

The Ocean Health Index Assessment Manual

Contents

1	Introduction	4
1.1	What to expect when conducting an assessment	5
1.2	Overview of best practices for OHI assessments	5
1.2.1	Understand completed OHI assessments	6
1.2.2	Incorporate core values and characteristics into the OHI assessment framework before gathering information	6
1.2.3	Strategically define spatial boundaries at the finest possible scale	7
1.2.4	Assemble input information	7
1.2.5	Maintain core values and characteristics within the assessment framework regardless of limited information quality	7
1.2.6	Carefully document and share all decisions in writing and computational code	7
1.3	The Toolbox software and WebApp	8
1.4	Outcomes of conducting an assessment	8
2	Overview of the OHI WebApp	8
2.1	Defining and displaying regions	10
2.2	Exploring inputs and outputs with the WebApp's App page	10
2.2.1	The App's Data tab	10
2.2.2	The App's Compare tab	13
3	Defining spatial boundaries	15
3.1	Drawing spatial boundaries	15
3.1.1	Updating the map in your WebApp	16
3.1.2	Buffers	16
4	Discovering and gathering input information	17
4.1	Thinking creatively	17
4.2	Data sources	17
4.3	Gathering responsibilities	18
4.4	Requirements for data and indicators	18
4.4.1	Relevance to ocean health	18
4.4.2	Accessibility	18
4.4.3	Quality	19
4.4.4	Reference point	19

4.4.5	Appropriate spatial scale	19
4.4.6	Appropriate temporal scale	19
4.4.7	The process of information discovery	19
4.4.8	Example: U.S. West Coast data discovery	20
4.4.9	Reasons data were excluded	20
4.5	Developing Goal Models and Setting Reference Points	21
4.5.1	Developing multiple goal models at the same time	21
4.5.2	Keeping Reference Points in Mind	22
4.5.3	Identifying pressures and resilience	22
5	The Ocean Health Index Toolbox	23
5.1	File system organization	25
5.1.1	Assessment repositories	25
5.1.2	Scenario folders	25
5.1.3	<code>subcountry2014</code> contents	28
5.2	Formatting Data for the Toolbox	33
5.2.1	Introduction	33
5.2.2	Uploading and formatting raw data files	34
5.2.3	Gapfilling	35
5.2.4	Long formatting	38
6	Installing the Toolbox	39
6.1	Overview	39
6.2	GitHub	40
6.2.1	Learning GitHub	40
6.3	Accessing GitHub Repositories	40
6.3.1	Create a GitHub account	41
6.3.2	Install <i>git</i> software	41
6.3.3	Set up your Git Identity	44
6.3.4	Create a folder called <i>github</i> on your computer	45
6.3.5	Update permissions	45
6.3.6	Work locally with R and RStudio	45
6.4	GitHub repository architecture	49

7 Using the Toolbox	50
7.1 Layer preparation workflow	50
7.2 Modifying and creating data layers	50
7.2.1 Create data layers with proper formatting	51
7.2.2 Save data layers in the <i>layers</i> folder	53
7.2.3 Register data layers in layers.csv	53
7.2.4 Check pressures and resilience matrices	54
7.3 Modifying pressures matrices	54
7.3.1 Create the new pressure layers and save in the layers folder	54
7.3.2 Register the new pressure layers in layers.csv	55
7.3.3 Register the new layers in pressure_matrix.csv	55
7.3.4 Modify the resilience matrix (if necessary)	56
7.4 Modifying resilience matrices	56
7.4.1 Updating resilience matrix with local habitat information	56
7.5 Modifying goal models	59
7.5.1 Update <i>functions.R</i>	59
7.5.2 Check and possibly update <i>goals.csv</i>	61
7.5.3 Example modification:	61
7.6 Removing goals	62
7.7 Modifying the pressures matrix for goals with categories	64
7.7.1 Background	64
7.7.2 Example 1: Pressures	65
7.7.3 Example 2: Resilience	66
7.8 Other example modifications	67
7.8.1 Preparing the fisheries sub-goal	67
7.9 Updating the WebApp's pages	70
7.9.1 Regions	71
7.9.2 Layers	71
7.9.3 Goals	71
7.9.4 Scores	72
7.10 R Tutorials for OHI	72
7.10.1 R Very Basics:	72
7.10.2 tidyverse functions	72
7.10.3 dplyr functions	73
7.10.4 Coding style	79

8 Toolbox Troubleshooting	80
8.1 General Software Errors	81
8.1.1 rpostback-askpass error	81
8.1.2 Git not detected on system path	83
8.1.3 Loading RWorkspace on Restart	86
8.2 Errors when Using the Toolbox	88
8.2.1 Useful Errors when Calculating Scores	88
8.2.2 Calculating Pressures...	90
8.2.3 Calculating Resilience	91
9 Frequently Asked Questions (FAQs)	92
9.1 Overall	92
9.2 Conceptual	92
9.3 Timing and Resources	94
9.4 Structure	95
9.5 Reference points	95
9.6 Appropriate data layers	95
9.7 Food Provision	96
9.8 Livelihoods & Economies	97
9.9 Tourism & Recreation	98
9.10 Natural Products	98
9.11 Species	98
9.12 Sense of Place	98
9.13 Pressures	99

1 Introduction

Summary:

This guide provides an overview of conducting an OHI+ assessment. An assessment involves incorporating information from your study area into goal models to calculate Ocean Health Index (OHI) scores using the OHI Toolbox software and WebApp. This process is explained in this guide.

The **OHI framework** allows you to synthesize the information and priorities relevant to your local context and produce comparable scores. Because the methods of the framework are repeatable, transparent, quantitative, and goal-driven, the process of carrying out an OHI+ assessment is as valuable as the final results.

The first completed assessment for a study area is valuable because it establishes a baseline and highlights the state of information quality and availability in an area. Any subsequent assessments carried out through time are also valuable because they can be used to track and monitor changes in ocean health. Your assessment

will require careful thought and consideration along the way, and we encourage documentation and scripting to be done within the OHI Toolbox to facilitate collaboration and transparency, as well as the reproducibility for future assessments.

Each OHI+ assessment should have a clear purpose. One of the typical reasons for conducting an independent assessment is to inform policy and management decisions. Assessments can be more relevant to management when they are conducted at the spatial scales at which policy decisions are made, such as states, provinces, or counties. The **regions** and the overall **study area** are definitions that will be used throughout the assessment. The study area is the entire spatial boundary of your assessment, while the regions are the smaller subdivisions within the study area. In the OHI framework, goal scores are calculated for regions separately and then combined to produce an overall OHI score for each study area. The number of regions varies with each assessment's study area; completed assessments have had between one and 221 regions.

The process of conducting an OHI+ assessment is as valuable as the final results. Documenting decisions made, as well as the challenges and successes encountered along the way, can lead to better understanding of the system, help inform management decisions, and guide future assessments to track changes through time.

1.1 What to expect when conducting an assessment

It is important to include information that best represents your study area, and to make science-driven decisions and clearly document what was done and why. Your team should be as creative and insightful as you can be while working within the bounds of informational and technical limitations.

There are **key processes and considerations** that will be a part of every assessment. Every assessment should build from the lessons learned of previously completed assessments and identify what local characteristics need to be included in a study. This is done partly by comparing the local situation to situations in previous assessments; it is also done by comparing the default information provided in the WebApp to what is known about local realities. After you have outlined and identified local characteristics and priorities, you should prepare to use the Toolbox software and fit the data you have found to be formatted correctly for that software. Finally, once working with the information within the Toolbox, your team will update and improve the methods of the assessment before being able to calculate the final results. You will also visualize the outputs in the WebApp's maps and flower plots that can be shared with other partners and collaborators. Above all, you should be prepared to **know that this process takes time and is iterative, meaning that you often return to previous steps**.

How long does an assessment take? Past assessments have taken between two and three years, with the time varying depending on the size and composition of the team, the challenges encountered in discovering and gathering information, and how many models are redeveloped. The amount of data processing and goal model development needed before you will be able to use the Toolbox also affects the amount of time it takes to conduct the assessment. The skill sets of the team members and the amount of technical resources available are also hugely important factors. You should think about which team members are needed at what stage of the process, including an R programmer and a spatial analyst. It will take time for the technical team to become familiar with the OHI Toolbox and GitHub.

1.2 Overview of best practices for OHI assessments

Conducting an assessment requires both an understanding of how past assessments have been completed and the innovation to capture important characteristics of your study area using the information available. You can start by understanding the structure of completed assessments at global and smaller scales and the models that were created. Understanding the approaches in different contexts will help you think about what should be done similarly and differently in your local context.

Navigating through the WebApp can help frame your thinking and introduce you to the structure of inputs that will be required for the OHI Toolbox software.

1.2.1 Understand completed OHI assessments

It is important to **understand methods used in completed OHI assessments** so that you can identify if previous approaches are appropriate for your assessment or whether you need to redevelop the methods for your study area. In many cases, studying completed OHI assessments will inform your approaches for discovering data and developing goal models later on in the process.

The OHI framework was developed through collaboration and iteration. Your assessment can leverage the collective knowledge and insight used in the methods of the global assessment by Halpern *et al.* in *Nature* (2012) as well as the subsequent assessments conducted annually (in 2013, 2014, and ongoing). Each annual global assessment has improved upon some of the goal models based on better data availability or a better understanding of the systems involved. Several smaller-scale assessments have been completed that are highly informative as well, and particularly for regional scale assessments. The following studies have been published with supplemental online materials, and are available at <http://ohi-science.org>:

- **Global**
 - Halpern et al. (2012) An index to assess the health and benefits of the global ocean. *Nature*.
 - Halpern et al. (2015) Patterns and emerging trends in global ocean health. *PLoS ONE*.
- **Brazil**
 - Elfes et al. (2014) A regional-scale Ocean Health Index for Brazil. *PLoS ONE*.
- **United States West Coast**
 - Halpern et al. (2014) Assessing the health of the U.S. West Coast with a regional-scale application of the Ocean Health Index. *PLoS ONE*.
- **Fiji**
 - Selig et al. (2015) Measuring indicators of ocean health for an island nation: The Ocean Health Index for Fiji. *Ecosystem Services*

Additionally, several OHI+ assessments have been completed. As information is available about those assessments they will be posted on <http://ohi-science.org>.

TIP: The OHI+ development team is prepared to provide guidance for assessments.

1.2.2 Incorporate core values and characteristics into the OHI assessment framework before gathering information

Begin your assessment by identifying local socio-cultural-economic characteristics and priorities related to ocean health, and how they would ideally be captured with the existing or modified OHI framework. This means understanding the rationale behind the components of the OHI framework and identifying what must be added or removed or redefined to ensure that it best represents the local context. Are all goals relevant to your study area? What should be added, removed, or redefined? In this process it is important to identify not only characteristics that could be included in goal models, but also the important stressors (pressures) and resilience elements within the study area. What are the key issues that should be included for your assessment to be credible, useful, and meaningful? How do people typically relate to the ocean in your area in terms of social and cultural patterns? These are the kinds of questions you should consider prior to assembling the available information.

The OHI framework should guide your assessment, but you should not be constrained by it. If a goal is not relevant, it should be removed. If there are elements important to your study area that are not present within the existing framework, how could they be included? Having a clear picture of how the framework should

be restructured and what the assessment should include is very important before moving on to assemble information, because otherwise the assessment could be biased by what information is available instead of what is important to include. When specific information is not available there are ways to capture them with indirect measures, called proxies, which will be discussed in the **Assemble Input Information** section.

1.2.3 Strategically define spatial boundaries at the finest possible scale

Identifying the spatial boundaries of the regions within the assessment area is extremely important because OHI scores are calculated for each unique region. Spatial boundaries should be defined with geographic information system (GIS) mapping software at the smallest scale possible, ideally within one management jurisdiction. This is optimal because it is often at these scales where management and policy decisions are made, cultural priorities and management targets are identified, and information is collected in standardized and therefore comparable ways.

1.2.4 Assemble input information

There are many decisions to be made when searching for and gathering data, and searches should extend beyond any one expertise, discipline, source, or data-type. This is because your data will come from disparate sources, and you will have to engage experts to help identifying good proxies and indicators, deciding reference points, and developing goal models. OHI+ assessments should incorporate higher-resolution information where possible for goal status models and pressures and resilience measures. The process of discovering and gathering so many different kinds of data and indicators is an important step that you will return to as you continue to conduct the assessment. This is where having a collaborative team that can work across disciplines will be key.

1.2.5 Maintain core values and characteristics within the assessment framework regardless of limited information quality

The models you develop and reference points you set must reflect the philosophy of the OHI framework while accommodating the attributes and shortcomings of the data. While goal status models developed in completed assessments offer good examples of approaches in different contexts, they should be considered as guides and should not limit exploration into new model development. It will likely be an iterative process to incorporate the best available information into a model that captures the philosophy of the goals. It will also require creative thinking and problem-solving abilities among your team, and documenting the decisions you make is important for transparency, communication and repeatability.

1.2.6 Carefully document and share all decisions in writing and computational code

It is important to plan for future assessments, as repeated assessments enable you to compare and track how scores have changed over time, with the aim of ultimately informing policy to improve ocean health. Repeated assessments will use the same methods and reference points, but incorporating updated data.

Detailed information about how the assessment is conducted will enhance its credibility and reproducibility. Decisions of why information was included and why models were developed in a certain manner are of great importance so that future assessments can incorporate the same logic and understanding of the system — or make improvements. Further, the type of workflow developed and software used to organize and process information will greatly affect the efficiency, transparency, and reproducibility of subsequent assessments. Providing public access to all such information, as well as input data and computational code is becoming the standard for scientific inquiry, so every effort should be made to achieve those aims.

1.3 The Toolbox software and WebApp

The **OHI Toolbox** is the main software used for organizing and processing information, documenting decisions made, calculating scores, and visualizing results. It was created to facilitate score calculations as well as the organization of information and transparency of the approach. The Toolbox is built with open-source software, meaning that it is freely available for you to use and can be modified to meet your needs. You will access the software from online and will use several free software tools to conduct your assessment in a collaborative, transparent, and reproducible manner.

The Toolbox software should be used when your team has gathered the information necessary for the goal models you have developed. The steps of carefully preparing and gathering data layers, indicators, and developing goal models can be done independently of the actual software use; however, if done within the Toolbox structure these steps will be traceable and collaborative. But of course the assessment can be done without all members of your team becoming familiar with the technical aspects of the Toolbox.

Accompanying the OHI Toolbox is the **OHI+ WebApp**, which is a visualization tool that displays input information and calculated scores in several ways, including interactive maps and flower plots. Most coastal countries have a WebApp that was created to facilitate planning and communication during assessments. The WebApp visually presents inputs, goal models and calculated scores for each defined region through interactive maps, histograms, and tables. All inputs presented in a country's WebApps were extracted for each country from global assessments, and scores were calculated using goal models from global assessments.

The WebApp is a widely useful communication tool. Not all team collaborators may be involved with the technical aspects of the Toolbox, but the WebApp enables everyone to explore inputs and calculated scores.

1.4 Outcomes of conducting an assessment

The process of conducting an OHI assessment can be as valuable as the final results. This is because while conducting an OHI assessment you will bring together meaningful ocean health information from many disciplines. In doing so, you will have a census of existing information and will also identify knowledge and data gaps. Further, conducting an OHI+ assessment can engage many different groups, including research institutions, government agencies, policy groups, non-governmental organizations, and both the civil and private sectors.

Your completed assessment will produce OHI scores for each goal for every region in your study area, and scores within the assessment can be compared with each other. These scores will not be quantitatively comparable to those of other OHI assessments because they differ in the underlying inputs, goal models, and reference points. The only *quantitative* comparisons can be made within an assessment's study area, whether between regions or through time. However, *qualitative* comparisons between different OHI assessments can be made because the scores are an indication of how far a region is to achieving its own targets. For instance, if two study areas have scores of seventy and sixty-five, it should be interpreted that the first study area is closer to its management targets than the second is, but since these management targets are different (in addition to the underlying data and models), they cannot be quantitatively compared.

2 Overview of the OHI WebApp

Section Summary:

Your team should be familiar with the structure of the WebApp since it demonstrates how information is organized and displayed. As you update inputs with local information, you can view these updates with the WebApp.

OHI+ WebApps are websites created to facilitate independent assessments. The WebApp is a good starting point when conducting an assessment because you can easily navigate how information is organized and displayed. The WebApp is also meant to be used to visualize and communicate results.

The WebApp displays input information (data and indicators) as well as final OHI scores. When prepared and formatted for the OHI, inputs are called **layers** and are used in all OHI calculations, including goal models, pressures and resilience. By default, the WebApp only displays layers and score information that have been extracted from the latest global assessment and allocated to subcountry regions with the study area. The default display therefore does not provide fine resolution nor does it guarantee accurate data for each study area. You will substitute these layers with higher-quality information at the local scale in your assessment. However, the default layers can be used as inputs into your assessment in cases where no better information exists. **Incorporating the best information possible will generate results that best represent your study area.**

The WebApp is powered by the **OHI Toolbox**, which organizes all of the layers and calculates Index scores. The Toolbox is where you will actively work to prepare and format layers and develop goal models, which can then be displayed with the WebApp.

A default WebApp is available for most coastal nations. For example, Ecuador's WebApp (ECU) is found at <http://ohi-science.org/ecu>. Note that it is possible to translate the page into your language of choice.

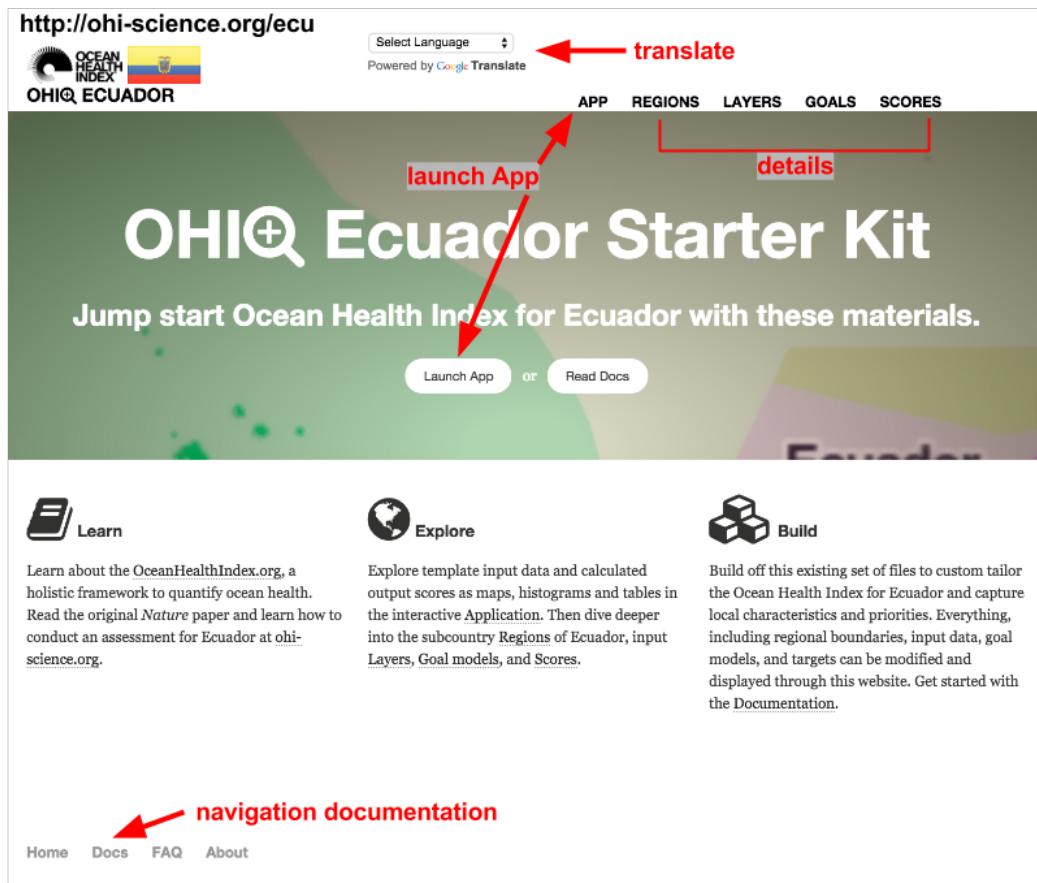


Figure 1: The WebApp start page. Note that it is possible to translate the page into your language of choice.

