results. That is followed with a discussion of why there is a need for a note taking feature. Finally, the design for a reporting tool will be discussed. The following chapter will walk through how these newly designed features were incorporated into FishPath.

Narrowing the Results

The main area that needed improvement is the ability to interact directly with the results within FishPath itself. The fifteen steps (Table 1) created by Dowling was a workable solution into the problem of needing a formalized methodology to narrow the results. Therefore, the focus of this project was on improving the functionality of the tool itself. The fifteen steps listed above were used as the starting point for designing what form the needed software functionality would take on.

For each step, it was determined what would be needed within the software for that step to be performed within FishPath (Table 2). It is important to note, that any new features needed to fit seamlessly into the current program and work within the existing codebase. The new tools should be easily accessible and intuitive and should integrate into the current workflow.

Table 2. Software tools or features required for the completion of a given step.

General Software Feature/Operation	**Which of Dowling's 15 Steps Useful For:**
Manually remove or hide an option from the list of potential options	1, 2, 3, 5, 13, 14
Remove or change the severity of a caveat	3
Change the "Meets Criteria" Flag	4
Rearrange the order of the options	5, 6, 7, 8
Label or allow sort by rigor level for assessment options	7
Label or allow sort by comprehensive level for monitoring options	8
Tool to compare options based on caveats; e.g. allow blind weighting of caveats and then apply weights to all options to calculate overall scores	9, 10
Tag options with key words/phrases	All
Note/comments associated with each option	All
Generate reports	14, 15
Tool that highlights possible synergistic relationships	12
Search options by caveat	3, 4, 5, 9, 10, 11

The next step was to determine how to guide users through the process of narrowing the results. One way this could be done is through a structured process such as through the creation of a software wizard. The wizard would be similar to software installation tools that guide users to complete one step at a time in a very organized and rigid fashion. Users must complete the action on the current screen before moving to the next screen. The advantages of this method are that it would be easy for users to follow and users would be guided through the process. The

disadvantage is that it is very structured, limiting flexibility of the process. This also means that the wizard would need to be updated anytime there was a change in the process.

Another option would be to provide the users with all the software features needed to perform the actions of narrowing the options within FishPath. Then the users can narrow the options in their own way or by following a set of guidelines without enforcement by the software. There are a number of advantages for this method. It would allow the users flexibility in how they approached the narrowing process. They would not be confined by the rigidness of the wizard. The users could perform the steps in any order, disregard steps not relevant to their situation, change or add steps, or develop their own process. This would require less maintenance as the software would not need to be modified as guidelines change over time.

There are also a couple disadvantages with this method. The users are not explicitly guided and therefore might be more prone to missing steps or making mistakes while trying to follow a set of guidelines to narrow the results. There is also an increased chance of users attempting to manipulate the results to deceive others about the best options. This would be especially so if there was the ability to directly change the caveats.

For FishPath, the increased flexibility obtained by providing the tools needed, but not forcing the use of a wizard outweighed any potential disadvantages. The features could also be designed to mitigate against these disadvantages. The rationale for this choice is as follows. First, FishPath is used around the world, in a wide variety of situations. Having increased flexibility would provide users with the ability to optimize the process for their fishery and situation, and support a more bottom-up approach. There was no foreseeable way to create a wizard that would work well in all situations. This option also allows for unforeseen situations to be handled with no or minimal software development needed to adapt to the new circumstances.

In addition, the fifteen step process is continually evolving based on case studies being done. If changes are made to it, or another set of guidelines become adopted instead, the wizard would have to be updated accordingly. This requires time, effort and cost for a software developer which might not be available. It also takes time to develop, test and deploy, thus slowing down the adaptive process. Anytime development is done, there is an increased risk of introducing bugs into the program. Therefore, the new features should minimize the amount of development required just to maintain a similar functional level. Additional software development can then focus on creating new features instead.

The decision to not use a wizard also opens up possibilities for the design of the features themselves. When not viewed through the lens of a step-by-step process, more possibilities become available. No longer is there a need to have a specific tool or process designed for each step. Instead, when looking through the fifteen steps, each step falls within one of two broad categories of an action to take: (1) sort or reorder the options and (2) remove or hide an option from the results page. Besides the ones explicitly listed in Table 2, the other steps could be thought of as simply hiding or sorting the options. For example, in step 9, the ultimate goal of the step is to rearrange the order of the options ranking by most favorable based on the analysis. Even though during each step users perform a different analysis, if the software allows for the ability to manually sort and hide the options, then the users would be able to perform the fifteen steps or any other narrowing process within FishPath. Therefore, first priority was given to this functionality. Tools to help with the analysis at each individual step could be developed in the future (as discussed in the section on next steps).

There are measures that can be taken to minimize the impacts of the disadvantages of this method. First, while the ultimate goal of FishPath is for anyone to be able to access and use it, it

is currently used mainly in workshops facilitated by members of the FishPath group with supplementary fisheries management training as needed. This allows FishPath experts to guide the users through the narrowing process and make sure that the process is being performed correctly. For users not at FishPath workshops, guiding documents for how to interact with FishPath and ways to narrow the results can be created and published electronically. These documents can be made accessible directly within FishPath so they are easy to access when users are using FishPath.

There are also a number of ways to counter any possibility of users trying to misrepresent the results. First, the output as originally presented by the program should always be easily accessible. This will allow others to review any changes made. It will also provide a check in case users accidentally makes changes and wants to undo them. Finally, there should be some form of visual cue for any explicit changes, such as removing a caveat, made by users to an option.

Notes to Document Changes

Next it was determined that if users are allowed to make changes to the results generated by FishPath, then they need to have a way to document those changes. There should be a note making capability associated with each option. This would make organization simpler for users as they would not have to create a separate document with a comprehensive lists of notes. Having a note associated with each option would allow users to provide the decision making rationale for each option. This creates a large benefit. The notes become a major source of institutional knowledge because they store the decision making thought process of the original and all subsequent users. The notes will persist in the FishPath database so that users can return

to it over the years to reexamine past decision processes. In addition, it will also be easier to disseminate this information as the notes should be included within the new reports. Another crucial advantage about including a note field for each management option is that it becomes a catch-all for performing the steps. For example, until a tool is developed to allow the users to change caveats, the users can record that information in the note. It is a short-term solution, but it at least allows for the documentation of any information from steps that do not have explicit tools or features developed for them.

Reporting Tool

Finally, based on feedback from users, a way to report the results was deemed necessary. This completes the decision support cycle of the tool. If the process of narrowing the results is performed within FishPath, then there needs to be a way to export that information. For this project, a reporting component for FishPath was designed. This reporting tool would have two pieces.

The first piece is the creation of report templates. Report templates provide the framework for how a report will be generated once the users specify which option to create the report for. Currently, FishPath will export a CSV file that lists each option along with the number of each type of caveat associated with that option. This existing reporting capacity should be recreated within the new reporting tool. The second report template should be an overview providing the details of an individual option. It should include the option title, description, any user notes and details about the associated caveats. Currently, this information is all contained with the option description view of FishPath. The new report should pull all the information

needed from this view and present it in a more stylized, easy to interpret way. It should also be exported as a universally used file format such as a pdf document.

Second, a framework within the software needs to be created that allows for the users to choose which reports should be generated and which options should be reported on. In the future, it is likely that more reported templates beyond the two described above will be desired. The framework should be designed in a way that it will be easy for additional reporting templates to be created and added to the reporting tool.

Chapter 4: Results - Changes to the FishPath Software

Overview and Demonstration of Software Features Added

The design process resulted in the development of four new features that were added to FishPath. These features are: 1) the ability for users to hide options from their view, 2) the ability for users to manually change the order of the options, 3) the ability to add notes for each option, and 4) the ability to generate reports. The following is a description of each of the options as they have been implemented within FishPath and appear to the users. First, the new layout of the results page is described, followed by a description of each of the new features in the order listed. The technical details for the development of these features can be found in Appendix A.

New Results Page

Figure 4 shows the layout of the new results page. The new visual features are described below:

1) The possible views that users may choose from. The highlighted button signifies which is currently being viewed.
    a) User Edits: This is the default view when users open the results page. In this view the users can perform hide and sort actions.
    b) Original: This contains the output of the results with no changes made. The users are not allowed to make any changes in this view, but they may edit the notes.
    c) Hidden: This contains all the options that have been hidden. An option may be unhidden to return it to the User Edits view. Options may also be sorted within this view.
2) Tools
    a) Hide/Unhide: If in the User Edits view, this removes the option from the User Edits view and sends it to the Hidden view. If in the Hidden view, then this returns an option to the User Edit view.
    b) Add/Edit Note: This will either create a new note if no note exists for that option or will open the current note to edit. In this picture, the first option has a note associated with it while the rest do not.
3) Generate Reports: This opens the report generator window.