Remember that this information is publicly available when stored on free GitHub accounts. If you would like your assessment to be private, you can choose a premium option.

The WebApp homepage provides tabs for you to explore your data, regions, and calculated scores. The main pages are **App**, **Regions**, **Layers**, **Goals**, and **Scores**, which were described in the **Conceptual Guide**. The App page is described more below.

The interactive **App** page allows you to explore input and output variables. The inputs are the layers and the outputs are calculated scores for each goal and dimension of the Index for each region in the study area. This page is where you should start your exploration. By choosing input layers you can see the range of values for a given variable and you can also see information about data sources. More detailed information about the default goal models and the calculation methods is found in the other pages of the WebApp.

The information displayed on the website is stored online in a **GitHub repository**. GitHub is an open-source development platform that allows multiple users to collaborate, track changes, and share their work to prepare data files and write code. Some members of your team will use GitHub to track layer preparation and view the history of changes made in this process. It also a a way for your team to document the decisions made during your assessment. Any changes made to files contained within the GitHub repository will be automatically displayed on the WebApp for other team members and collaborators to view. The history of these changes is also stored on this platform as an archive, and it can be used to display changes made over time (See the section on **GitHub** for how to modify files using this platform).

2.1 Defining and displaying regions

WebApps display subcountry regions within each study area. The boundaries for these subcountry regions are usually states, provinces, or districts reported to Global Administrative Areas (GADM: www.gadm.org). These land-based regions are extended offshore to divide the Exclusive Economic Zones (EEZs) into offshore regions of the study area. Offshore regions are important for Index calculations, in part because scores for each region are combined using the offshore area to weight the average of the final Index score. You can redefine these regional boundaries; these subcountry regions have been provided as a starting point. To redefine the boundaries you will need a spatial analyst; details are below.

It is important to note that the provided WebApps do not claim to take a stance on disputed territories. The boundaries for all EEZs were identified by MarineRegions.org (<http://www.marineresregions.org>), and subcountry regions were identified by the Global Administrative Regions database (<http://gadm.org>).

2.2 Exploring inputs and outputs with the WebApp's App page

The App page allows you to explore the input layers and calculated output scores for each region in the study area. The page presents data and scores from the global assessment that are applied to each subcountry region in the study area by default. In order to explore data and scores, you can select them on the left to view their attributes and you can also visualize them in a number of ways on this page.

The App page allows you to view displays through the **Data** and **Compare** tabs. The **Data tab** provides summary information on each layer and metadata descriptions that accompany them. The **Compare tab** is mainly used for comparing output scores when modifications are made to the underlying data or models.

2.2.1 The App's Data tab

2.2.1.1 Overview of display options The Data tab displays input layer or calculated scores for each goal parameter. It presents the information through a *Map*, *Histogram*, or *Table*. These options are available as sub-tabs on the Data tab page. The *Map* sub-tab is the default display option for the Data tab, and all data presented are drawn from the global assessments by default. This means they are either directly duplicated across regions, or the raw values are down-scaled using offshore area- or population-weightings. The *Histogram* sub-tab likewise draws from the same data source, but it displays a histogram of observed values with a smoothed line added. The *Table* sub-tab also draws from the same data but offers information in a table.

Data displayed in the Map sub-tab:

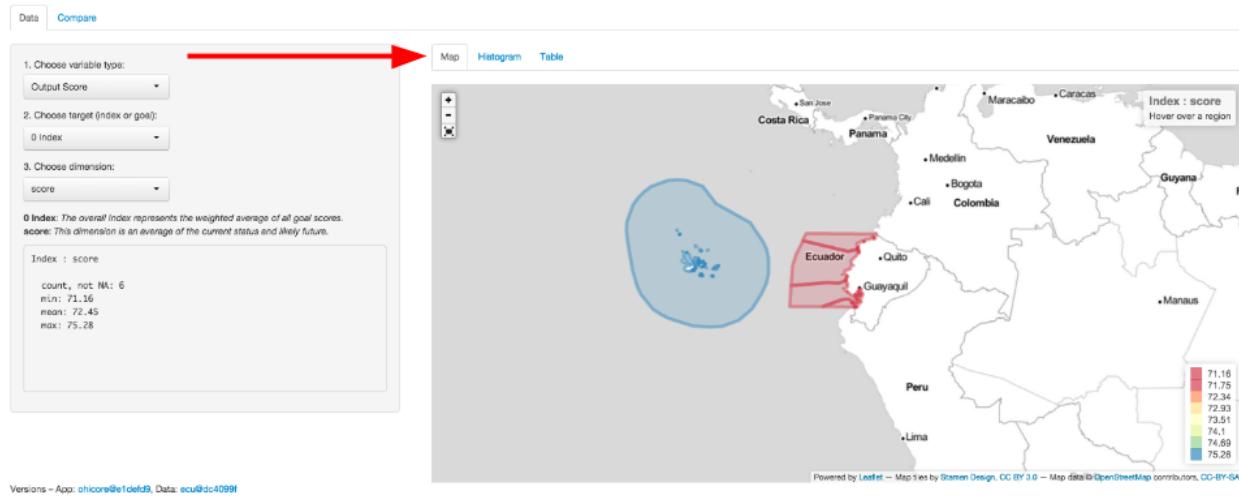


Figure 2: The Map sub-tab. Click on ‘Map’ to see a geographic view of your assessment region. Colors indicate scores or values for your input layers or output scores. This example shows Index scores for each region in Ecuador.

The *Map* displays data for every region. A legend is displayed in the lower right-hand corner of the map to explain the meaning of the colors presented. The range of values will change when variables are selected, and the colors will automatically change to match that range.

Data displayed in the Histogram sub-tab:

The *Histogram* shows the distribution of values of the selected variable as the number of observations for each value bin (shown as white bars) and it also automatically creates a smoothed density function (shown as pink shading).

Data displayed in the Table sub-tab:

The *Table* displays the variable’s value for each region in the study area. It provides an identifying code (*rgn_id*), name (*rgn_name*), and value (*value*) for each observation. The variables are also searchable since you can use the textbox at the bottom of the page to filter the results displayed.

2.2.1.2 Overview of variable options When you choose the variables to be displayed, you will also see summary descriptions for the layer. These descriptions, statistics, and metadata for the chosen fields are displayed below the drop-down menus on the left side of the page.

TIP: As you prepare new layers, your updated descriptions will appear here.

The first selection you should make from the drop-down menus is the variable type. This means you can choose either **Input Layer** or **Output Score**. The **Input Layer** will show the layer used for a particular target you select. The targets in this case are either goals, pressures, resilience, or spatial information. The **Output Score** will show calculated scores for the alternative target selections you will make. In this case, the targets are Index or goal scores. In either case, you then have the option to further refine your search by either going into a specific layer or a specific dimension that is used in the overall Index calculations. If you do not make a selection, the **Output Score** is displayed by default.

For example, if you select **Output Score** as the variable type, you will then be able to choose a target goal or sub-goal, and then you will be able to choose the OHI dimension to be displayed. Remember that the



Figure 3: The Histogram sub-tab. Click on ‘Histogram’ to see the distribution of layers or scores after selecting a variable layer on the left. This example shows the Species sub-goal scores for the study regions of Ecuador.

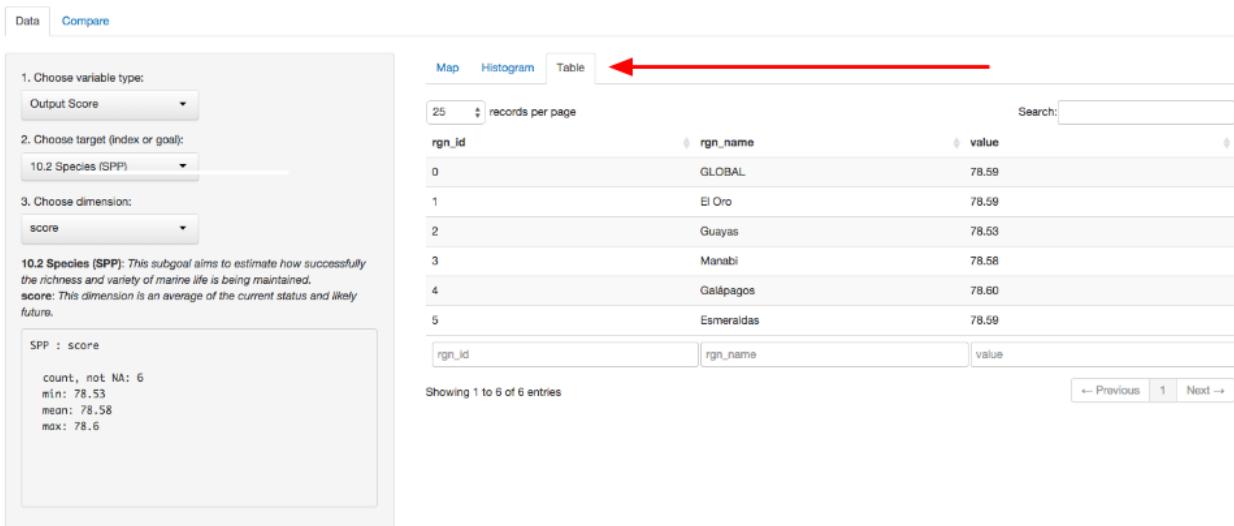


Figure 4: The Table sub-tab. Click on ‘Table’ to see a table of your data or scores, after selecting a variable layer on the left. This example shows the Species sub-goal scores for the regions of Ecuador.

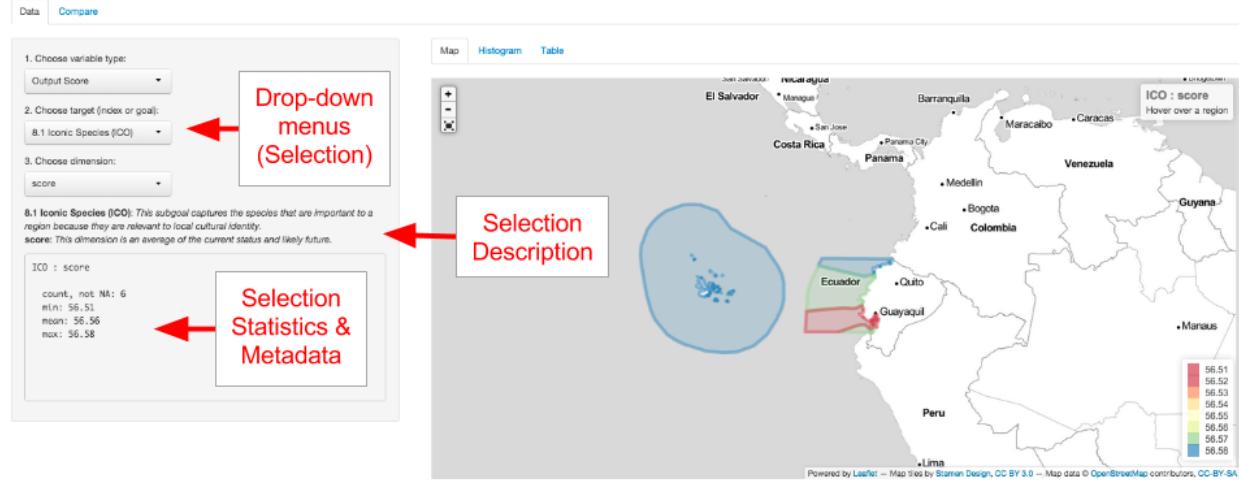


Figure 5: Overview of the Data tab. Choose the variable you would like to explore through the drop-down menus on the left-hand side of the page. Once you select either input data or an output score, you can view a description and summary of values below.

dimensions are status, trend, pressures, resilience, future state, and score. In this way you can investigate the components that combine to create the goal scores.

As another example, if you select **Input Layer** as the variable type, you will be able to choose a target such as a goal and a specific layer associated with that goal. If that input layer has multiple categories of input types, or if it has multiple years of information available, you will be able to select more specific information. If you do not make a selection, the default setting is the first alphabetical category and the most recent year available.

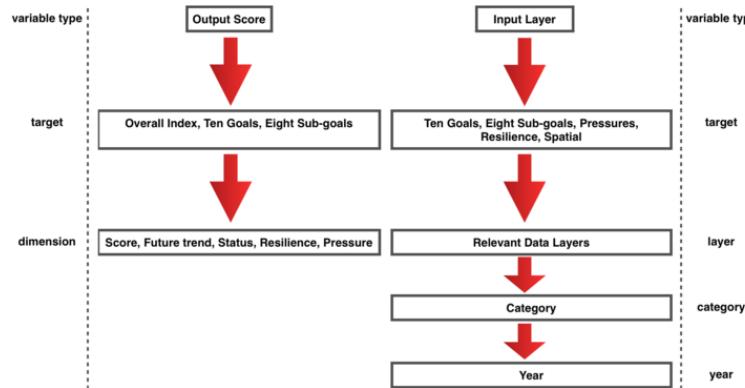


Figure 6: Overview of the variable options. You can choose to select and view either **input layers** or **output scores**.

2.2.2 The App's Compare tab

The **Compare** tab allows you to compare differences in calculated scores based on changes you have made to the underlying layers. These changes can be the values of the layers themselves, or they can be from changing the goal models. Any component you change is tracked through the archiving system of **GitHub** (See the section on **GitHub**) and each version of the changes be visualized here. You can take advantage of this ability to compare one saved version of your calculated Index output to another version of your calculated

output. This is done to compare the how changes made to your data or indicators for goals, pressures, or resilience would affect the resulting scores.

You can use this in two ways. One way is use this is to visualize updates as you make them: viewing differences is extremely helpful for error checking and for sharing tests to the data among your technical team. Another way to use the Compare tab is to compare different management scenario to how changes in your assumptions would impact score results. These changes could occur in the goal models themselves, such as through changes to targets or reference points, or they could be changes made to the values of pressures and resilience layers, for example.

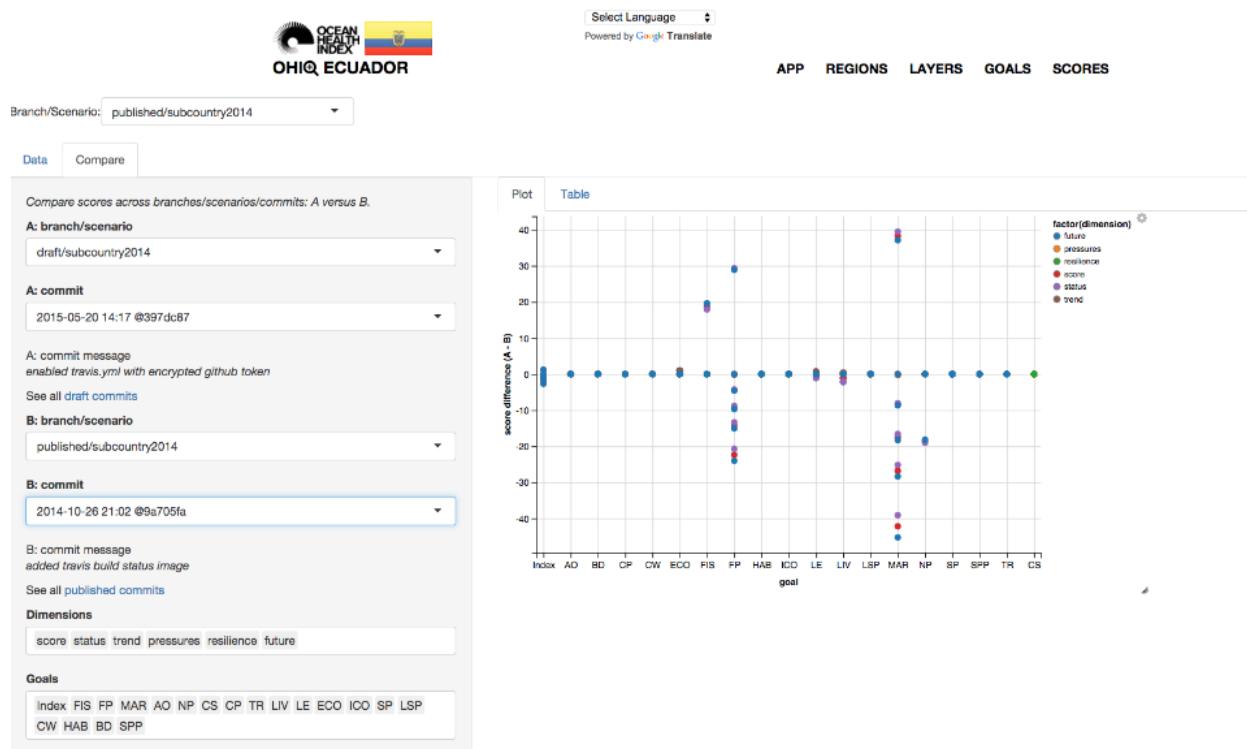


Figure 7: You can use the OHI+ WebApp’s ‘Compare’ tab to error check, and check the outcomes of alternate scenarios of your assessment.

The App page also offers the ability to view different **branches** or **scenarios** in the upper left-hand corner of the page. The **branches** refer to unique copies of a GitHub repository where information is stored. Each branch is a copy of a repository that is meant to be modified independently of other branches. This is done to ensure that changes made to one branch will not affect the information in another branch. This allows for active collaboration and offers a way to archive different outputs to Index calculations. For example, the *published* branch shows information that has been vetted for sharing, while the *draft* branch can be used for experimentation. These branches can be merged together at any time, and that is typically done when important milestones in the assessment process are reached. The *subcountry* folders displayed also offer another way to compartmentalize outcomes by allowing you to compare different *scenarios* within the same branch of your repository.

The App displays a *published* branch by default. It is recommended work on the *draft* branch until your assessment is finalized. When it is finalized, you can then merge the *draft* branch with the *published* branch.

These options for displaying and comparing information will be useful for understanding the multiple objectives in your OHI+ assessment.

3 Defining spatial boundaries

Defining spatial boundaries for the reporting regions (study area and regions) is a very important step in the assessment process. It is important because all data, analyses, and results will be at this spatial scale, and boundaries may be used to aggregate or disaggregate information reported at spatial scales different from your regions. Boundary definitions should match the purpose of the assessment and be informed by the scale at which information is available.

It is possible to redefine the spatial boundaries for your study area and regions. The boundaries displayed in your WebApp** are provided by default using subcountry region definitions from Global Administrative Areas (GADM: www.gadm.org).

Note that the OHI does not take a stance on disputed territories. The boundaries are defined by the original map data providers.

There is no limit to the number of regions that can exist within the study area; the size and number are only constrained by data availability and the utility of having scores calculated for a particular region. Although it is possible to assess only one region in the study area (i.e. the region is the assessment area), this might not be ideal because it eliminates the possibility of making comparisons or identifying geographic priorities within the study area.