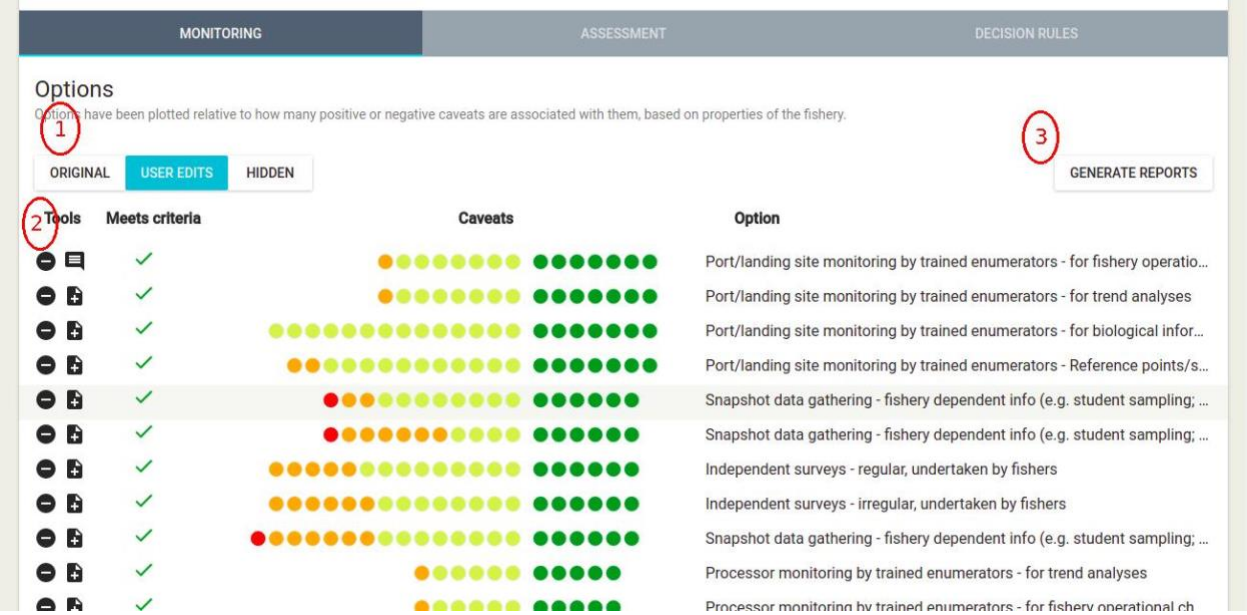

Figure 4. The new results page.

Hide Function

This feature allows users to ‘hide’, i.e. remove, any option from the User Edits view. After hiding an option, it will be removed from the User Edits view and will display at the bottom of the list in the Hidden view. An option may be returned to the User Edits view by clicking the plus icon in the tools column from the Hidden view. The option will then be added to the display in the User Edits view and placed at the bottom of the list. Always placing the option at the bottom of the list creates a consistent behavior, makes it easy to find and is the safest place as options may have been sorted since the returned option had been hidden.

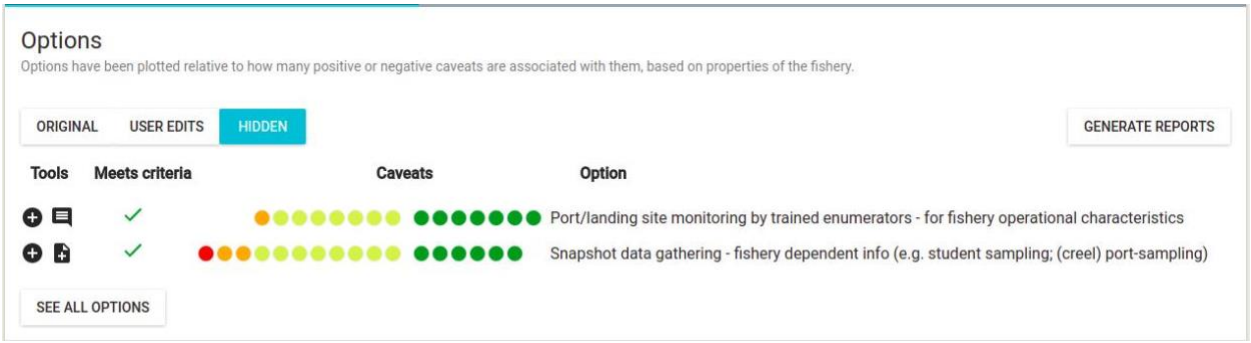

Figure 5. The Hidden view shows all options that have been hidden from the User Edits view.

Sort Function

Sorting has been implemented through a drag and drop list (Figures 6a,b,c). Users simply have to click and hold on an option, then the users can drag the option to the desired place. Other options will automatically adjust when the option being moved is placed in a new position. For example, if the option in the fourth position is moved to the second position, then the option previously in the second position will drop to the third position, the option in the third position will move to the fourth position and the rest of the options will remain where they are.

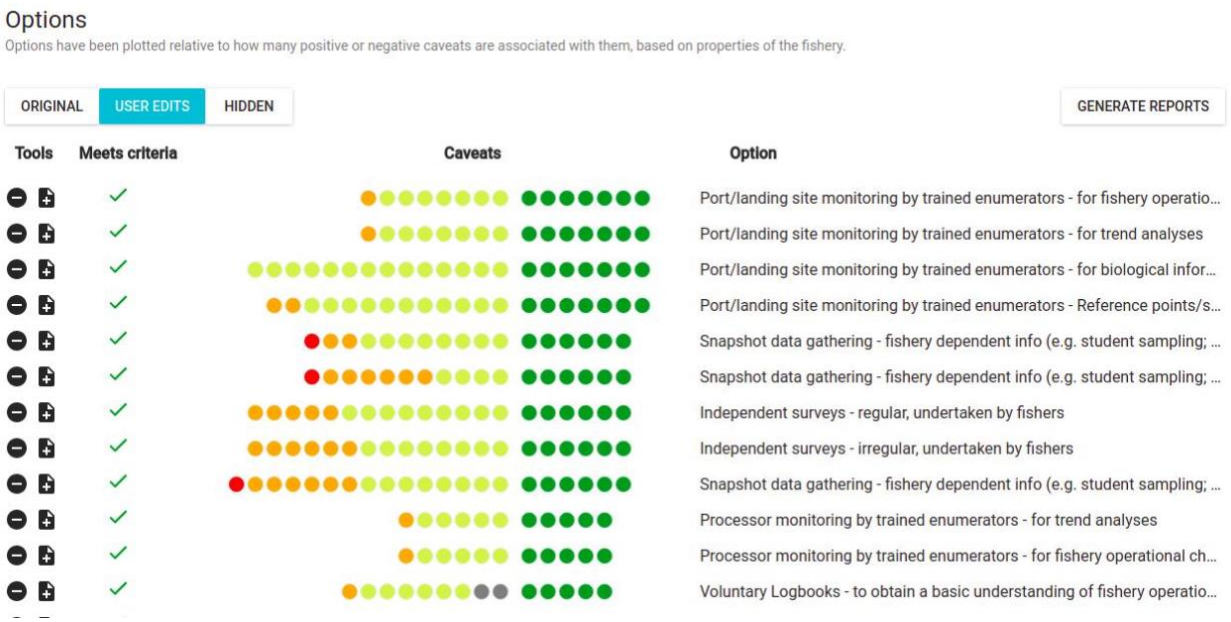

Figure 6a. Before taking a sorting action.