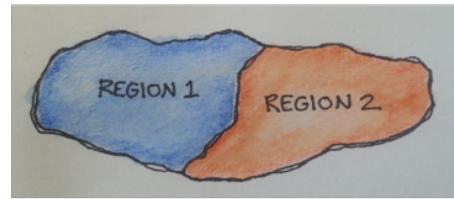
3.1 Drawing spatial boundaries

Spatial boundaries must be drawn with geographic information system (GIS) mapping software such as ArcGIS, QGIS, or GRASS. You will need someone with GIS skills to create a **shapefile** that will be used by the Toolbox to display your information. The shapefile will also be used to extract information for each of your defined regions when data are reported in raster format for a different area. For more information see https://en.wikipedia.org/wiki/Geographic_information_system and <http://en.wikipedia.org/wiki/Shapefile>.

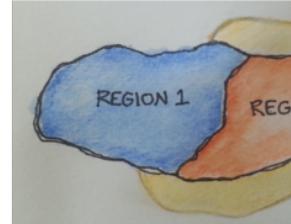
Regions must be unique (non-overlapping), and boundaries must be drawn offshore, extending to the exclusive economic zone (EEZ) edge in most cases. Offshore boundaries should be made with spatial methods in order to extend boundaries from those designated on land. One possible method is to create boundaries with Thiessen Polygons, and we provide a Python script that can be used, but it requires ArcGIS. The Python script and further details can be found at http://ohi-science.org/pages/create_regions.html. Using Thiessen Polygons, offshore boundaries are created with the following steps.

1. Start with land-based boundaries
2. Draw offshore buffers for each region

3. But the buffers overlap
4. For the Thiessen Polygon approach, the overlap is divided



1. Start with land-based boundaries



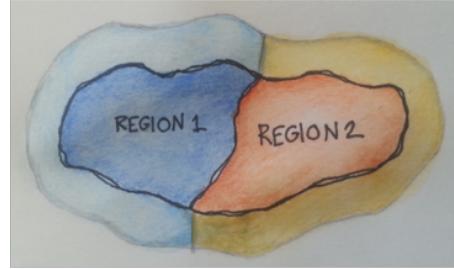
2. Draw offshore buffers



3. Offshore buffers overlap



4. With the Thiessen Polygons the overlap is divided



5. ...to produce the final map between the regions

5. To produce the borders between the regions

3.1.1 Updating the map in your WebApp

Once you have created your boundaries with GIS software, you will need to send them to us. Please send us a .zip file of all files produced. Files with the following extensions are required (but you can send all files):

- .dbf
- .shp
- .shx
- .prj

The .dbf file needs the following in its attribute table:

- **rgn_id** (unique numeric region identifier)
- **rgn_name** (unique named region identifier)
- **area_km2** or **area_hectare** (area in km² or hectares)

Note that we can send you the shapefiles used to create your WebApp if you would like to modify them.

3.1.2 Buffers

When drawing your regions, it is also a good idea to create inland and offshore buffers that will be used to extract data in your assessment. Buffers are not necessary for display in the WebApp but they will be

important for later layer preparation. For example, the global assessment used coastal population information, and raster data were available for entire countries. This meant that ‘coastal’ had to be defined: for global assessments it was defined as 25 miles from the coast. To extract just the coastal population from the population raster file, we created a 25 mile inland buffer for each reporting region. But to extract mangrove data for each region from raster files, global assessments used 1km inland and 1km offshore as the buffer.

At this point, you may not know which buffers you will need, as they depend on the data available, your goal models and definitions. Some buffers used in the global assessments were 1km inland, 25miles inland, 1km offshore, 3nm offshore.

4 Discovering and gathering input information

A hallmark of the OHI is that it uses freely-available existing information (data and indicators) to create the models that capture the philosophies of individual goals. The quality of the inputs are important because calculated Index scores area only as good as the inputs on which they are based. Assembling the appropriate input information, which means both discovering and gathering data and indicators, is an important part of any OHI assessment.

Once your team has tailored the OHI framework appropriately for your study area and identified the information that ideally would be included, the data discovery and gathering process can begin. There are many decisions to make when deciding which data are available and appropriate to include in your assessment. Finding appropriate data requires problem-solving abilities and creativity, particularly when ideal data are unavailable. You will need input information to calculate status models as well as pressures and resilience.

4.1 Thinking creatively

Remember that you are trying to capture information that is meaningful for ocean health.

Humans interact with and depend upon the oceans in complex ways, some of which are easy to measure and others of which are harder to define. More familiar measurements include providing seafood, or disposing of waste. A less familiar measurement is how marine-related jobs affect coastal communities, or how different people receive or perceive benefits simply from living near the ocean. Thinking creatively and exploring the information available can make your assessment more representative of reality.

Data used in OHI assessments spans a wide array of disciplines beyond oceanography and marine ecology. It is important to think creatively and beyond the interests of a specific institution or one particular field of study. Therefore, it is necessary to look beyond the most known or obvious data sources to find data relevant for the goals in the study area. Discussions with colleagues, literature searches, emails to experts, and search engines are good ways to understand what kinds of data are collected and to hunt for appropriate data. Investigate what kinds of information are available from government and public records, scientific literature, academic studies, surveys and reports etc.

4.2 Data sources

Existing data and indicators can be gathered from many sources across environmental, social, and economic disciplines. This includes government reports and project websites, peer-reviewed literature, masters and PhD theses, university websites, and information from non-profit organizations, among others.

All data must be rescaled to specific reference points (targets) before being combined with the Toolbox; therefore setting these reference points at the appropriate scale is a fundamental component of any OHI assessment. This requires your assessment team to capture the philosophy of each Index goal and sub-goal using the best available data and indicators. Indicators that are already scaled (e.g., from 0-1 or 0-10) can easily be incorporated into your assessment; they have already been scaled to some kind of identified target

or reference point. Data that have not been scaled in most cases will need to be, whether this is by scaling to the maximum value in the range or to some other understood value. You should think about how you would rescale data during your search.

Because data and indicators will come from different sources, they will also have different formatting. To include these data and indicators in your assessment, you will need to process these files into the format required by the Toolbox, which is explained in the section **Formatting Data for the Toolbox**. When data have been prepared and formatted for the Toolbox, they are called **layers**. Because creating layers can be quite time-intensive, data should only be prepared for the Toolbox after final decisions have been made to include the data or indicator in your assessment, and after the appropriate goal model and reference points have been finalized.

4.3 Gathering responsibilities

Gathering appropriate data requires identifying and accessing existing data. It is important that team members responsible for data discovery make thoughtful decisions about whether data are appropriate for the assessment. Data discovery and acquisition are typically an iterative process, as there are both practical and philosophical reasons for including or excluding data.

4.4 Requirements for data and indicators

There are six requirements to remember when investigating (or ‘scoping’) potential data and indicators that are presented in this section. It is important that data satisfy as many of these requirements as possible. To meet these requirements, you may have use appropriate methods to fill gaps in the data set. Data sources may need to be excluded from the analyses if requirements are not met and gap-filling solutions are not possible. If data cannot be included, you may elect to use layers from the global assessment or identify other data or modeling approaches.

4.4.1 Relevance to ocean health

There must be a clear connection between the data and ocean health, and determining this will be closely linked to each goal model.

4.4.2 Accessibility

The two main points regarding accessibility are whether the source is open access and whether the data or indicators will be updated regularly.

The Index was created in the spirit of transparency and open-access, using open-source software and online platforms such as GitHub, is to ensure as much accessibility and open collaboration as possible. Data and indicators included should also follow these guidelines, so that anyone wishing to understand more about the Index may be able to see what data were used and how. For this reason we emphasize the importance of using data that may be made freely downloadable, as well as the importance of clearly documenting all decisions and reasons for the choices made in selecting data, indicators, and models.

Index scores can be recalculated annually as new data become available. This can establish a baseline of ocean health and serve as a monitoring mechanism to evaluate the effectiveness of actions and policies in improving the status of overall ocean health. This is good to keep in mind while looking for data: will it be available again in the future? It is also important to document the sources of all data so that it is both transparent where it came from and you will be able to find it in the future.

4.4.3 Quality

Understanding how the data or indicators were collected or created is important. Are they collected by a respected organization with quality control? Are there any protocol changes to be aware of? For instance, were there changes in the collection protocol to be aware of when interpreting temporal trends?

4.4.4 Reference point

Most data will need to be scaled to a reference point. As you consider different data sources it is important to think about or identify what a reasonable reference point may be. Ask the following types of questions as you explore data possibilities:

- Has past research identified potential targets for these data?
- For example, fisheries goal require a Maximum Sustainable Yield (MSY).
- Have policy targets been set regarding these data?
- For example, maximum levels of pollutants allowed in beaches.
- Would a historic reference point be an appropriate target?
- For example, the percent of habitat coverage before coastal development took place.
- Could a region within the study area be set as a spatial reference point?
- For example, a certain region is regarded as the leader in creating protected areas.

4.4.5 Appropriate spatial scale

Data must be available for every region within the study area. It is not always possible to fully meet the spatial and temporal requirements with each source. In these cases, provided that the gaps are not extensive, it can still be possible to use these data if appropriate gap-filling techniques are used (See: **Formatting Data for Toolbox** section).

4.4.6 Appropriate temporal scale

Data must be available for ideally the five most-recent years to calculate the recent trend. For some goals, where temporal reference points are desirable, longer time series are preferable.

4.4.7 The process of information discovery

The most important thing to remember when gathering data and indicators is that they must contribute to measuring ocean health. Not all information that enhances our knowledge of marine processes directly convey information about ocean health and may not be appropriate within the OHI framework. Because of this, compiled indicators can sometimes be more suitable than raw data measuring single marine attributes.

Whether you are working goal-by-goal, or layer by layer, it is important to consider where you can find synergies in data discovery. For example, while you are looking for information for the fisheries goal, you may also find data layers for fishing pressures, such as metrics on bycatch or trawling intensity. This will save you time and allow you to start thinking about how to rank pressures and resilience weights on your goals as well. Conceptually, it will help your team build a picture of how your goals are interlocking in a way that is reflective of the actual linkages that exist in the connected systems you are studying. Some key examples are listed below, and are further explained in the following sections.

You should begin by understanding and comparing the best approaches used in assessments that have been completed, including the global assessments (Halpern *et al.* 2012; 2013), Brazil (Elfes *et al.* 2014), Fiji (Selig *et al.*, 2014), and the U.S. West Coast Assessment (Halpern *et al.*, 2014). For OHI+ assessments, if

finer-resolution local data were available in the study area, these data were either incorporated into modified goal models that used locally appropriate and informed approaches or into the existing global goal model. When local data were not available, the global-scale data and global goal models were used, which is least desirable because it does not provide more information than the global study.

When looking for data, the following decision tree may be useful when going goal-by-goal for discovering data and developing models:

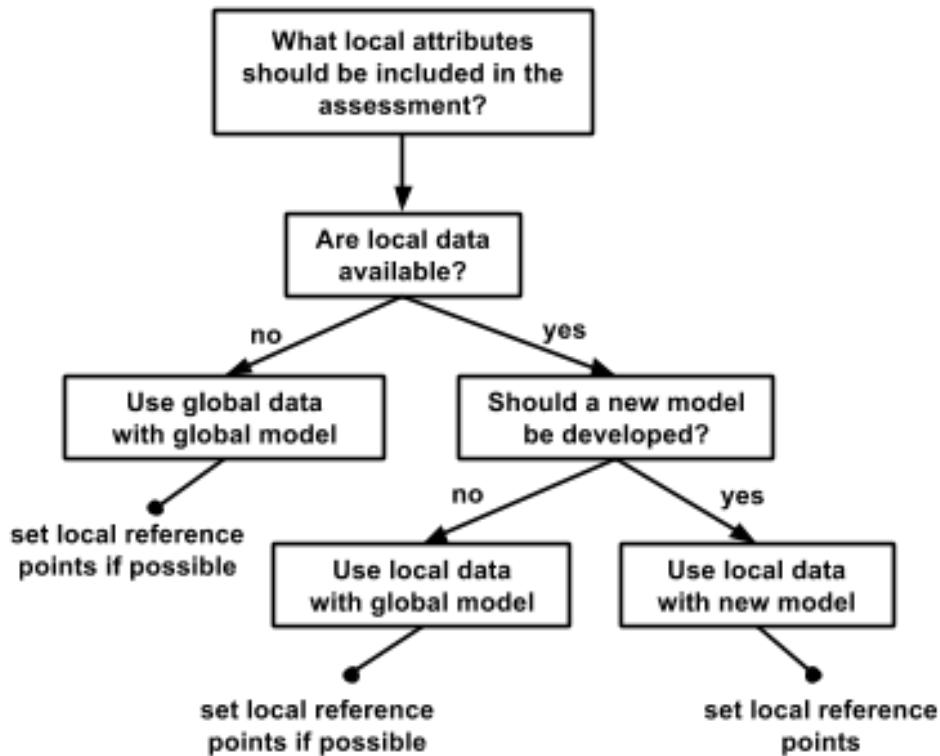


Figure 8:

4.4.8 Example: U.S. West Coast data discovery

Below are examples of some decisions made when exploring available data for the U.S. West Coast assessment. Determining whether certain data could be included began with a solid understanding of the layers and models included in the global assessment. Since the U.S. West Coast is a data-rich region, finer-resolution local data could be used in place of many of the global data layers. The U.S. West Coast assessment had five regions: Washington, Oregon, Northern California, Central California, and Southern California.

4.4.9 Reasons data were excluded

There are a lot of existing data that contribute to our scientific understanding of ocean processes and interactions but are not ideal for the OHI. Reasons to exclude data are both due to practical requirements (e.g., spatial or temporal resolution) and philosophical requirements (i.e., they do not help capture the attributes of interest for assessing ocean health). Some common reasons for excluding data are:

- **The data do not cover the entire area of the reporting region.** The state of California had excellent, long-term data on public attendance at state parks that would have been quite useful in the calculation of the tourism and recreation goal. However, data were only available for three of the five regions (the three California regions but not Oregon and Washington), so they could not be used.
- **There is not a clear and scientifically observed relationship between the data and ocean health.** Along the U.S. West Coast, kelp beds are a very important habitat because of their contribution to biodiversity and coastal protection. However, kelp coverage variation is driven primarily by abiotic natural forcing (wave or storm disturbance and temperature) and thus is not a good indicator of kelp forest health, particularly in the case of anthropogenic impacts. For these reasons kelp coverage was not included in the assessment.
- **The feature being measured may provide benefits to people, but this feature is not derived from marine or coastal ecosystems.** Sea walls and riprap provide coastal protection to many people along the U.S. West Coast. However, these structures are not a benefit that is derived from the marine ecosystems, so only coastal habitats were included in the calculation of this goal. These data can be included as a pressure due to habitat loss. They were not used as a resilience measure because they can often have negative side effects (e.g., by altering sedimentation dynamics), and because they have limited long-term sustainability (i.e., they need maintenance).
- **Data collection is biased and might misrepresent ocean health.** The U.S. Endangered Species Act identifies a species list focused on species of concern within the US. As such, these data are biased in the context of ocean health since they only assess species whose populations may be in danger. For the calculation of the biodiversity goal, using these data would be inappropriate because this goal represents the status of all species in the region, not just those that are currently of conservation concern. Using these data may have shown the status of biodiversity to be lower than it really is because the selection of species to assess was already biased towards species of concern.
- **Time series data are not long enough to calculate a trend or a reference point** (when a historical reference point is most appropriate). For the U.S. West Coast, the current extent of seagrass habitats was available, however, these do not exist for previous points in time in most areas, so could not be used to calculate the trend or set a historical reference point. Therefore, we estimated the trend in health of seagrass habitats using as a proxy the trend in the main stressor (i.e., turbidity). In other words, we assumed that the rate of seagrass loss was directly proportional to the rate of increase in turbidity. Similar solutions may be used to estimate trends in your own assessment, if there is scientific support for assuming that the trend of what we want to assess (or the relationship between the current state and the state in the reference year) has a strong relationship with the trend of the proxy data available.

4.5 Developing Goal Models and Setting Reference Points

Once you have determined which goals are assessed and have begun searching for data and indicators, you can start to develop goal models and set reference points. The decision tree of the data discovery process also applies here: first consider how goals can be tailored to your local context before you consider replicating what was done in the Global Assessments. It is always better to use local goal model and reference point approaches where possible.

4.5.1 Developing multiple goal models at the same time

Goals can be assessed independent of one another. As each goal model is developed and data gathered, it can be assessed without affecting other goals.

However, you can develop some goal models simultaneously and streamline the data search. For example, the habitat-based goals **Carbon Storage**, **Coastal Protection**, and the **Habitats sub-goal of Biodiversity**

all rely on the same underlying data, and their models can be developed together. A spatial analyst can create the spatial layers used for these goals with the same source material. This will greatly expedite your data layer preparation. Species data for **Iconic Species sub-goal of Sense of Place** is often a subset of data from **Species sub-goal of Biodiversity**. Data for non-food marine products for **Natural Products** and food products for **Fisheries sub-goal of Food Provision** are often recorded in similar data sources and may need partitioning.

If you wish to further coordinate these activities on a higher level, you could have the same team member coordinate activities for the development of certain goals. That is a consideration when assembling your team and planning your workflow. For more details, please see the goal-specific sections.

4.5.2 Keeping Reference Points in Mind

Setting a reference point is required for every goal model you develop. It is an “ideal” condition, or target, where the goal is considered to be achieved to its full potential. Achieving or exceeding the reference point will result in a score of 100. The choice of a reference point will thus affect how the final scores are calculated, and must be balanced between knowledge of the system, expert judgment, and limitations of the data. You may set an universal reference point for all regions in your study area, or you may set a unique reference point for each region.

Generally there are four types of reference points: + *Functional*: Scientifically sound target set based on the known responses of variables measured, such as Maximum Sustainable Yield. + *Temporal*: A historical benchmark is used as a the “ideal” point in the past, such as mangrove coverage in the 1980’s. + *Spatial*: A region within the study area with the highest input values, and all others are scaled to it. + *Established target*: Such as a sustainable catch yield by a certain year, or the number of people employed in a marine sector by a certain year.

Which type of reference point to use depends on the goal and available data. How many years of data are available? Can you set a temporal reference point with these data, or do you have to find another dataset or other source of information? In any case, you must balance being realistic with being ambitious. We suggest following the S.M.A.R.T. criteria when choosing a reference point: “*Specific*,” “*Measurable*,” “*Ambitious*,” “*Realistic*,” and “*Time-bound*.”

You will learn more, and think more critically about reference points, as you develop the data layers for your assessment.

How to use the reference point in a model

It’s best to explicitly include the reference point in the model equation whenever possible. For example, the Carbon Storage goal model in the global assessment is written like this:

$$x_{CS} = \sum_1^k \frac{C_s}{C_r} * \frac{A_k}{A_T},$$

where Cr is the reference condition of each habitat. See goal-specific sections for more examples.

4.5.3 Identifying pressures and resilience

While you are developing goal models, you should note the links between your goals and pressures and resilience: both the pressures and resilience that affect them and whether the goal acts as pressure or resilience on other goals. It is recommended to begin gathering data of pressure and resilience from the start of the assessment. The team members who are developing specific goals should think about the pressures that act upon those goals as they are data-gathering, and they should think about the data sources that could provide pressures information. However, it may be most useful when one team member gathers all of the data for

pressures, since the same pressures often affect multiple goals. See **Pressure and Resilience** section of this chapter for more information.

Some pressure data are the same or closely-related to data for goals. For example, the **Wild-Caught Fisheries** goal model requires catch data, which may be the same data source for information on commercial high- and low-bycatch data, which are used as pressures layers that affect **Livelihoods and Economies** and **Biodiversity**. In global assessments, the **Clean Waters** goal is very much linked to pressures layers because the input layers for its status are used as pressure layers. Trash pollution is a pressure that affects **Tourism and Recreation**, **Lasting Special Places**, **Livelihoods and Economies**, and **Species**. It is important to remember these linkages as you go through the data discovery process.