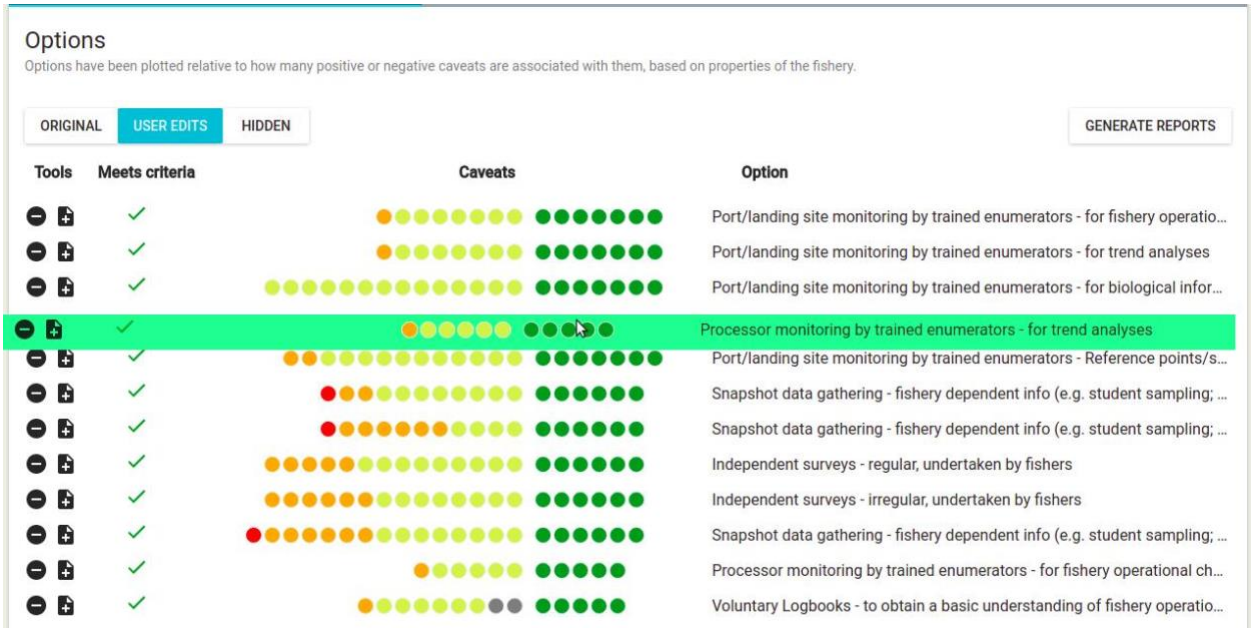

Figure 6b. During a sorting action. The user clicks and holds an option, then drags into place. Here the user has selected an option near the bottom of the screen and is in the process of dragging it to the beginning of the list.

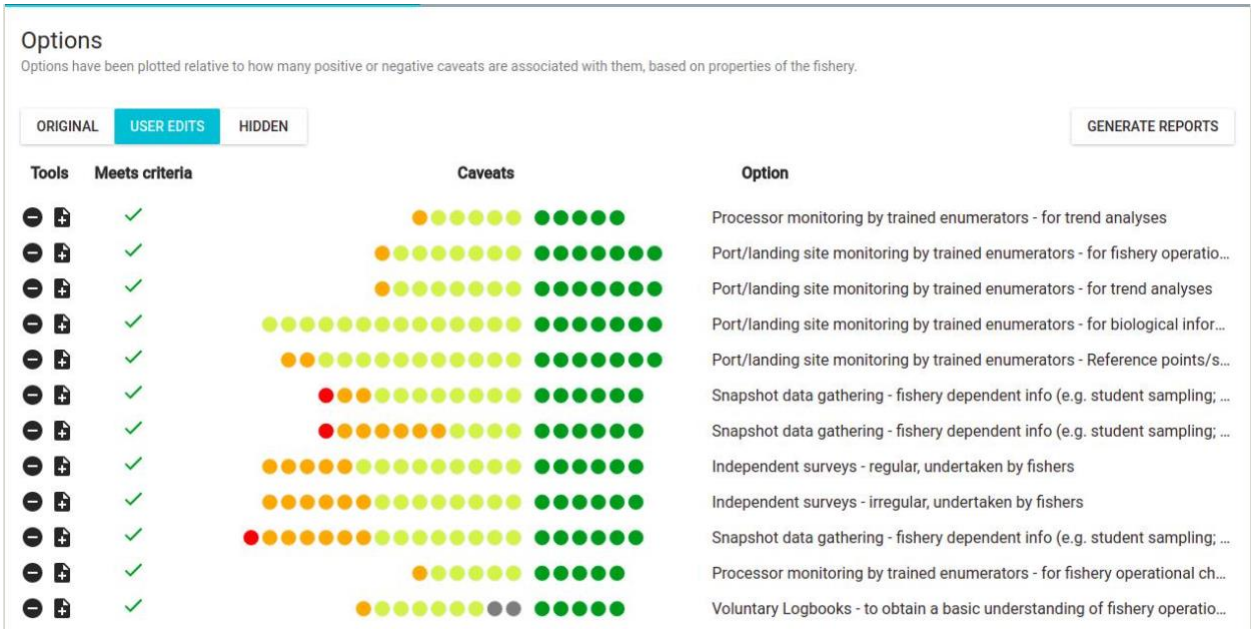

Figure 6c. Releasing the click drops the option into the spot it is hovering over.