You should also start searching for pressures data independent from data for goals. An example would be how climate change impacts will appear in various places in your assessment. Climate change pressures layers can include UV radiation, sea surface temperature (SST), sea-level rise (SLR), and ocean acidification, and these impacts might affect such goals as **Natural Products**, **Carbon Storage**, **Coastal Protection**, **Sense of Place**, **Livelihoods and Economies**, and **Biodiversity**. These linkages will become more clear as you go through the OHI+ assessment process.

->

5 The Ocean Health Index Toolbox

Section Summary:

In this section, you will learn the basics of how to use the OHI Toolbox to conduct your assessment.

You will be introduced to files the Toolbox requires, how you will modify them, and how they interact to calculate the final output scores.

The **OHI Toolbox** is an ecosystem of small files and scripts that are the tools needed to calculate OHI scores. These files and scripts are stored in two ‘*repositories*’: folders that are synchronized with collaborators. The first folder is your **assessment repository** that has a three-letter code, such as *esp* for Spain or *ecu* for Ecuador. You will edit this repository with your data, goal models, and updated pressures and resilience matrix tables. The second repository is called **ohicore** and it contains core functions for combining your data and goal models to calculate OHI scores. You will not edit **ohicore**, but you are able to explore it to understand the calculations.

Your **assessment repository** contains data input layers, configuration files, and scripts. These files are organized in the same way within a *scenario folder* called **subcountry2014**, with data layers, goal model equations, and configuration files from the global 2014 assessment. Files within the scenario folder are comma-separated-value (*.csv*) files and scripts written in the programming language *R*.

Each **OHI+ assessment repository** has inputs and goal models based on the 2014 global assessment. This means that each assessment repository isolates the information used for each region in the global assessment and stores it in a separate OHI+ assessment repository. Therefore, it can be an easy way to explore the inputs used in the global assessment for one specific place. When conducting an assessment, you will replace and modify as much of this information with local information that better represents your study area, since information reported at a national scale cannot always be attributed to its subcountry regions, as has been done in most cases in each OHI+ assessment repository. See more details in the discussion of the **layers folder**.

The Toolbox is open-source and can be downloaded and installed for free. You are able to navigate through these files both at www.github.com/OHI-Science and on your own computer once you have cloned the repository to your computer. GitHub is an online platform used by the OHI that facilitates collaboration and archives past versions of all files with the author identified. It can be accessed remotely by all members of your team and enables team members to synchronize their work together. Because all versions are saved, you

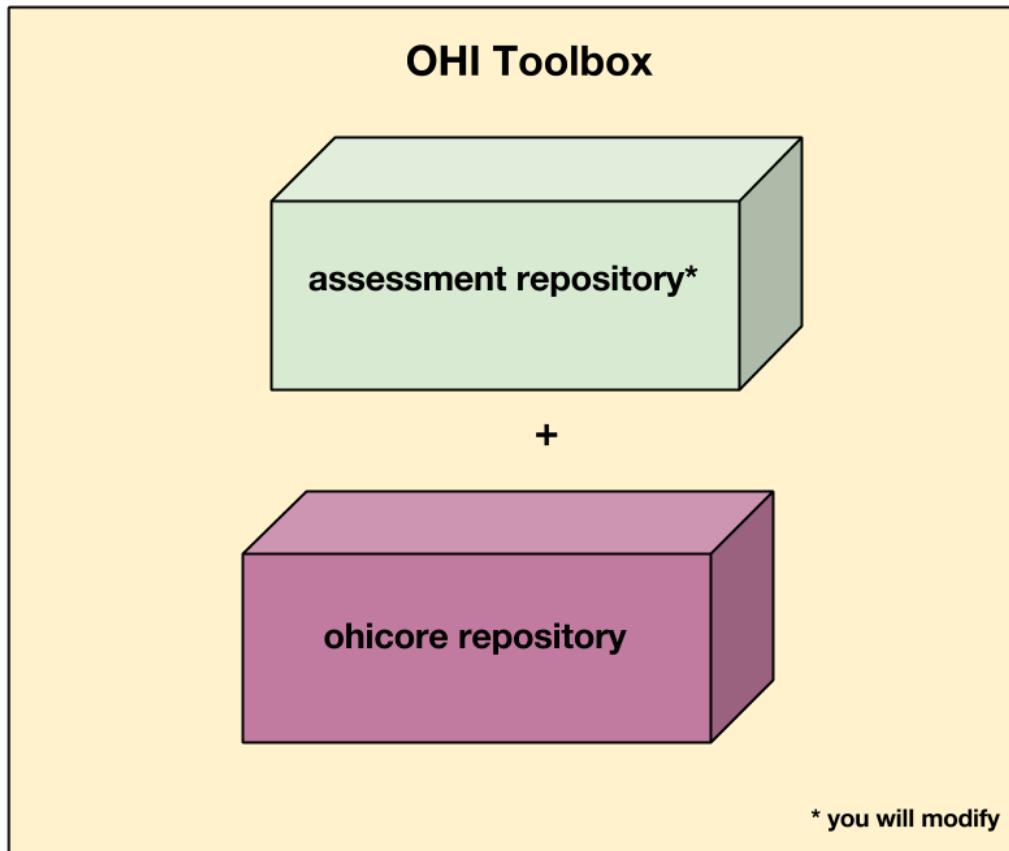


Figure 9: Toolbox = your repo + ohicore

can return to previous work and also compare different points in history to track how changes you make affect the output scores. Instruction on how to access your assessment repository is in the [Installing the Toolbox](#) section.

The following sections will describe the files included in the Toolbox. You will then learn what is required for data layers for your assessment and how to change goal models.

5.1 File system organization

This section is an orientation to the files within your assessment repository. The file system organization is the same for all assessment repositories, and can be viewed at github.com/OHI-Science or on your computer. While reading this section it is helpful to explore a repository at the same time to become familiar with its contents and structure. The following uses the assessment repository for Ecuador (*ecu*) as an example, available at www.github.com/OHI-Science/ecu.

Most of your time will be spent preparing input layers and developing goal models. You will also register prepared layers to be used in the goal models. This all will be an iterative process, but generally speaking you will work goal-by-goal, preparing the layers first, registering them, and then developing the goal models in *R*. to calculate the scores.

5.1.1 Assessment repositories

Assessment repositories are identified by a three-letter code; Ecuador's assessment repository is called '*ecu*'. Assessment repositories contain several things:

- The **scenario folder** is the most important folder within the repository; by default it is named **subcountry2014**. It contains all of the inputs needed to calculate OHI scores, and you will modify these inputs when conducting your assessment. The scenario folder is explained in detail in this section.
- All other files in the assessment repository are accessory files. Files with names beginning with a ‘.’ are required for versioning capabilities by GitHub and do not appear when the assessment repository is viewed on your computer.

5.1.2 Scenario folders

Scenario folders contain all files and scripts necessary to calculate OHI scores. There are two file types:

- **** .csv files**** contain data inputs or configuration information.
- **** .R scripts**** are written in the programming language R and use data inputs for processing and calculations.

There is one scenario folder in your assessment repository and it is called **subcountry2014** to indicate that the assessment is conducted at the subcountry scale (province, state, district, etc.), based on input layers and goal models used in the 2014 global assessment. When conducting your assessment, you can rename your scenario folder to reflect the subcountry regions in your study area and year the assessment was completed. For example, **province2015** would indicate the assessment was conducted for coastal provinces in the year 2015.

Once you complete your assessment with the **subcountry2014** (or equivalent) scenario, further assessments can be done simply by copying the **subcountry2014** folder and renaming it. This can be done for future assessments, for example **subcountry2016** or **subcountry2018**, which eventually would enable you to track changes in ocean health over time. You can also copy scenario folders to explore different policy and management scenarios, for example **subcountry2014_policy1**.

www.github.com/OHI-Science/ecu ← **assessment URL**

GitHub This repository Search Explore Features Enterprise Blog

OHI-Science / ecu ← **assessment repository**

Ocean Health Index for Ecuador <http://ohi-science.org/ecu> ← **WebApp URL**

88 commits 4 branches 0 releases 1 contributor

branch: draft / +

Update .travis.yml
bbest authored on Nov 23, 2014 latest commit dc4099fc9f

scenario folder

File	Commit Message	Time Ago
subcountry2014	Update goals.Rmd	2 months ago
.Rbuildignore	auto-calculate from commit c449dfc	2 months ago
.gitignore	adding debug files to .gitignore	2 months ago
.travis.yml	Update .travis.yml	2 months ago
README.md	Update README.md	2 months ago
ecu.Rproj	install_github git2r	2 months ago

Figure 10:

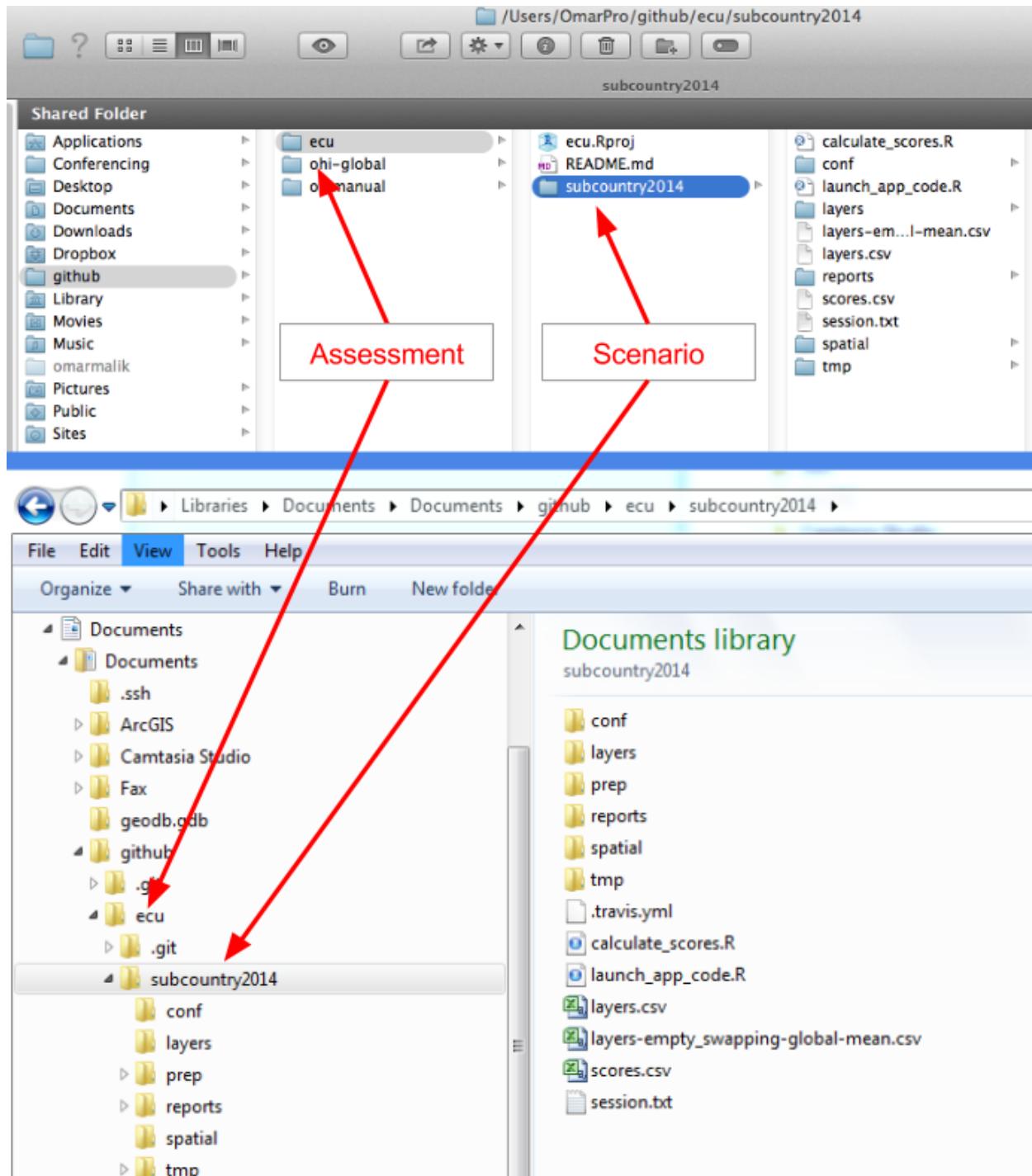


Figure 11: Navigating the assessment repository. The figure shows Mac folder navigation above and Windows navigation below.

5.1.3 subcountry2014 contents

This figure illustrates the files contained within the assessment repository's `subcountry2014` scenario folder. Important files are either `.csv` text files or `.R` script files. Files are organized into different folders within the `subcountry2014` folder, and you will modify some of these files while leaving others as they are.

File system organization of the Ocean Health Index Toolbox

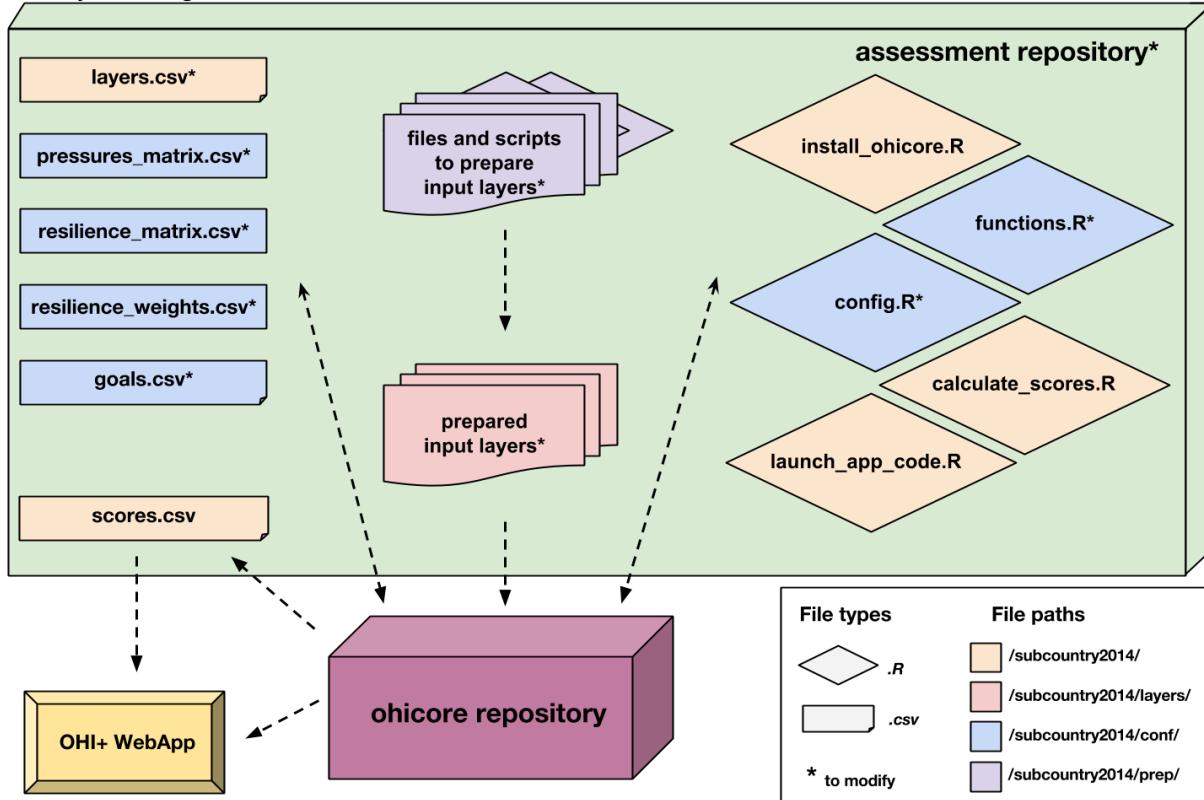


Figure 12: File system organization of the Ocean Health Index Toolbox

Files and folders are presented here in alphabetical order. See the **Using the Toolbox** section for the workflow of how you will use the files.

5.1.3.1 `calculate_scores.R` `calculate_scores.R` is a script that runs everything required to calculate OHI scores using the prepared layers the `layers` folder that are registered in `layers.csv`. Scores will be saved in `scores.csv`.

5.1.3.2 `conf` folder The `conf` folder includes important configuration files required to calculate OHI scores. There are both `.R` scripts (`config.R` and `functions.R`) and `.csv` files (`goals.csv`, `pressures_matrix.csv`, `resilience_matrix.csv`, and `resilience_weights.csv`).

5.1.3.3 `config.R` `config.R` is an R script that configures labeling and constants appropriately. You will only need to modify this file when working with goals that have categories (example: habitat types or economy sectors) that are affected differently by pressures and resilience measures.

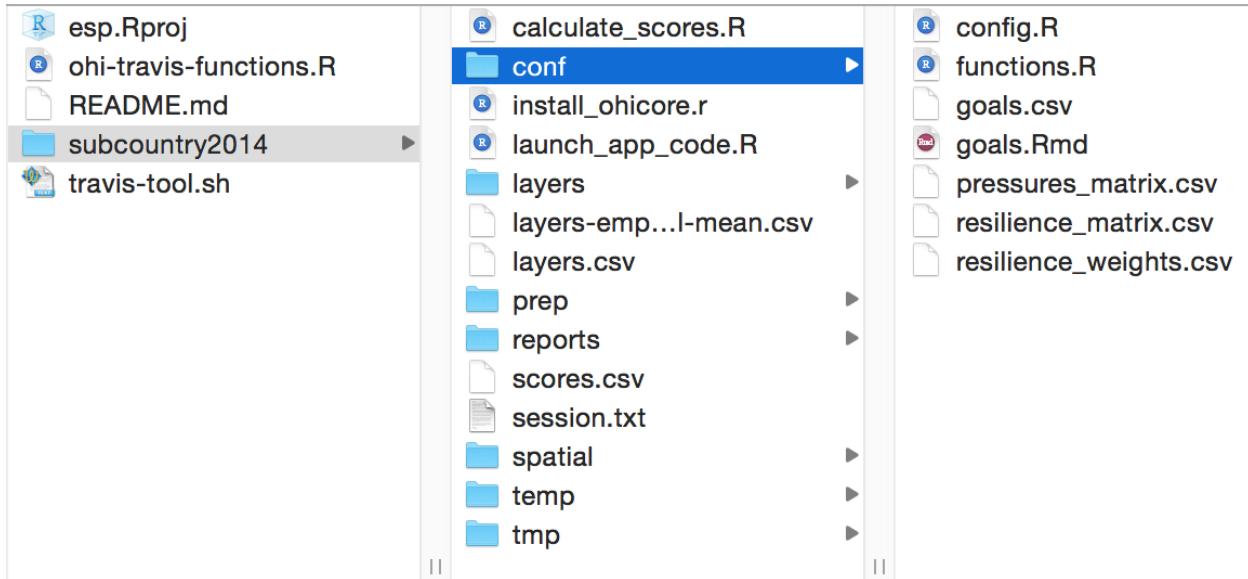


Figure 13: The `conf` folder contains important R functions and `.csv` files.

5.1.3.4 *install_ohicore.R* `install_ohicore.R` is a script that will install `ohicore`, which is the second repository required for the Toolbox and is the engine behind all OHI calculations. You will need to run this script only once when you begin.

5.1.3.5 *functions.R* `functions.R` is an R script containing the equations for each goal and sub-goal model. Each goal and sub-goal equation is stored as a separate function within the script. These functions calculate the status and trend using prepared layers saved in the ‘`layers`’ folder and registered in `layers.csv`. You will need to code in R to modify or develop new models, and it is best to work on one goal at a time.