Notes Function

The notes tool is a fully featured text editor (Figure 7). It allows for a wide array of formatting options as well as supports an undo feature.

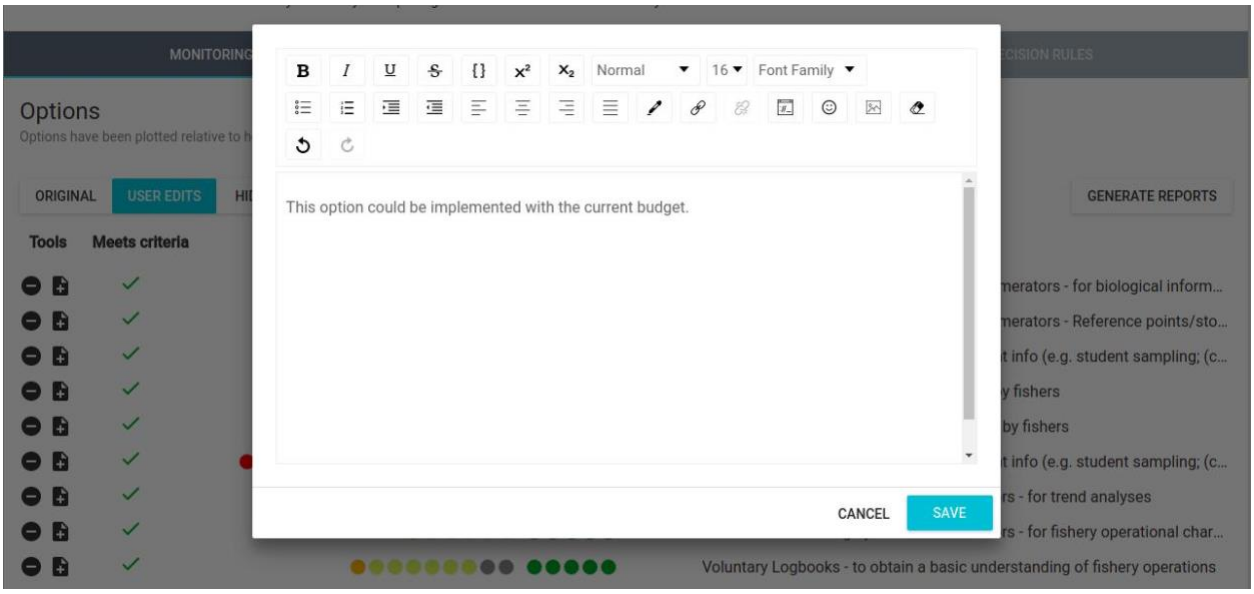

Figure 7. The full featured notes editor.

Reports Function

The report generator (Figure 8) allows users to select from which options to generate reports. The report generator provides print options allowing users to choose between landscape and portrait page orientation and between a letter or A4 paper size. This is to provide flexibility when printing for different types of documents and in different countries around the world. Upon clicking “Generate”, both the results summary report and the option detail report for each option will be opened as PDFs in new tabs of the browser. From there the files can be downloaded and saved to the preferred destination. Appendices B and C have examples of the results summary report and option detail reports, respectively.

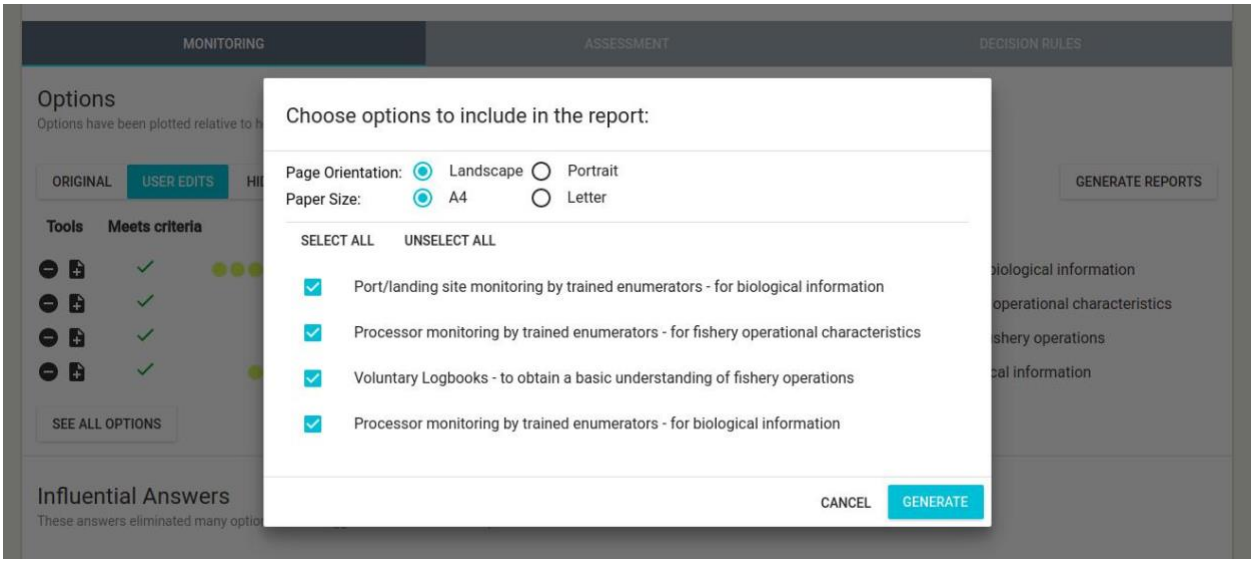

Figure 8. The report generator allows users to select any option that is in the current view.

Chapter 5: Conclusions and Recommendations for Next Steps in the Development of FishPath

This thesis project results in a major improvement over the old functionality of FishPath. It is a big step in the right direction to addressing some of the limitations of FishPath user interaction; however, these are not the only possible improvements.

Ground Truthing

First these improvements need to be tested in real life situations. They have been tested and demonstrated to a majority of the members of the FishPath Core Team. Overall, there is lots of enthusiasm for the new features and excitement for them to be deployed to the production website so that they can be used (FishPath Core Team, personal communication, November 3, 2017). However, the effectiveness of these features will not be fully known until they have been tested at a number of different workshops or case studies. These features might prove to be

limited in their usefulness or they might actually be more useful than anticipated. The design decision to provide flexible tools instead of a rigid step-by-step wizard means that there is potential for these tools to be used in unforeseen ways. It allows users creativity in their use of FishPath. This might lead to other methods besides Dowling's fifteen steps to be developed. The potential for this flexibility will not be seen until the tools are tested in the field.

Potential Limitations and Obstacles of the New Features

This project is a good first step, but more functionality is still needed to make FishPath a more powerful decision support tool for managers. There are a number of features or tools that would make analysis for specific steps easier. These are briefly mentioned in Table 2 above. The ability to edit, change or remove caveats is the most powerful of these. It will give users true flexibility to tailor the results to their specific circumstances. For example, Dowling highlights an example in Peru where FishPath did not recommend a temporal restriction option due to a lack of enforcement capacity. However, due to the nature of the supply chain, all the catch had to be transported down a single road making it easy to enforce out of season poaching (N. Dowling, personal communication, June 15, 2017). Here was a case that FishPath had inaccurately eliminated an option due to a unique situation of the market. It would have been useful for the users to change the caveat to show this. Note that even without this ability, the new features would have greatly improved the situation as the option could have been sorted to the top if it was desirable and a note could be added explaining why this was the case. Outlining a viable solution to overcome a caveat would be another situation where this feature would be useful. In this case, as plans are detailed to overcome bad caveats, then the users could remove the caveats to represent the situation of their hypothetical plan.

Additional Features Discussed

This project did not develop tools to provide analysis for specific steps. Possibilities for what these tools could be and their potential usefulness should be explored. For example, it might be useful to have a tool that allows users to rate or compare options against each other based on criteria outlined in Dowling's step 9 or 10 (Table 1). One possibility would be for a tool where users can rank every caveat of the remaining options based on the difficulty to overcome. The tool could display the caveats without displaying which options they pertain to in order to avoid any bias. Then the tool could calculate a score for each option. More simply, there could be a field in each row of the results page that allows users to input a score. This way users could use any desired means of scoring the options.

The ability to search options for caveats, keywords, etc., is a limitation discussed but not directly addressed by this project. Some sort of searching would be a beneficial next step to take in the immediate future. There a number of different forms that this could take. There could be a search field where the search could highlight any option that contains the search term, whether in the title, description or caveats. It could also be a tool to find all caveats of a similar nature. For example, users might want to find any option that has a caveat related to a IUU fishing. While not directly designed for it, this project does allow users to address this in a stop gap type of way. The option detail report contains all the information contained within FishPath and the notes for each option in the report. Anytime users want to search the options, they could create an option detail report containing all the remaining options. The way that the reports are generated allows for text searching. Users could then search the report for specific keywords using the find function of the browser or PDF viewer.

Another useful tool would be to allow users to see how a hypothetical change to the fishery would impact the caveats of the options. For example, the managers might be considering changing the monitoring plan to include effort data and would like to know how that might affect the possible caveats of assessment or decision rule options. One way to accomplish this would be to design a tool that allows users to see the outcome based on changing the answer without actually updating the answers and results of the questionnaire.

More Flexibility Without Proper Guidance Could Lead to Misuse

There is always some concern that a user could misuse the added power and flexibility of these new features. This would increase as other proposed features are developed as well, such as the ability to manually change the caveats. There are a number of ways to mitigate this risk. First, this project is designed with a mindset that it will be well tested in expert led workshops and case study groups similar to how FishPath is being used currently. The experts will help guide the users in the correct application of the tools and through synthesizing the results. The end goal is for FishPath to be accessed by any group through the internet and therefore in the future, users might not have this guidance. In this case, instructions, best practices and guiding documents should be developed and easily accessible from multiple points within the FishPath program. These documents should be based on the lessons learned and experience gained from the multitude of workshops being run. Instructions or links to instructions directly on the results page would help ensure that the tool is being used properly.