5.1.3.6 *goals.csv* `goals.csv` is a table with information about goals and sub-goals. This includes the weight of each goal that is used to calculate the final Index scores when all goals are combined. Other information includes the goal description that is also presented in the WebApp. `goals.csv` also indicates the arguments passed to `functions.R`. These are indicated by two columns: `preindex_function` (functions for all goals that do not have sub-goals, and functions for all sub-goals) and `postindex_function` (functions for goals with sub-goals).

TIP: It’s important to check `goals.csv`’s weightings and preindex functions when you change goal or sub-goal model equations in `functions.r`.

5.1.3.7 *launch_app_code.R* `launch_app_code.R` will launch a version of the App on your computer so that you can visualize any edits you make before synching to `github.com`.

5.1.3.8 *layers folder* The `layers` folder contains all layers required to calculate goal scores, and each layer is an individual `.csv` file. The names of the `.csv` files within the `layers` folder correspond to those listed in the `filename` column of the `layers.csv`. All `.csv` files can be read in R, or with text editors or spreadsheet editors like Microsoft Excel.

Note that each `.csv` file within the `layers` folder has been formatted consistently. The Toolbox expects all data layers to be in the correct ‘long format’ and in separate files (see **Using the Toolbox**). Each file also has a column with unique region identifier (`rgn_id`). These numeric region identifiers have region names associated with them, that are set in `rgn_labels.csv` and can be modified.

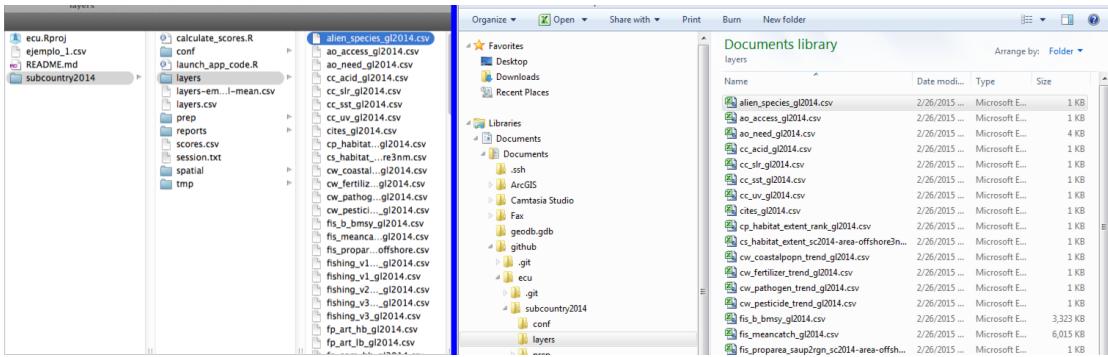


Figure 14: The `layers` folder contains every data layer as an individual `.csv` file. Mac navigation is shown on the left and Windows navigation is shown on the right.

TIP: You can check your region identifiers (`rgn_id`) in the `rgn_labels.csv` file in the `layers` folder.

5.1.3.8.1 *`_gl2014*` and *`_sc2014*` suffixes In your repository, layers are provided for your country based on input information from the 2014 global assessment. The global assessment had information for your country at the the spatial scale of the entire country, whereas your assessment has information for each subcountry region within your country. In most cases, layers from the global assessment was allocated equally to all regions in your study area (country). When this occurred, the layer was given a suffix of `_gl2014` to indicate that information is equal across all regions in the study area. While these layers may not provide much useful information to your assessment, the proper input structure is provided in these layers. Some layers contain information such as km² of habitat that could not be equally allocated across all regions since this would provide a sum much greater than reality. In these cases, layers were down-weighted based on the proportion of offshore area or coastal population density. These layers have the suffix `_sc2014` with an indication of what was used to downweight. While this method removes any error of inflated sums and provides the Toolbox with functioning layers, the allocation of these values may not be sensical to your study (i.e. if corals are only present in some regions of your study area but they are allocated to all).

5.1.3.9 `layers-empty_swapping-global-mean.csv` `layers-empty_swapping-global-mean.csv` contains a list of layers where information for your country was not available for the global assessment. For the Toolbox to be able to run, these layers were filled with averages from all other countries included in the global assessment. This file is not used anywhere by the Toolbox but is a registry of layers that should prioritized to be replaced with your own local layers if you require these layers for the models you develop.

5.1.3.10 `layers.csv` The `layers.csv` file is the registry and directory that manages all data required for you assessment. All relevant input information is prepared as individual data layers and then registered in this file. The Toolbox uses `layers.csv` to access the proper input information and display information on the WebApp. You will update some of the columns in `layers.csv`, and some of them will be auto-generated by the Toolbox code when it is running.

TIP: `layers.csv` is a very useful reference throughout the assessment process.

`layers.csv` is easiest to view in spreadsheet software (i.e. Microsoft Excel). When you open it, you will see that each row of information represents an individual input layer that has been prepared for the Toolbox. The first columns contain information that will be updated by your team as you incorporate modified or new layers; all other columns are generated later by the Toolbox as it confirms data formatting and content

Figure 15: Differences in input layers with equal information for each region (suffixed with `_gl2014`) and weighted information for each region (suffixed with `_sc2014`).

1	targets	layer	name	description	fld_value	units	filename
2	AO	ao_access	Fisheries management	The opportunity for value	value		ao_access.csv
3	AO	ao_need	Purchasing power	The per capita pu value	value		ao_need.csv
4	CW	cw_coastalpopn_trend	Coastal human population	Coastal population trend	trend score		cw_coastalpopn_trend
5	CW	cw_fertilizer_trend	Fertilizer consumption	Statistics on fertilizer trend	trend score		cw_fertilizer_trend
6	CW	cw_pathogen_trend	Trends in access	Trends in percent trend	trend score		cw_pathogen_trend
7	CW	cw_pesticide_trend	Pesticide consumption	Statistics on pesticide trend	trend score		cw_pesticide_trend
8	FIS	fis_b_bmsy	B/Bmsy estimates	Estimated B/Bmsy	B / B_msy		fis_b_bmsy.csv
9	FIS	fis_meancatch	Catch data for each area	Reported data including mean catch	metric tons		fis_meancatch.csv

Figure 16:

and alerts you of any formatting inconsistencies. The columns you will update are: *targets*, *layer*, *name*, *description*, *fld_value*, *units*, *filename*.

Columns you will update

- **targets** indicates which goal or dimension uses the layer. Goals are indicated with two-letter codes and sub-goals are indicated with three-letter codes (see the table just below). Pressures, resilience, and spatial layers indicated separately.
- **layer** is the identifying name of the input layer that will be used in R scripts like **functions.R** and **.csv** files like **pressures_matrix.csv** and **resilience_matrix.csv**. This is also displayed on the WebApp under the drop-down menu when the variable type is ‘input layer’.
- **name** is a longer title of the input layer; this is displayed on the WebApp under the drop-down menu when the variable type is ‘input layer’.
- **description** is further description of the input layer, including the source of the original data. This is also displayed on the WebApp under the drop-down menu when the variable type is ‘input layer’.
- **fld_value** the values’ units in the input layer. The information in this column must match the column header in the input layer.
- **units** the values’ units in the input layer. This differs from *fld_value* above as the *units* column is displayed on the WebApp and can have more descriptive naming.
- **filename** is the input layer itself. This file has input information for each region within the study area, and is located in the **subcountry2014/layers** folder.

Goal	Subgoal	2- or 3- letter code
Food Provision		FP
	Fisheries	FIS
	Mariculture	MAR
Artisanal Fishing Opportunity		AO
Natural Products		NP
Coastal Protection		CP
Carbon Storage		CS
Livelihoods and Economies		LE
	Livelihoods	LIV
	Economies	ECO
Tourism and Recreation		TR
Sense of Place		SP
	Lasting Special Places	LSP
	Iconic Species	ICO
Clean Waters		CW
Biodiversity		BD
	Habitats	HAB
	Species	SPP

5.1.3.11 prep folder The **prep** folder is included in your repository so that layer preparation can be collaborative and version controlled. It is not necessary to use this folder but you may find it useful as other assessments have.

5.1.3.12 pressures_matrix.csv **pressures_matrix.csv** is a table that indicates which individual pressures (stressors) affect which goal, sub-goals, or components, and weights them from 1-3 (a weight of 0 is shown as a blank). These weights are relative to each row of the matrix (goal, sub-goal, or component). These weights are used in global assessments based on scientific literature and expert opinion, and you can

modify the weightings if necessary for your assessment. The pressures matrix is the same as Table S25 in the Supplementary Information for Halpern *et al.* 2012.

Each pressure (column) of the pressures matrix is the layer name of the pressures layer file that is saved in the `layers` folder and is registered in `layers.csv`. Pressures layers have values for every region in the study area and the filenames have prefixes to indicate the pressure category (for example: `po_` for the pollution category). Pressures values are scaled such that all values range from 0-1.

5.1.3.13 *reports* folder The `reports` folder contains flower plots and tables for every region in the study area and for the study area itself, which by convention is called ‘GLOBAL’ in these files.

5.1.3.14 *resilience_matrix.csv* `resilience_matrix.csv` is a table that indicates which individual resilience measures affect which goal, sub-goals, or components. Like the pressures matrix, the resilience matrix also has weights, but these weights depend on the level of information available. These weights are stored in a separate file in the `conf` folder: `resilience_weights.csv`. The resilience matrix is the same as Table S26 in the Supplementary Information for Halpern *et al.* 2012.

Each resilience measure (column) of the resilience matrix is the layer name of the resilience layer file that is saved in the `layers` folder and is registered in `layers.csv`. Resilience layers have values for every region in the study area. Resilience values are scaled such that all values range from 0-1.

5.1.3.15 *resilience_weights.csv* `resilience_weights.csv` is a table that indicates the weight of each resilience layer based on the level of information available.

5.1.3.16 *scores.csv* `scores.csv` is a text file containing the calculated scores for each dimension (future, pressures, resilience, score, status, trend) for each region in the study area. Regions have the numeric identifiers set in `subcountry2014/layers/rgn_labels.csv` and the study area has the numeric identifier of 0. Scores are calculated with registered layers in `layers.csv`: when you begin an assessment this will be information for your country from the global 2014 assessment and goal models from the global 2014 assessment. Scores from `scores.csv` are viewed through the WebApp using the ‘Output Score’ pulldown menu on the ‘App’ page.

5.1.3.17 *session.txt* `session.txt` is not used in OHI calculations but stores information about how the Toolbox was installed which may be useful for debugging purposes.

5.1.3.18 *spatial* folder The `spatial` folder contains two spatial files: `regions_gcs.geojson` and `regions_gcs.js`. These files spatially identifies the study area and regions for the assessment and are stored in the JSON and GeoJSON formats that can be displayed by the App. If you plan to redefine the spatial boundaries for your assessment, you will need to provide a shapefile to the OHI+ development team and we will create the proper `regions_gcs.geojson` and `regions_gcs.js` files for you. You will need a spatial analyst to do this: see the **Defining spatial boundaries** section for instruction.

5.1.3.19 *temp* or *tmp* folders Contents within the `temp` or `tmp` folders are not used to calculate scores but can be used for temporary organization for your assessment.

5.2 Formatting Data for the Toolbox

5.2.1 Introduction

The OHI Toolbox is designed to work in the programming language **R** using input data stored in text-based `.csv` files (`csv` stands for ‘comma-separated value’; these files can be opened as a spreadsheet using Microsoft

Excel or similar programs). Each data layer (data input) has its own *.csv* file, which is combined with others within the Toolbox for the model calculations. These data layers are used for calculating goal scores, meaning that they are inputs for status, trend, pressures, and resilience. The global analysis included over 100 data layer files, and there will probably be as many in your own assessments. This section describes and provides examples of how to format the data layers for the Toolbox.

OHI goal scores are calculated at the scale of the reporting unit, which is called a ‘**region**’ and then combined using an area-weighted average to produce the score for the overall area assessed, called a ‘**study area**’. The OHI Toolbox expects each data file to be in a specific format, with data available for every region within the study area, with data layers organized in ‘long’ format (as few columns as possible), and with a unique region identifier (*rgn_id*) associated with a single *score* or *value*. In order to calculate trend, input data must be available as a time series for at least 5 recent years (and the longer the time series the better, as this can be used in setting temporal reference points).

The example below shows information for a study area with 4 regions. There are two different (and separate) data layer files: tourism count (*tr_total.csv*) and natural products harvested, in metric tonnes (*np_harvest_tonnes.csv*). Each file has data for four regions (1-4) in different years, and the second has an additional ‘categories’ column for the different types of natural products that were harvested. In this example, the two data layers are appropriate for status calculations with the Toolbox because:

1. At least five years of data are available,
2. There are no data gaps
3. Data are presented in ‘long’ or ‘narrow’ format (not ‘wide’ format – see “**Long Formatting**” section).

5.2.2 Uploading and formatting raw data files

Unformatted data files can be uploaded to the `pre-proc` folder in your github repository and processed with R. Saving raw data in the same repository helps to keep track of how the data has been treated. Raw files can be uploaded as *.csv* or *.xlsx*. However, formatted data has to be saved as *.csv* in the `layers` folder.

In addition to `pre-proc`, a `prep` folder has been set up for data formatting. Inside the folder: - several sub-folders exist to house formatted data files for each goal/sub-goal - `prep.r` is where formatting occurs for each goal/sub-goal. - `README` is where you can record information on raw data files and processing for future reference

Example of data in the appropriate format:

<code>rgn_id</code>	<code>year</code>	<code>count</code>
1	2005	177.14
1	2006	201.39
1	2007	199.81
1	2008	212.99
1	2009	228.81
2	2005	580.98
2	2006	730.18
2	2007	717.00
2	2008	851.44
2	2009	836.68
3	2005	129.69
3	2006	173.45
3	2007	229.86
3	2008	231.44
3	2009	221.95
4	2005	397.00
4	2006	566.00
4	2007	591.00
4	2008	1154.00
4	2009	1570.00

<code>rgn_id</code>	<code>product</code>	<code>year</code>	<code>tonnes</code>
1	ornamentals	2005	10327
1	ornamentals	2006	10389
1	ornamentals	2007	10897
1	ornamentals	2008	9985
1	ornamentals	2009	9001
2	shells	2005	6179
2	shells	2006	6823
2	shells	2007	8239
2	shells	2008	8819
2	shells	2009	9205
3	coral	2005	22079
3	coral	2006	25297
3	coral	2007	25361
3	coral	2008	23817
3	coral	2009	23623
4	shells	2005	7500
4	shells	2006	9700
4	shells	2007	8600
4	shells	2008	9400
4	shells	2009	9300

Figure 17:

5.2.3 Gapfilling

It is important that data prepared for the Toolbox have no missing values or ‘gaps’. Data gaps can occur in two main ways: 1) **temporal gaps**: when several years in a time series in a single region have missing data, and 2) **spatial gaps**: when all years for a region have missing data (and therefore the whole region is ‘missing’ for that data layer).

How these gaps are filled will depend on the data and regions themselves, and requires thoughtful, logical decisions to most reasonably fill gaps. Each data layer can be gapfilled using different approaches. Some data layers will require both temporal and spatial gapfilling. The examples below highlight some example of temporal and spatial gapfilling.

All decisions of gapfilling should be documented to ensure transparency and reproducibility. The examples below are in Excel, but programming these changes in software like R is preferred because it promotes easy transparency and reproducibility.

5.2.3.1 Temporal gapfilling Temporal gaps occur when a region is missing data for some years. The Toolbox requires data for each year for every region. It is important to make an informed decision about how to temporally gapfill data.

rgn_id	year	count
1	2005	177.14
1	2006	
1	2007	
1	2008	212.99
1	2009	228.81
2	2005	580.98
2	2006	730.18
2	2007	717.00
2	2008	851.44
2	2009	836.68
3	2005	129.69
3	2006	173.45
3	2007	229.86
3	2008	231.44
3	2009	
4	2005	397.00
4	2006	566.00
4	2007	
4	2008	1154.00
4	2009	1570.00

In this data layer, there are three regions that have missing values for one or more years and will require temporal gapfilling:
Regions 1, 3, 4.

No regions in this example require spatial gapfilling.

Figure 18:

Often, regression models are the best way to estimate data and fill temporal gaps. Here we give an example that assumes a linear relationship between the year and value variables within a region. If data do not fit a linear framework, other models may be fit to help with gapfilling. Here we give an example assuming linearity.

Using a linear model can be done in most programming languages using specific functions, but here we show this step-by-step using functions in Excel for Region 1.

Temporal gapfilling example (assumes linearity: able to be represented by a straight line on a graph):

There are four steps to temporally gapfill with a linear model, illustrated in the figures with four columns.

1. Calculate the slope for each region

The first step is to calculate the slope of the line that is fitted through the available data points. This can be done in Excel using the **SLOPE(known_y's,known_x's)** function as highlighted in the figure below. In this case, the x-axis is *years* (2005, 2006, etc...), the y-axis is *count*, and the Excel function automatically plots and fits a line through the known values (177.14 in 2005, 212.99 in 2008, and 228.81 in 2009), and subsequently calculates the slope (12.69).

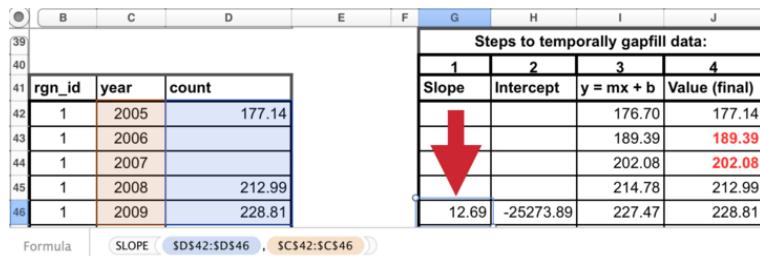


Figure 19:

2. Calculate the y-intercept for each region

The next step is to calculate the intercept of the line that is fitted through the available data points. This can be done in Excel similarly as for the slope calculation, using the the **INTERCEPT(known_y's,known_x's)** function that calculates the y-intercept (-25273.89) of the fitted line.

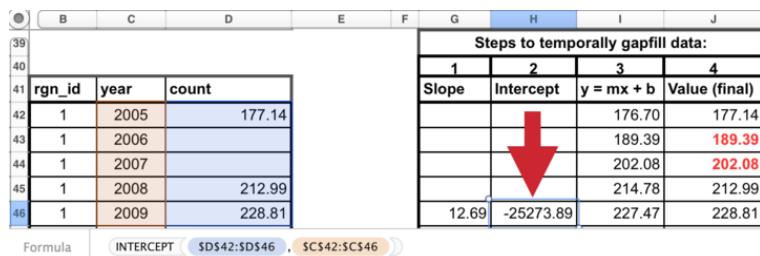


Figure 20:

3. Calculate y for all years

The slope and y-intercept that were calculated in steps 1 and 2 can then be used along with the year (independent variable) to calculate the unknown 'y-values'. To do so, simply replace the known three values into the $y = mx + b$ equation (m=slope, x=year, b=intercept), to calculate the unknown 'count' for a given year (189.39 in 2006, and 202.08 in 2007).

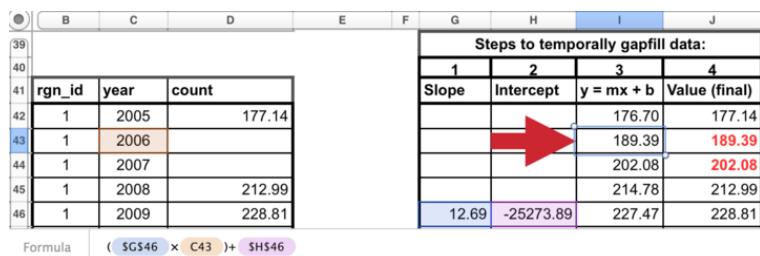


Figure 21:

4. Replace modeled values into original data where gaps had occurred

Substitute these modeled values that were previously gaps in the timeseriew. *The data layer is now ready for the Toolbox, gapfilled and in the appropriate format.*

5.2.3.2 Spatial gapfilling Spatial gaps are when no data are available for a particular region. The Toolbox requires data for each region. It is important to make an informed decision about how to spatially gapfilling data.