Another way to mitigate this is to design the features in a safe fashion that makes it difficult to improperly construe the results of FishPath. One main reason that the original, read-only view was included is so that any user can audit the edited options against the results as

FishPath generated them. Tools that make changes to an option, such as editing caveats, should maintain visual cues that the option was changed. For example, if a caveat is updated from a red to a yellow, the new caveat icon could be faded yellow with a red outline so it is obvious that it was changed from what it originally was.

Develop a Knowledge Sharing Network of Managers

One of the main aspects of FishPath is that it allows for a bottom-up approach to fishery management decision making. It provides decision support to navigate a confusing array of management options and the information needed to make intelligent decisions for deciding among these options, often times for managers that lack a deep technical training in these methods. One way to help empower these managers is to use FishPath to create a knowledge sharing forum. While these fisheries are often quite different in nature, there is a potential for the managers to learn from each other's experiences. This could be related directly to the use of FishPath as a tool itself. For example, one group might develop a way to compare options that might be useful to another group. Or they could share solutions that they have developed to any variety of challenges managing their fishery. As FishPath matures, it is easy to envision the user base growing. With its growing ability to preserve institutional knowledge, FishPath will become a tool that managers can continually refer to over the years. These factors will make FishPath an excellent candidate to become a forum empowering fishery managers around the world.

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Appendix A

Technical Details of Software Development Techniques and Tools Used

The FishPath codebase is written in Javascript and uses a React-Redux paradigm. React is a "declarative, efficient, and flexible JavaScript library for building user interfaces" (Facebook Inc., 2017). It breaks the UI of a webpage into smaller components. A component can also be comprised of child or sub-components. Each component is made up of React elements. These elements are what translate into the web browser displays through the HTML document object model (DOM). When an element is created, React will then add it to the DOM which displays the element to the users. As the elements are simply objects within JavaScript, they require less performance cost to create than actual objects in the DOM. When a change is made, React will compare all of the new React elements with the previous ones and only updates the DOM for the elements that have changed. This improves the performance of the website compared to refreshing the entire DOM (Facebook Inc., 2017). This makes it possible for FishPath to have interactive UI components without creating a lag in the performance for users.

Redux is a state management tool that allows for consistent behavior from the application. The state of the application contains all the data needed for that program to replicate the current embodiment of the application. In the case of FishPath, the state holds things such as information about the current user that is logged in, all the options and associated caveats, the questions, the answers to the questions for each fishery of that user, among many other things. In Redux, the state contains the whole truth of the application. No other information should be needed to reproduce that given embodiment. The state cannot be modified directly. This means that changes happen in a linear order and race conditions, which might make unexpected results,

are avoided. Instead anytime that a piece of data is changed, a new copy of the state is created with the relevant changes. When data are changed, a corresponding action is generated. This action describes what type of change is made and how to update the new state to contain this change. The action is sent to a reducer. The reducer is a function that takes the previous state and creates a new state based on the action received (Abramov, 2017).

In Redux, a state can become a large object. It is often advisable to split apart the reducer into multiple reducers. Each reducer then is focused on a specific part of the state. This makes the codebase much more understandable, manageable, testable and easier to debug (Abramov, 2017), which is the case within FishPath. Among others, there are reducers focused specifically on maintaining objects, questions, information about the fishery, and answers within the fishery.

The new features of this project were created within this same paradigm. The data about each fishery have an associated section of the state called the response. Each response contains a list of answers to the questions, the id of the user that created the fishery object, the fishery name, and various metadata about the response. To create the new features, a new section was added within the response section of the state. This piece is called the userEdits (Figure A1). It holds all the changes made by the user for that particular fishery. In particular, for each harvest strategy component (assessment, monitoring, and decision rules), the state stores the order of the options in both the User Edits view and Hidden view. A list also stores the notes and associates them with their respective option. A new reducer was also created to maintain this section of the state. Anytime an action corresponding to a user edit is taken (e.g. hiding an option), the reducer updates the state.

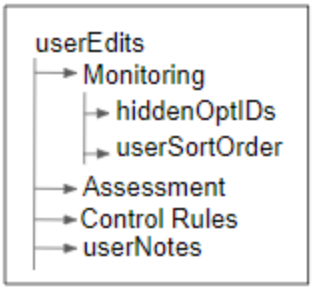

Figure A1. The structure of the new section of state added: userEdits. hiddentOptIDs is an array containing the order of the options in the Hidden view. userSortOrder is an array containing the order of the options in the User Edits view. Assessment and Control Rules each contain hiddenOptIDs and userSortOrder arrays as well.