<i>rgn_id</i>	<i>year</i>	<i>count</i>
1	2005	177.14
1	2006	201.39
1	2007	199.81
1	2008	212.99
1	2009	228.81
2	2005	
2	2006	
2	2007	
2	2008	
2	2009	
3	2005	129.69
3	2006	173.45
3	2007	229.86
3	2008	231.44
3	2009	221.95
4	2005	397.00
4	2006	566.00
4	2007	591.00
4	2008	1154.00
4	2009	1570.00

In this data layer, Region 2 is missing from this dataset and requires spatial gapfilling.

No temporal gapfilling is required in this example.

Figure 22:

To fill gaps spatially, you must assume that one region is like another, and data from another region is adequate to be substituted in place of the missing data. This will depend on the type of data and the properties of the regions requiring gapfilling. For example, if a region is missing data but has similar properties to a different region that does have data, the missing data could be ‘borrowed’ from the region with information. Each data layer can be gapfilled using a different approach when necessary.

Characteristics of regions requiring gapfilling that can help determine which type of spatial gapfilling to use:

1. proximity: can it be assumed that nearby regions have similar properties?
2. study area: are data reported for the study area, and can those data be used for subcountry regions?
3. demographic information: can it be assumed a region with a similar population size has similar data?

Spatial gapfilling example:

For a certain data layer, suppose the second region (*rgn_id* 2) has no data reported, as illustrated in the figure above. How to spatially gapfill *rgn_id* 2 requires thinking about the properties and characteristics of the region and the data, in this case, tourist count.

Here are properties that can be important for decision making:

rgn_id 2:

- is located between *rgn_id* 1 and 3
- is larger than *rgn_id* 1
- has similar population size/demographics to *rgn_id* 3
- has not been growing as quickly as *rgn_id* 4

There is no absolute answer of how to best gapfill *rgn_id* 2. Here are a few reasonable possibilities:

Assign *rgn_id* 2 values from:

- *rgn_id* 1 because it is in close proximity to *rgn_id* 2
- *rgn_id* 3 because it is in close proximity to *rgn_id* 2 and has similar population size/demographics
- *rgn_id* 1 and 3 averaged since they are in close proximity to *rgn_id* 2

Suppose the decision was made to gapfill *rgn_id* 2 using the mean of *rgn_id* 1 and 3 since this would use a combination of both of those regions. Again, other possibilities could be equally correct. But some form of spatial gapfilling is required so a decision must be made. The image below illustrates this in Excel.

rgn_id	year	count
1	2005	177.14
1	2006	201.39
1	2007	199.81
1	2008	212.99
1	2009	228.81
2	2005	
2	2006	
2	2007	
2	2008	
2	2009	
3	2005	129.69
3	2006	173.45
3	2007	229.86
3	2008	231.44
3	2009	221.95
4	2005	397.00
4	2006	566.00
4	2007	591.00
4	2008	1154.00
4	2009	1570.00

rgn_id	year	count
1	2005	177.14
1	2006	201.39
1	2007	199.81
1	2008	212.99
1	2009	228.81
2	2005	153.42
2	2006	187.42
2	2007	214.84
2	2008	222.22
2	2009	225.38
3	2005	129.69
3	2006	173.45
3	2007	229.86
3	2008	231.44
3	2009	221.95
4	2005	397.00
4	2006	566.00
4	2007	591.00
4	2008	1154.00
4	2009	1570.00

Figure 23:

The data layer is now ready for the Toolbox, gapfilled and in the appropriate format.

5.2.4 Long formatting

The Toolbox expects data to be in ‘long’ or ‘narrow’ format. Below are examples of correct and incorrect formatting, and tips on how to transform data into the appropriate format.

Example of data in an incorrect format:

Region	DataLayer	Year									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
A	GDP_USDx1000	8	7	30	26	69	39	108	92	261	151
B	GDP_USDx1000	13	9	13	14	10	12	14	10	6	5
C	GDP_USDx1000	2132	2325	2963	3214	2942	2910	1759	2029	2077	2453
D	GDP_USDx1000	21	5	14	2	11	3	26	14	15	100
A	governance_indicator						0.8545	0.5400	0.7062	1	1
B	governance_indicator						0.8564	0.7794	0.8614	1	1
C	governance_indicator						0.8779	1	1	0.8986	1
D	governance_indicator						0.8537	0.5373	0.7044	1	1

Figure 24:

With ‘wide’ format, data layers are more difficult to combine with others and more difficult to read and to analyze.

Transforming data into ‘narrow’ format:

Data are easily transformed in a programming language such as R.

In R, the *tidyR* package has the *gather* command, which will gather the data from a wide format into a narrow format. It also can *spread* the data back into a wide format if desired. R documentation:

- <http://blog.rstudio.org/2014/07/22/introducing-tidyr/>
- <http://www.rstudio.com/resources/cheatsheets/>

Example code using the *melt* command in the *reshape2* library. Assume the data above is in a variable called *data_wide*:

```

install.packages('reshape2')
library(reshape2)
data_melt = melt(data=data_wide, id.vars=c('Region', 'DataLayer'), variable.name='Year')
data_melt = data_melt[order(data_melt$DataLayer, data_melt$Region),]

```

Figure 25:

This will melt everything except any identified columns (*Region* and *DataLayer*), and put all other column headers into a new column named *Year*. Data values will then be found in a new column called *value*.

The final step is optional: ordering the data will make it easier for humans to read (R and the Toolbox can read these data without this final step):

Example of data in the appropriate (long) format:

GDP_USDx1000.csv			governance_indicator.csv		
Region	Year	value	Region	Year	value
A	2000	8	A	2000	
A	2001	7	A	2001	
A	2002	30	A	2002	
A	2003	26	A	2003	
A	2004	69	A	2004	
A	2005	39	A	2005	0.854599407
A	2006	108	A	2006	0.540059347
A	2007	92	A	2007	0.706231454
A	2008	261	A	2008	1
A	2009	151	A	2009	1
B	2000	13	B	2000	
B	2001	9	B	2001	
B	2002	13	B	2002	
B	2003	14	B	2003	
B	2004	10	B	2004	
B	2005	12	B	2005	0.856410256
B	2006	14	B	2006	0.779487179
B	2007	10	B	2007	0.861538462
B	2008	6	B	2008	1
B	2009	5	B	2009	1

Figure 26:

6 Installing the Toolbox

Section Summary:

In this section, you will learn how to successfully download, install, and use the software required to conduct an assessment. You will create a GitHub account and install R, RStudio, git, and the Github desktop app. OHI assessments are conducted through open-source platforms that allow you to make real-time changes with collaborators, and to track progress so that errors can be corrected and new insights can be shared in the future.

6.1 Overview

Your assessment repository is located at github.com/OHI-Science and we recommend saving it to your computer so that you can sync changes back online to save versions and facilitate collaboration. Conducting an OHI assessment using GitHub enables collaboration and transparency, and will provide access to the latest developments in the Toolbox software, allowing the OHI team to provide support remotely if necessary.

This section explains the GitHub workflow and how to access and setup required software. You can use GitHub to upload any modifications you make so that you can work collaboratively with your team.

Required software:

1. **Github App**
2. **** git ****
3. **R**
4. **RStudio**



Figure 27:

6.2 GitHub

GitHub is an open-source development platform that enables easy collaboration and versioning, which means that all saved versions are archived and attributed to each user. It is possible to revert back to any previous version, which is incredibly useful to not only to document what work has been done, but how it differs from work done in the past, and who is responsible for the changes.

GitHub Vocabulary:

- **clone** ~ download to your computer from online version with syncing capabilities enabled
- **commit** ~ message associated with your changes at a point in time
- **pull** ~ sync a repo on your computer with online version
- **push** ~ sync the online repo with your version, only possible after committing

sync = pull + commit + push

6.2.1 Learning GitHub

The following section describes how to use GitHub to access and sync your assessment repository. There are also many great resources available online with more in-depth information:

- **Git and GitHub** by Hadley Wickham: <http://r-pkgs.had.co.nz/git.html>
- **Collaboration and Time Travel: Version Control with Git, GitHub and RStudio** video tutorial by Hadley Wickham: www.rstudio.com/resources/webinars
- **Good Resources for Learning Git and GitHub** by GitHub: <https://help.github.com/articles/good-resources-for-learning-git-and-github/>

6.3 Accessing GitHub Repositories

GitHub has an online interface and a desktop application for the version-control software called **** git****, where your project repository and any changes done to it are kept and recorded. All changes within your local, desktop repository will be tracked by GitHub regardless of the software you use to make the changes, and saved shared via its online interface. This means that you can delete or paste files in the Mac Finder or

Windows Explorer and edit *.csv* files in Excel or a text editor, and still sync these changes with the online repository. To do so, you will need to create a GitHub account online and install git, R, and RStudio on your local computer. All are freely available.

6.3.1 Create a GitHub account

Create a GitHub account at <http://github.com>. Choose a username and password. You will use this username and password when you install and set up *git* on your computer.

6.3.2 Install *git* software

How you install *git* will depend on whether you are working on a Windows or Mac computer. It will also depend on your operating system version. If you have problems following these instructions, it is likely because your operating system requires a previous version of *git*. Previous versions are available from <http://www.wandisco.com/git/download> (you will need to provide your email address).

For Windows:

- Download *git* at <http://git-scm.com/downloads> and follow the install instructions.
- When running the Windows installer, use all default options except “Adjusting your PATH environment”: instead, select “***Run Git from the Windows Command Prompt***”. This will allow later compatibility with RStudio.

For Mac:

- Download *git* at <http://git-scm.com/downloads> and follow the install instructions.
- Apple’s **Xcode** has a command line tools option during install which can override the preferred *git* command line tools. To ensure you are using the latest preferred version of *git*, you will need to launch Terminal and type the following few lines of code:
- Access Terminal from the Applications folder: **Applications > Utilities > Terminal**. When you launch Terminal a window will appear with your computer’s name followed by a \$. When you type, your commands will appear after the \$.

Add access your ‘bash profile’ by typing:

```
pico ~/.bash_profile
```

You are now able to edit your ‘bash profile’ and your screen will change; it will look like this:

Now type:

```
export PATH=/usr/local/git/bin:$PATH
```

Exit pico by entering:

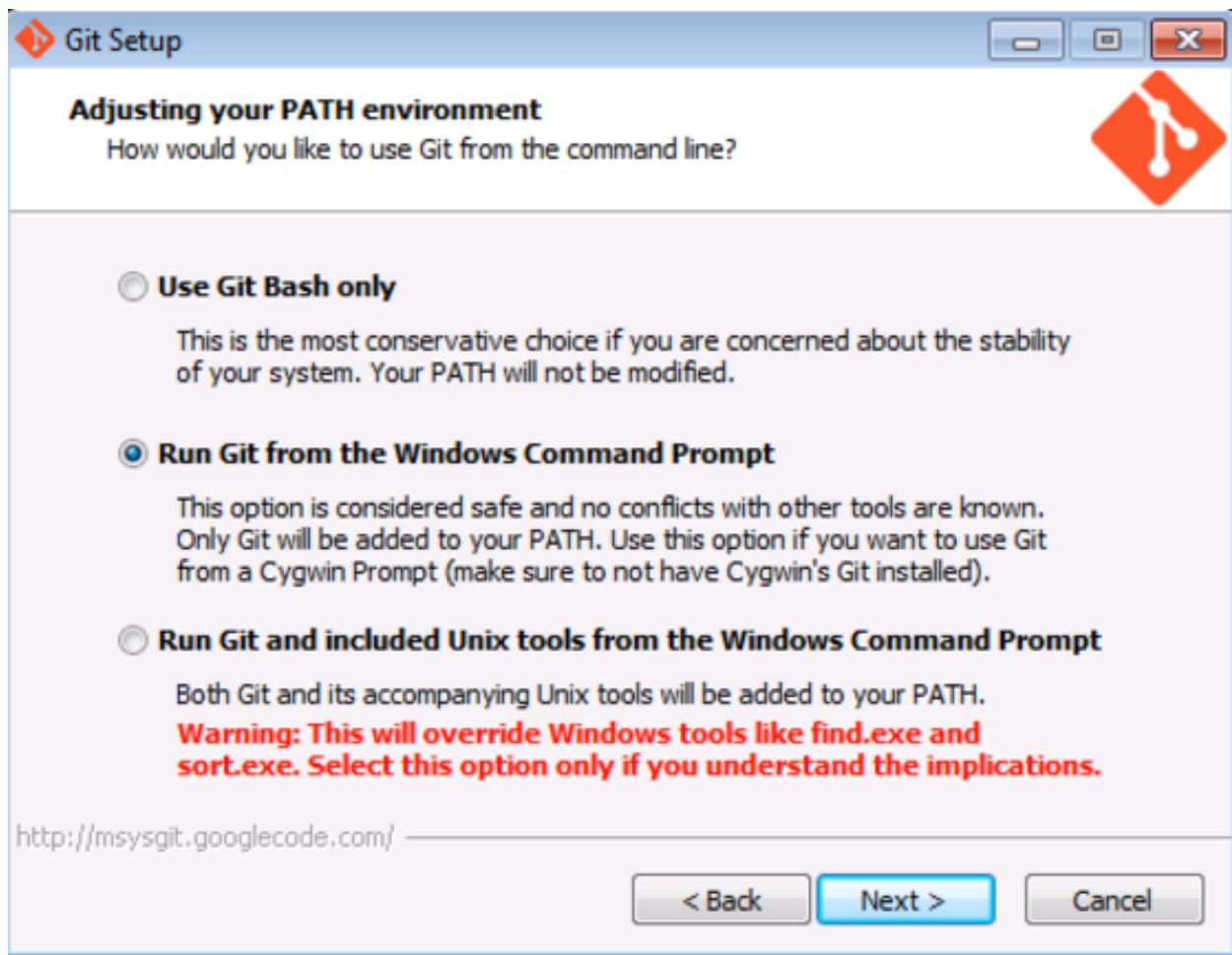


Figure 28:

```
GNU nano 2.0.6      File: /Users/julialowndes/.bash_profile

export PATH=/usr/local/git/bin:$PATH

[ Read 1 line ]
^G Get Help  ^O WriteOut  ^R Read File  ^Y Prev Page  ^K Cut Text  ^C Cur Pos
^X Exit     ^J Justify   ^W Where Is   ^V Next Page  ^U UnCut Text^T To Spell
```

Figure 29:

```
control-X  
y  
return/enter
```

Exit Terminal by typing:

```
exit
```

Finally, quit Terminal.

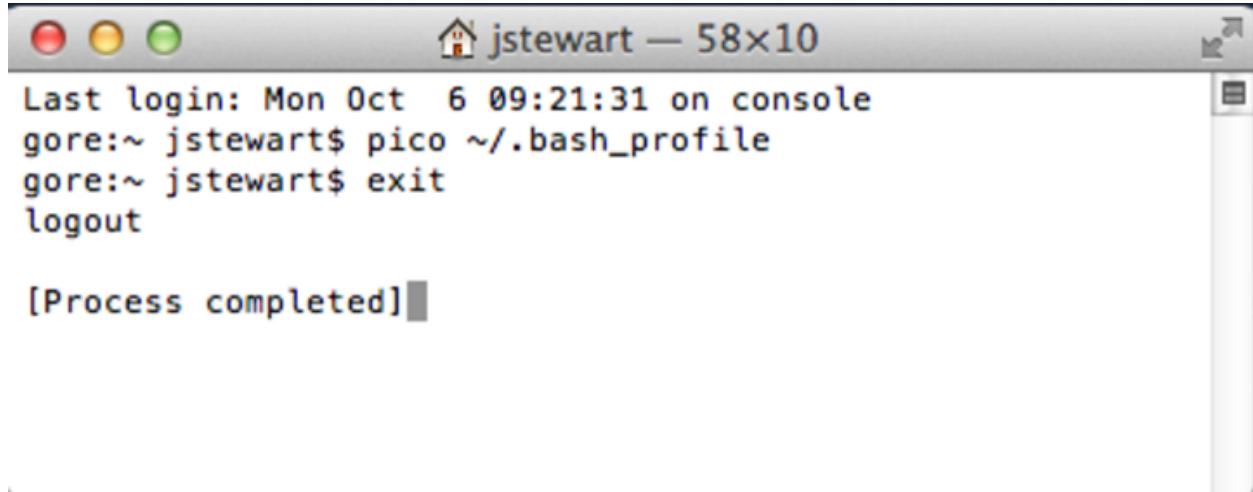


Figure 30:

6.3.3 Set up your Git Identity

After downloading and installing *git*, you will need to set up your **Git Identity**, which identifies you with your work. *Note:* if you have any problems with the following instructions, it is likely because of incompatibility between the version of your operating system and the version of git you downloaded in the previous section. In this case, find and download a compatible version at www.wandisco.com/git/download and then follow the instructions below.

You will set up your GitHub identity using the command line specific to Windows or Mac:

- **Windows:** Start > Run > cmd
- **Mac:** Applications > Utilities > Terminal

In the window, you will see a cursor where you are able to type. Type the following and press return (or enter) at each step. Make sure all spaces and symbols are identical to the example below, including all spaces () and dashes (-).

Substitute your GitHub username instead of jdoe:

```
git config --global user.name jdoe
```

and then: substitute the email address you used to create your GitHub account:

```
git config --global user.email john.doe@example.com
```

You can check settings with the following:

```
git config --list
```

Quit the Terminal after typing:

```
exit
```

6.3.4 Create a folder called *github* on your computer

Because you will use GitHub to collaborate with your team or request support from the OHI team, it is important you save files in places where the file path that is universal and not specific to your computer. When team members save files in different places, this will create a lot of problems when collaborating, particularly between Macs and Windows machines.

Please create a folder called *github* in your root directory. The file path for this folder will be:

- **Windows:** `Users\[User]\Documents\github\`
- **Mac:** `Users/[User]/github/`

This folder can be identified by any computer as `~/github/`.

TIP: You can check the location of your *github* folder by right-clicking the folder icon and selecting ‘Get Info’ on a Mac or ‘Properties’ on Windows.

6.3.5 Update permissions

You need to **email your username to ohi-science@nceas.ucsb.edu** for permission to upload modifications to your GitHub repository (you only need to do this once). Only team members who will be modifying files will need to do this; all other members can view online and download the repository without these permissions.

6.3.6 Work locally with R and RStudio

You will then work locally on your own computer, modifying the files in the repository to reflect the desired modifications your team has identified for your assessment. Multiple users can work on the same repository at the same time, so there are steps involved to ‘check in’ your modifications so they can merge with the work of others without problems. GitHub has specific words for each of these steps. You have already successfully **cloned** an online repository to your local machine. After making modifications, you will **commit** these changes with a description before being able to sync back to the online repository. **Synching** involves both **pulling** any updates from the online repository before **pushing** committed changes back to the server.

TIP: While you can edit files in the online GitHub repository, we do not recommend this. It is good practice to track changes through commits and syncing.

The example below illustrates GitHub’s collaborative workflow:

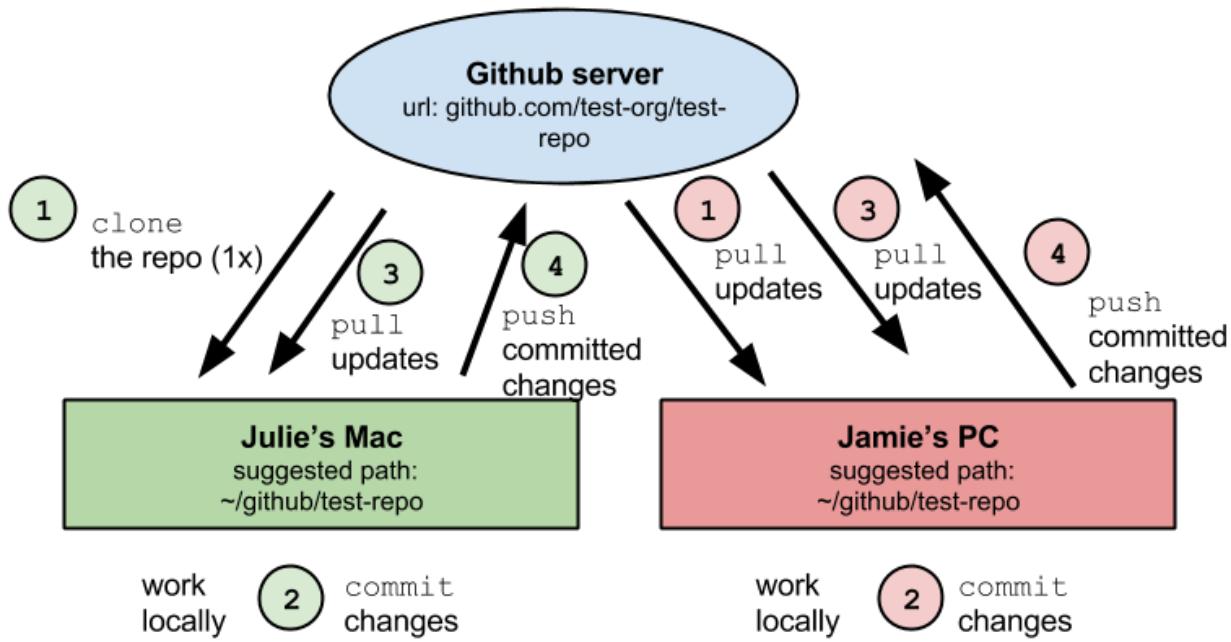


Figure 31:

All changes within your local repository will be tracked by GitHub regardless of the software you use to make the changes. This means that you can delete or paste files in the Mac Finder or Windows Explorer and edit `.csv` files in Excel or a text editor, and still sync these changes with the online repository. We recommend doing as much data manipulation as possible in a programming language like R, to maximize transparency and reproducibility.

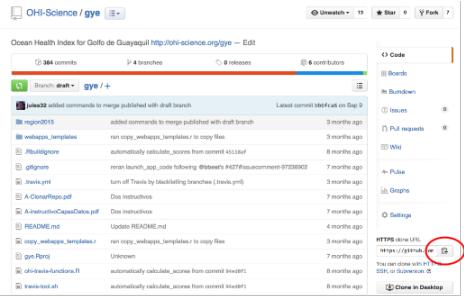
- **R** is a free computing and graphical software where all the modifications to your OHI repository are done. Download the latest version of R appropriate for your operating system at <http://cran.r-project.org/> and follow the instructions to install it on your computer.
- **RStudio** is a user-friendly R interface that can be used to synchronize any modifications you make to files in your assessment's repository. It is also where model modifications and calculations occur. Install the latest version of RStudio at <https://www.rstudio.com/>.

R and RStudio update frequently. If you already have those softwares installed, check on the websites for the most recent version. In general, it's good practice to check periodically for updates. When you run into unexplained errors while modifying contents in RStudio, check first if your versions of R or Rstudio are out-of-date. For R, you can see what you already have on your computer by typing “`sessionInfo()`” into your R console.

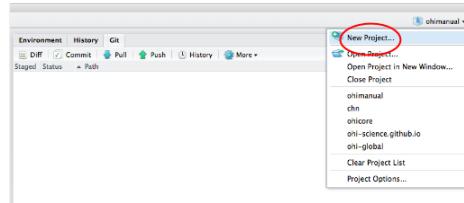
If you are working on a *Mac*, you will need to tell RStudio to use the proper version of Git by doing the updating the preferences for ‘Git executable’:

RStudio > Preferences... > Git/SVN > Git executable: /usr/local/git/bin/git

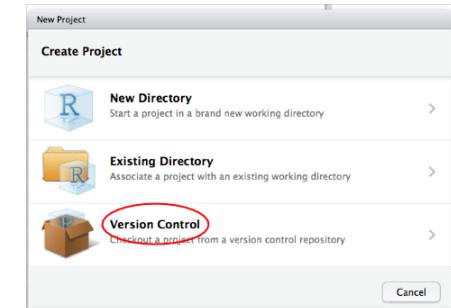
6.3.6.1 Cloning a repository to your local computer In order to sync GitHub and RStudio, you need to clone your GitHub repository to RStudio. Here is a step-by-step guide on how to do so:



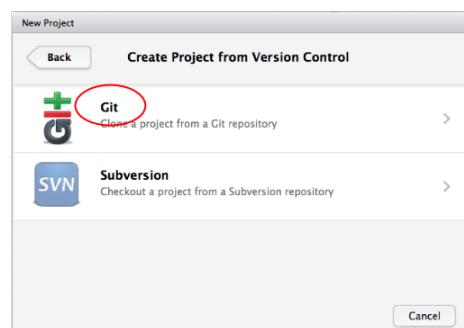
Step 1: Copy the link by clicking the highlighted button, or select and copy the link inside the text box.



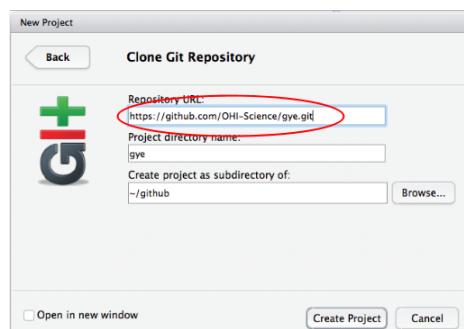
Step 2: Open Rstudio interface, click the project button (eg. ohimanual) at the upper right corner, select "New Project".



Step 3: Click "Version Control".



Step 4: Click "Git".



Step 5: Paste the link you copied from step 1 in the circled box. Hit the "tab" key on your keyboard and the following two boxes will be filled automatically. Click "Create Project". Once downloading is complete, the proper project R page will open automatically.

Figure 32: How to clone repository to Rstudio
47

6.3.6.2 Syncing your repository with RStudio RStudio can sync files with GitHub directly. It will capture the changes made to any files within the repository, no matter which software was used to modify them. In RStudio, you sync by first pulling and then pushing (separately); in the GitHub App these two functions are done together.

Launch your project in RStudio by double-clicking the `.Rproj` file in the assessment folder on your local hard drive.

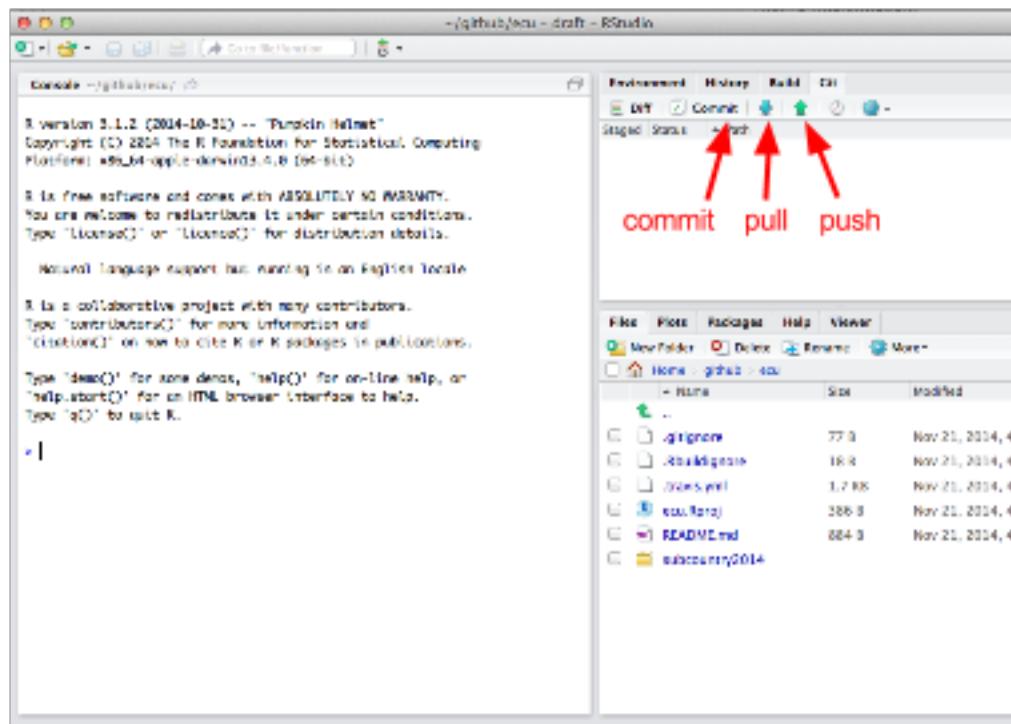


Figure 33:

When you modify or add a file, the file will appear in the ‘Git’ window once it has been saved. In the example below, the file `test.R` was created.

1. Clicking the ‘*Staged*’ (checked) box and the ‘*Commit*’ button opens a new window where you can review changes.
2. Type a commit message that is informative to the changes you’ve made.
 - Note 1: there will often be multiple files ‘staged’ at the same time, and so the same commit message will be associated with all of the updated files. It is best to commit changes often with informative commit messages.
 - Note 2: clicking on a staged file will identify additions and deletions within that file for your review
3. Click ‘*Commit*’ to commit the changes and the commit message.
4. “Pull” any changes that have been made to the online repository. This is important to ensure there are no conflicts with updating the online repository, especially if you are working with collaborators who might be working on the same files as you are.

5. “Push” your committed changes to the online repository. Your changes are now visible online.

TIP: If you aren’t seeing your changes in the ‘Git’ window, try saving the file again.

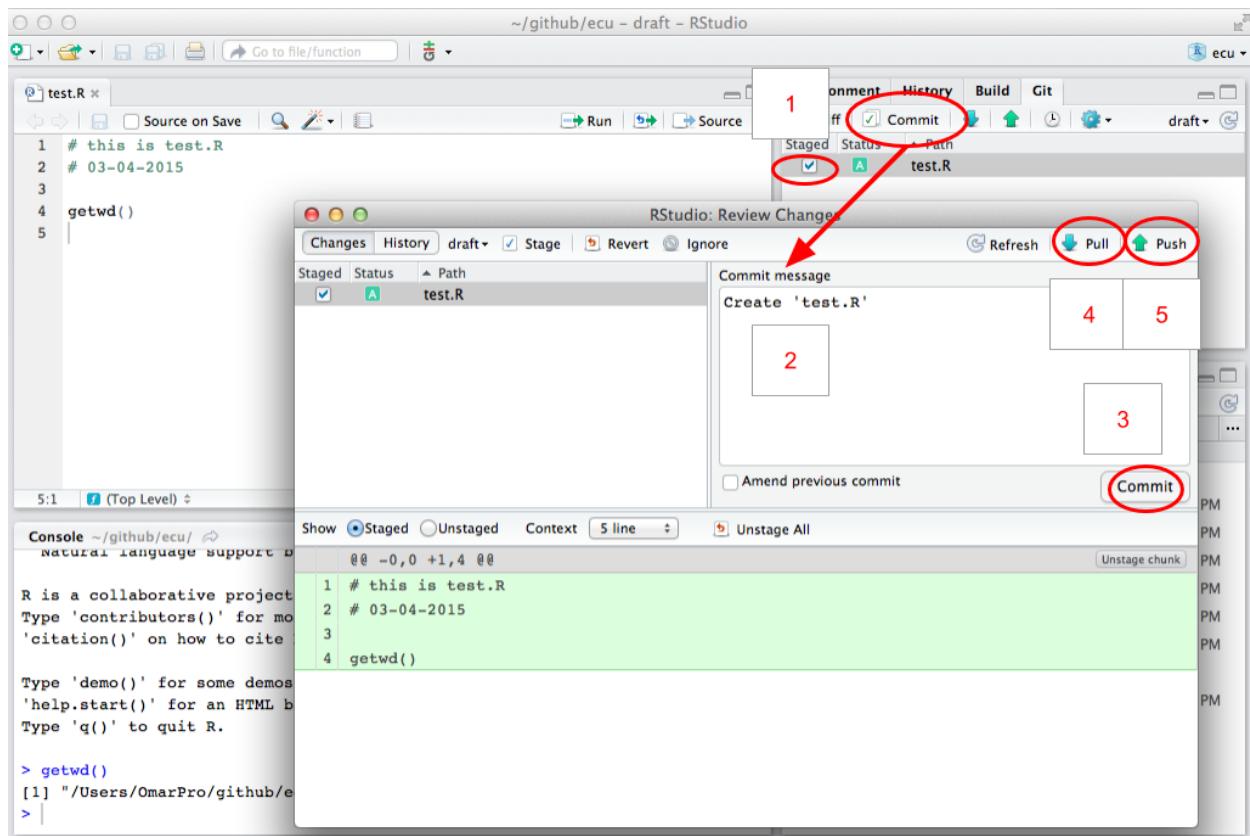


Figure 34: Figure showing RStudio when syncing. After first staging your changes, click the ‘commit’ button to open a new window where you can enter a ‘commit message’ and then pull and push new changes.

Note: Another option to syncing your edits on a repo with the online version is to use **Command Lines**, if you are familiar with it. There are resources available online on how to do so.

6.4 GitHub repository architecture

GitHub stores all data files and scripts for your assessment in a repository (a folder). Different copies or complements to these folders, called *branches* can also exist, which aid with versioning and drafting. Your repository has four branches, two of which are displayed on your website (e.g., ohi-science.org/ecu):

1. **draft** branch is for editing. This is the default branch and the main working area where existing scenario data files can be edited and new scenarios added.
2. **published** branch is a vetted copy of the draft branch, not for direct editing. This branch is only updated by automatic calculation of scores if:
 1. no errors occur during the calculation of scores in the draft branch, and
 2. publishing is turned on. During the draft editing and testing phases of development, it is typically desirable to turn this off.

3. **gh-pages** branch is this website. The results sections of the site (regions, layers, goals, scores per branch/scenario) are overwritten into this repository after automatic calculation of scores. The rest of the site can be manually altered.
4. **app** branch is the interactive layer and map viewer application. The user interface and server-side processing use the [Shiny](#) R package and are deployed online via [ShinyApps.io](#) to your website. Once deployed, the WebApp pulls updates from the data branches (draft and published) every time a new connection is initiated (i.e., browser refreshes).

TIP: When looking at files on GitHub, note that the timestamps are associated with the ‘commit’ time rather than the ‘push’ time.

7 Using the Toolbox

Section Summary:

In this section, you will learn about the most common modifications made to repositories. You will be given examples to follow to help with your own assessment. The most common modifications are changing the pressures and resilience matrices, changing or creating data layers, and changing or removing goals models.

TIP: You should have access to your assessment repository and be familiar with the files in the folder.

As your team finalizes which data should be included in the assessment and begins developing goal models, you can incorporate this information into your repository. Input information must be properly formatted into **layers**, which are registered with the Toolbox for use. Layers for the Toolbox can be prepared with any software that handles *.csv* files, but goal models must be updated in R. It is recommended that layer preparation occurs within your repository’s **prep** folder as much as possible, as it will also be archived by GitHub. Calculations can be done locally and offline by running `subcountry2014/calculate_scores.R`.

7.1 Layer preparation workflow

It is recommended that you construct a useful workflow with your team to incorporate local information into the Toolbox. Adding layers to the Toolbox will require working with GitHub and the Toolbox file system structure. The overall process involves preparing the layers (which can be done in the **prep** folder), saving them in the **layers** folder, and registering the layers. The layer preparation process can occur in tandem with the model modification process.

7.2 Modifying and creating data layers

Data layers are *.csv* files and are located in the `[assessment]/subcountry.year/layers` folder (example: `gye/subcountry2014/layers`). Remember that all data layers provided in your repository are extracted from the global 2014 assessment.

- Layers with the suffix `_gl2014.csv` (*gl* for *global*) have been exactly copied from the global assessment and applied equally to each region, and therefore the values will be the same across all subcountry regions.

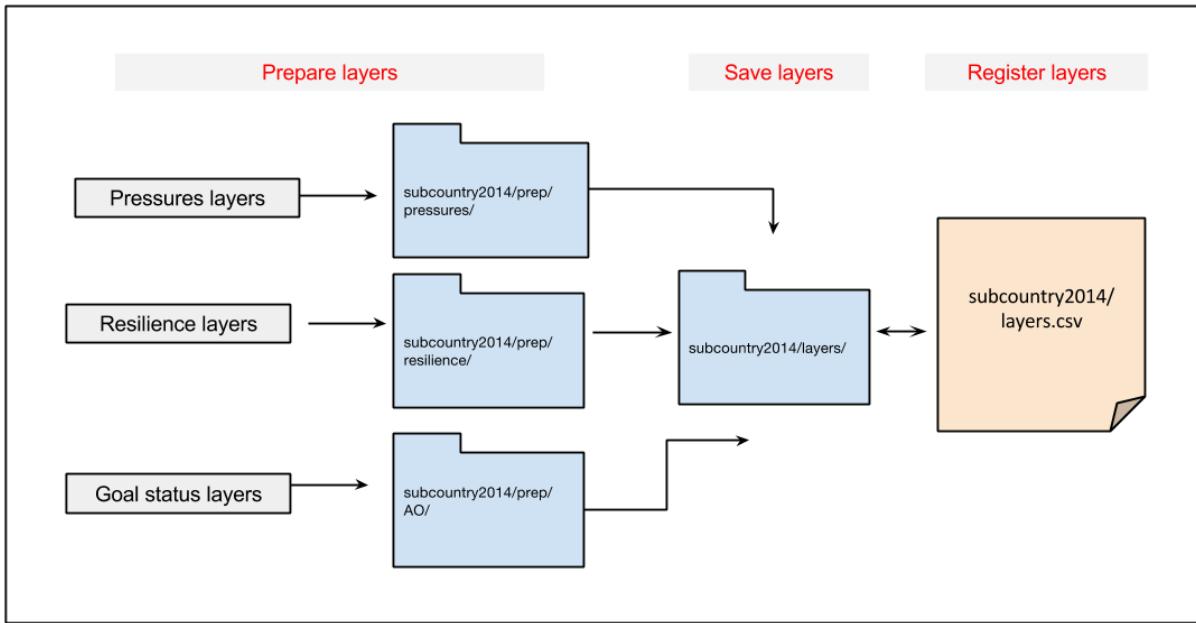


Figure 35: Diagram of OHI Toolbox data preparation workflow. You should start by prepping the files, loading them into the `layers` folder when they're ready for the Toolbox, and then registering them in `layers.csv`

- Layers with the suffix `_sc2014.csv` (*sc* for *subcountry*) have been spatially-extracted from global data or adjusted with spatially-extracted data so that each region in your assessment has a unique value. For example, gross domestic product (GDP) used in the global assessment was reported at the national (most often country) level. Instead of being applied equally across all subcountry regions (which would incorrectly increase the nation's GDP several times), national GDP was down-weighted by the proportion of coastal population in each region compared with the total coastal population.

Both types of default data layers are of coarse-resolution and should be replaced with local, high-resolution data when possible. The priority should be to replace as much of the `_gl2014.csv` data as possible.