Several open source primitives and components were leveraged to improve the quality of the tools created. These are components that have been built by other developers and are available as building blocks to be incorporated into other software projects. The sorting function uses react-beautiful-dnd as the base component that creates the drag and drop action (Reardon, 2017). React-beautiful-dnd was chosen for a number of reasons. First, the primitive drag and drop functionality contained within HTML5 has not been implemented well and is inconsistent in its functionality (Reardon, 2017). There are a number of drag and drop or list sorting primitive components that have been built on top of the HTML5 drag and drop functionality, but have cleaned up a number of the issues and provided smooth, consistent operating components. React-beautiful-dnd is designed specifically for lists. It provides a number of prebuilt pieces to make the development of sortable lists simpler. It also allows for the creation of multiple lists and for moving items between lists. While this functionality is currently not needed, there are a number of potential features that would require this ability. This component was created with a focus on physical design and having a natural feel. It also allows for sorting to be done using a keyboard instead of a mouse if desired. Finally, this component has a large and active support base compared to other options (Reardon, 2017). This is important for open source tools as the more

developers that contribute and the more active they are means that any issues or bugs that are found will be fixed faster.

The text editor being used to write the notes is react-draft-wysiwyg (Puri, 2017). This component provides a fully functional text editor. It allows toolbar options to be customized and supports features such as changing font, font size, font color, font style, alignment, among many other options. This text editor is also the editor being used in other parts of FishPath such as the option and question builders.

The report generator tool uses a few open source components as well. FIrst, jsPDF is used (Hall, 2017). This tool facilitates building pdf documents on the client. The generator also utilizes jspdf-autotable (Bengtsson, 2017). This tool creates professionally formatted tables in a pdf. jsPDF requires manual placement of every element of the pdf file; however, autotable automates much of that work and creates these layouts automatically. It also provides a number of styling options which allows for customization of the tables. Finally, the reporting tool utilizes the HTML to text parser, textversionjs (EDMdesigner, 2017). The text editor, react-draft-wysiwyg, stores the text in an HTML format in order to maintain the styles and layout of the text. This cannot be copied directly into a pdf file. Instead it must be transformed into plain text and have the HTML interpreted for the styles and formatting. This parser is not fully featured however. It merely extracts the plaintext and removes the styling and formatting. This is something that should be looked into improving in the next steps.

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Appendix B

Results Summary Report

Red Snapper: Summary of Selected Results - Monitoring

Title	Meets Criteria	Green Caveats	Gray Caveats	Yellow Caveats	Orange Caveats	Red Caveats
Port/landing site monitoring by trained enumerators - for fishery operational characteristics	Yes	6	0	7	0	0
Market surveys - for fishery operational characteristics	Yes	3	0	4	0	0
Snapshot data gathering - fishery dependent info (e.g. student sampling; (creel) port-sampling)	Yes	6	0	4	3	1
Logbooks: formal government (licensing) requirement	No	2	1	5	1	3

Appendix C

Option Detail Report

Red Snapper: Port/landing site monitoring by trained enumerators - for fishery operational characteristics

Description

---Species ID, species composition, location.

Caveats

Green Caveats

Question	Answer	Caveat
Rank the current or potential research and/or institutional capacity to implement and maintain a formal management strategy (i.e. monitoring, assessment, decision rules).	low-moderate	This option may be used with low research or institutional capacity.
Are there existing cooperatives or associations that could provide a starting point to fisher cooperation?	Yes	Helpful if so
Are fishers, or can fishers be, incentivised/motivated/willing to be involved in a data collection program?	Yes	Helpful if so
Do government officials have the capacity for local enforcement of regulations?	Yes	Helpful if so
Is any monitoring program able to be undertaken with temporal regularity and reasonable frequency (e.g. more than every 5 years)?	Yes	Helpful if so
Is the spatial range of the fishing activity geographically vast such that direct sampling (e.g. from landing sites or fishing activity) is challenging?	No	Easier to facilitate for smaller fishing area

Gray Caveats

There are no gray caveats.

Yellow Caveats

Question	Answer	Caveat
Is there strong governance leadership (i.e. agency and/or government-based, as distinguished from community leadership) in place to support/facilitate management measures?	No	If not, consideration needs be given regarding how this is coordinated - who is leading, who is accountable, what is the design, what are the logistics? Fishery cooperatives/associations, and/or strong community leadership and buy-in, would be helpful in this context.
Are regulations enforced, and, if they are enforced, are the regulations/governance respected/complied with?	Yes, but not respected	If governance/enforcement is not trusted or respected, fisher information may be biased.
Are home ports/landing sites and markets numerous/spatially disaggregated, such that representative sampling would be difficult to obtain given the available capacity?	Yes	May not be able to obtain representative coverage
Is any monitoring program able to be conducted at the	No	comparison may not be meaningful

Question	Answer	Caveat
same time and in the same manner interannually and spatially?		
Is the nature of fishing operations (e.g. target species, gear types, fishing locations, markets) changing?	Yes	May not be representative
Are the main fishing locations and/or ports variable, such that implementation of a monitoring program or obtaining a representative sample will be difficult?	Yes	May not be representative
Static Caveat	This caveat always applies to this option.	Potential for misreporting (especially for fisheries with low cooperation/subsistence/low GVP/low research capacity) - but less incentive to misreport given that the context is not about C,E, and enforcement. Could also be about selling less valuable component of catch informally (for e.g.). Also, motivation from buyers (and e.g. for export approval, chain of custody, RFMO affiliation)

Orange Caveats

There are no orange caveats.

Red Caveats

There are no red caveats.

Notes

Concern over the caveat regarding strong governance. Need to develop a plan to address this.