There are several steps to follow when working with data layers:

1. Modify or create data layer with proper formatting
2. Save the layer in the `layers` folder
3. Register the layer in `layers.csv`
4. Check (and update when appropriate) `pressures_matrix.csv` and `resilience_matrix.csv` (located in: `[assessment]/subcountry2014/conf`)

7.2.1 Create data layers with proper formatting

The OHI Toolbox expects each data layer to be in its own `.csv` file and to be in a specific format, with data available for every region within the study area, with data organized in ‘long’ format (as few columns as possible), and with a unique region identifier (`rgn_id`) associated with a single score or value. See the ‘Formatting data for the Toolbox’ section for more information.

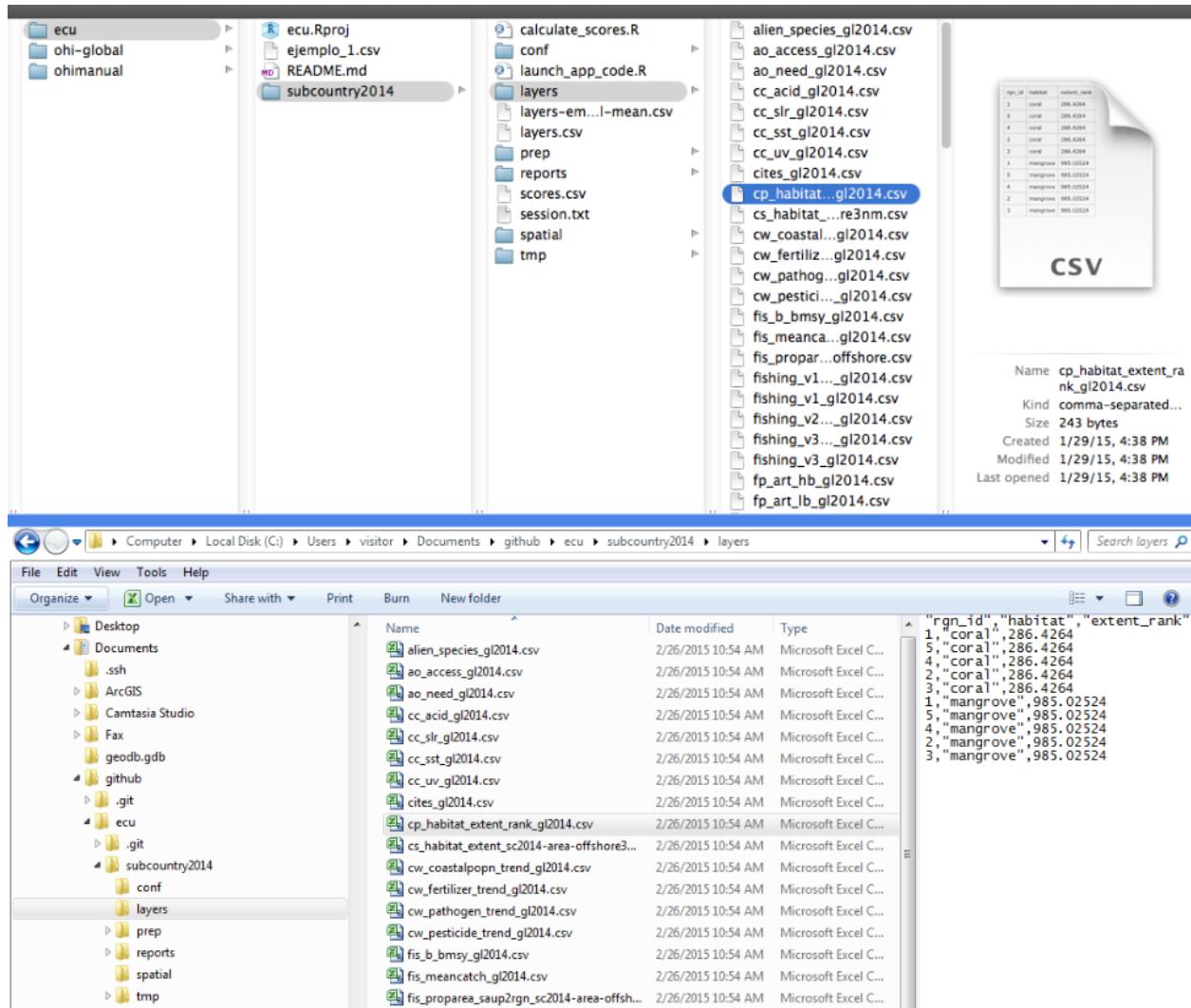


Figure 36: This figure shows the location of your data layers. Mac navigation is shown above and Windows is shown below.

7.2.2 Save data layers in the *layers* folder

When you modify existing or create new data layers, we recommend saving this as a new *.csv* file with a suffix identifying your assessment (example: *_sc2014.csv*). Modifying the layer name provides an easy way to track which data layers have been updated regionally, and which rely on global data. Then, the original layers (*_g2014.csv* and *_sc2014.csv*) can be deleted.

* Note: filenames should not have any spaces: use an underscore (' ') instead. This will reduce problems when R reads the files.

7.2.3 Register data layers in *layers.csv*

When there are new filenames associated with each layer, they will need to be registered in *[assessment]/subcountry2014/layers.csv*. If a layer simply has a new filename, only the *filename* column needs to be updated:

1	targets	layer	name	description	fld_value	units	filename	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
2	AO	ao_access	Fisheries	The per value	value	ao_access	g2014.csv	equal	global	manager	ao_access	"/github/global	rgn_id			value	TRUE	0.555772				
3	AO	ao_need	Purchasing	The per value	value	ao_need	g2014.csv	equal	global	purchasi	ao_need	"/github/global	rgn_id		year	value	TRUE	1990	2013	0.063467		
4	CW	cw_coasta	Coastal	trend	trend	scor_cw	coastalpopn_trend_g2014.csv	equal	global	trends	w_cw_coasta	"/github/global	rgn_id		trend	TRUE					0.077218	
5	CW	cw_fertiliz	Fertilizer	Statistics	trend	scor_cw_fertilizer	trend_g2014.csv	equal	global	trends	w_cw_fertiliz	"/github/global	rgn_id		trend.score	TRUE					-1	
6	CW	cw_patho	Trends	In Trends	trend	trend	scor_cw_pathogen_trend_g2014.csv	equal	global	trends	w_cw_patho	"/github/global	rgn_id		trend	TRUE					0.002294	
7	CW	cw_pestic	Pesticide	Statistics	trend	scor_cw_pesticide	trend_g2014.csv	equal	global	trends	w_cw_pestic	"/github/global	rgn_id		trend.score	TRUE					0.878753	
8	FIS	fis_b_bmsy	B/Bmsy	Et The ratio	b_bmsy	B/B_msy	fis_b_bmsy_g2014.csv	equal	global	b_bmsy	fis_b_bmsy	"/github/global	fao_id		taxon_nar_year	b_bmsy	TRUE	1954	2011	0.054352		
9	FIS	fis_meanac	MeanCatch	data	Mean	mean_cat	metric	for fis_meanacatch_g2014.csv	equal	global	mean	fis_meanac	"/github/global	fao_id		fao_taxon_nar_year	mean_catch	TRUE	2006	2011	8.18e-18	
10	FIS	fis_prepared	of ea	Lookup	prop_area	proportion	fis_preparesauprgn_sc2014-area-offshore.csv	area_offshore	global	propotion	fis_preparesaup	"/github/global	rgn_id		saup_id	prop_area	TRUE				0.001827	
11	FP	fp_wildca	Fisheries	Proportion	w_fis	value	fp_wildcaught_weight_g2014-area-offshore.csv	area_offshore	global	weights	fp_wildca	"/github/global	rgn_id		w_fis	TRUE					0.469561	
12	HAB CS	CF_hab_exten	Habitat	ext Modelled	km2	hab_extent	g2014.csv	raster area_offshore	hab_exten	/github/global	rgn_id	habitat	km2	TRUE							71.6066	
13	HAB CS	CF_hab_health	Habitat	Health Modelled	health	hab_health	g2014.csv	raster area_offshore	habitat	hab	habitat	health	TRUE							0.741379		
14	HAB CS	CF_hab_trend	Habitat	Modelled	trend	trend	scor_hab_trend_g2014.csv	rgl	global	habitat	hab	trend	TRUE								-1	
15	ICO	ico_spp_iUCN	extir	Internati	category	category	ico_spp_extinction_status_g2014.csv	rgl	global	proportion	ico_spp	"/github/global	rgn_id		rgn_id	sciname	category	TRUE				
16	ICO	ico_spp_iUCN_popn	Internati	popn	trtrend	scor	ico_spp_poppn_trend_g2014.csv	rgl	global	populatio	ico_spp	"/github/global	rgn_id		rgn_id	sciname	popn_trtrend	TRUE				
17	LE	le_gdp	GDP	Gross	usd	value	2010 USD le_gdp_sc2014-popn-inland25km.csv	populatio	rgl	global	populatio	le_gdp	2010 USD	rgn_id		rgn_id	year	usd	TRUE	1998	2011	1327122
18	LE	le_jobs_sjJob	gapfilled	value	jobs	le_jobs_sector_year	g2014.csv	rgl	global	rgl	rgl	sector	year	rgn_id		rgn_id	sector	value	TRUE	1997	2010	15.32
19	LE	le_unemp	Unemploy	gapfilled	percent	unle	le_unemployment_g2014.csv	rgl	global	rgl	rgl	year	percent	rgn_id		rgn_id	sector	value	TRUE	1997	2010	6.065547
20	LE	le_wage_Wages	gapfilled	value	2010 USD	le_wage_sector_g2014.csv	rgl	global	rgl	rgl	rgl	rgl	value	rgn_id		rgn_id	sector	value	TRUE	1993	2008	307.6993
21	LE	le_workforce	Modelled	adjusted	jobs	jobs	le_workforce_adjs_sc2014-popn-inland25km.csv	rgl	global	rgl	rgl	rgl	jobs	rgn_id		rgn_id	sector	value	TRUE	1990	2012	112.473
22	LE	le_pressure	le_secto	Jobs	weig	Jobs	le_sector_weight_g2014.csv	rgl	global	rgl	rgl	rgl	weight	rgn_id		rgn_id	sector	weight	TRUE			1
23	LIV ECO	le_popn	Total popu	Populatio	count	count	le_popn_g2014.csv	rgl	global	rgl	rgl	rgl	count	rgn_id		rgn_id	sector	count	TRUE	1960	2012	4514593
24	LSP	lsp_prot_Coastal	pr Coastal	area_km2	km^2	lsp_prot_area_inlandkm	g2014.csv	raster area_inlandkm	lsp_prot_x	/github/global	rgn_id		year	area_km2	TRUE	1959	2007	1				
25	LSP	lsp_prot_Coastal	m Coastal	area_km2	km^2	lsp_prot_area_offshore3nm	g2014.csv	raster area_offshore3nm	lsp_prot_y	/github/global	rgn_id		year	area_km2	TRUE	1959	2007	3				

Figure 37: Register new layers in *layers.csv*. Be sure to note if there is a change in the filename.

TIP: This part is done manually. If you prefer not to manipulate your file by hand, you can generate a script that automates this.

However, if a new layer has been added (for example when a new goal model is developed), you will need to add a new row in the registry for the new data layer and fill in the first eight columns (columns A-H):

- **targets:** Add the goal/dimension that the new data layer relates to. Goals are indicated with two-letter codes and sub-goals are indicated with three-letter codes, with pressures, resilience, and spatial layers indicated separately.
- **layer:** Add an identifying name for the new data layer, which will be referenced in R scripts like *functions.R* and *.csv* files like *pressures_matrix.csv* and *resilience_matrix.csv*.
- **name:** Add a longer title for the data layer–this will be displayed on your WebApp.
- **description:** Add a longer description of the new data layer–this will be displayed on your WebApp.
- **fld_value:** Add the appropriate units for the new data layer. It is *the same as the column name in the data file*, which will be referenced in R scripts in subsequent calculations. (example: *area_km2*)
- **units:** Add a description about the *units* chosen in the *fld_value* column above. Think about what units you would like to be displayed on the WebApp when filling out “units.” (example: *km^2*)

- **filename:** Add a filename for the new data layer that matches the name of the *.csv* file that was created previously in the **layers** folder.
- **fld_id_num:** Area designation that applies to the newly created data layer, such as: *rgn_id* and *fao_id*.

It is important to check that you have filled you the fields correctly, for instance, if “fld_value” does not match the header of the source data layer, you will see an error message when you try to calculate scores. Other columns are generated later by the Toolbox as it confirms data formatting and content.

7.2.4 Check pressures and resilience matrices

If the new or modified layer is a pressures layer, check that **pressures_matrix.csv** and **resilience_matrix.csv** have been properly modified to register the new data layers.

7.3 Modifying pressures matrices

Your team will identify if any pressures layers should be added to the pressures matrices, and if so, which goals the pressure affects and what weight they should have. You can transfer this information in **pressures_matrix.csv** (located in the **[assessment]/subcountry2014/conf** folder). It is important to note that the matrix identifies the pressures relevant to each goal, and which weight will be applied in the calculation. Each pressure is a data layer, located in the **subcountry2014/layers** folder. This means that pressure layers need information for each region in the study area, and some layers will need to be updated with local data. In modifying pressures, you will need to consider whether data layers can be updated or added, and whether data layers map onto goals appropriately in the local context.

Adding a new pressure to the pressures matrix requires the following steps:

1. Create new pressure layer(s) and save in the **layers** folder
2. Register pressure layer(s) in **layers.csv**
3. Register pressure layer(s) in **pressures_matrix.csv**
 - a. Set the pressure category
 - b. Identify the goals affected and set the weighting
 - c. Modify the resilience matrix (if necessary)

The following is an example of adding two new pressures layers.

7.3.1 Create the new pressure layers and save in the **layers** folder

If you create a new data layer, give it a short but descriptive name that also includes a prefix that signifies the pressure category (for example: *po_* for the pollution category). There are five physical categories and one social category:

- *po_* = pollution
- *hd_* = habitat destruction
- *fp_* = fishing pressure
- *sp_* = species pollution
- *cc_* = climate change
- *ss_* = social pressure

So for example, `po_trash` is a pollution layer with trash on beaches, and `sp_alien` is species pollution due to alien (invasive) species.

In the current example, the two new layers created to account for the input and output effects of desalination operations will be called `po_desal_in`, and `po_desal_out`.

These new layers will have scores from 0 to 1, with values for each region in your study area, and will be saved in the `layers` folder.

7.3.2 Register the new pressure layers in `layers.csv`

Add two new rows in `layers.csv`, and register the new pressure layers by filling out the first eight columns for `po_desal_in`, and `po_desal_out`.

	A	B	C	D	E	F	G	H
1	targets	layer	name	description	fid_value	units	filename	fid_id_num
60	TR	tr_sustainability	Sustainability in Tourism	Comp score	score		tr_sustainability_global2013.csv	rgn_id
61	TR	tr_unemployment	Percent unemployment	percent	percent	unemp	tr_unemployment_global2013.csv	rgn_id
62	pressures	po_desal_in	Example data	Made-up data value	pressure score		po_desal_in_china2014.csv	rgn_id
63	pressures	po_desal_out	Example data	Made-up data value	pressure score		po_desal_out_china2014.csv	rgn_id
64	pressures	cc_acid	Ocean acidification	Modelled distri pressure score	pressure score		cc_acid_global2013.csv	rgn_id
65	pressures	rr_dlr	Sea level rise	Modelled sea level rise pressure score	pressure score		rr_dlr_global2013.csv	rgn_id

Figure 38:

7.3.3 Register the new layers in `pressure_matrix.csv`

`pressures_matrix.csv` identifies the different types of ocean pressures (columns) with the goals that they affect (rows). Adding a new pressures layer to `pressures_matrix.csv` requires adding a new column with the pressure layer name.

7.3.3.1 Set the pressure category This step requires transferring previous decisions made by your team into `pressures_matrix.csv`. Each pressure category is calculated separately before being combined with the others, so it is important to register the new pressure with the appropriate category prefix decided by your regional assessment team.

7.3.3.2 Identify the goals affected and set the weighting This step also requires transferring prior decisions into `pressures_matrix.csv`. Mark which goals are affected by this new pressure, and then set the weighting. Pressures weighting by goal should be based on scientific literature and expert opinion (3 = highly influential pressure, 2 = moderately influential pressure, 1 = not very influential pressure). Remember that the rankings in the pressures matrix are separate from the actual data within the pressures data layers. The rankings ensure that within a particular goal (e.g. within a row of the pressures matrix), the stressors that more strongly influence the goal's delivery have a larger contribution to that goal's overall pressure score. Therefore, the rankings are assigned independently of the actual pressure scores, and only determine their importance within the calculations.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	goal	component	component_name	po_desal_in	po_desal_out	po_chemicals	po_pathogens	po_nutrients	po_nutrients(po_trash)	hd_subtidal	sl_hd	subtidal_h	hd_intertidal	
2	FSR			3	2	1			3	1	3	1	3	1
3	AD			2	2	1			2	1	2	1	3	1
4	AD			1	2	1			1	1	1	1	3	1
5	NP			1	2	2			2	1	2	1	3	1
6	NP			1	2	2			2	1	2	1	3	1
7	NP			1	2	2			2	1	2	1	3	1
8	NP			1	2	2			2	1	2	1	3	1
9	NP			1	2	2			2	1	2	1	3	1
10	NP			1	2	2			2	1	2	1	3	1
11	CS			2	1	2			1	1	1	1	3	1
12	CS			2	2	2			1	2	2	1	3	1
13	CS			2	2	2			2	1	2	1	3	1
14	CP			2	2	2			1	2	2	1	3	1
15	CP			2	2	2			1	2	2	1	3	1
16	CP			2	2	2			1	2	2	1	3	1
17	CP			2	2	2			1	2	2	1	3	1
18	CP			2	2	2			1	2	2	1	3	1
37	LSP								2	3	2	3	2	3
38	CMV								3	3	3	3	2	3
39	HAB								1	2	2	3	3	3
40	HAB								1	2	2	3	3	3
41	HAB								1	2	2	3	3	3
42	HAB								1	2	2	3	3	3
43	HAB								1	2	2	3	3	3
44	HAB								1	2	2	3	3	3
45	SPP								2	3	2	3	2	2

Figure 39:

7.3.4 Modify the resilience matrix (if necessary)

Resilience is included in OHI as the sum of the ecological factors and social initiatives (policies, laws, etc.) that can positively affect goal scores by reducing or eliminating pressures. The addition of new pressure layers may therefore warrant the addition of new resilience layers that were not previously relevant. Similarly, the removal of pressure layers may warrant the removal of now irrelevant resilience layers.

7.4 Modifying resilience matrices

Previous decisions made with your team will identify if any resilience layers should be added to the resilience matrices, and if so, which goals and/or pressures the resilience affects and what weight they should have. You can then transfer this information into `resilience_matrix.csv` (located in the [assessment]/subcountry2014/conf folder).

`resilience_matrix.csv` maps the different types of resilience (columns) with the goals that they affect (rows). New resilience layers may be added to `resilience_matrix.csv` based on finer-scale local information either in response to a new pressures layer, or as a new independent measure. Any added layer must be associated with a pressures layer that has a weight of 2 or 3 in the OHI framework so that resilience measures can mitigate pressures in each region.

Each goal must have a resilience measure associated with it. In the figure below, the Toolbox would give an error because there are no resilience layers indicated for the natural products (NP) goal.

goal	component	alien_species_cites	fishing_v1	fishing_v1_eez	fishing_v2_eez	fishing_v3	fishing_v3_eez	habitat	habitat_combo	habitat_combo_ii	ii_sector_over	mariculture	msi_gov	species_diver	species_diver_tourism	water	wg_all
AO		alien_species						habitat_combo						species_diver	species_diver_tourism	water	wg_all
HAB	coral only	alien_species							habitat_combo_eez			mariculture		species_diver	tourism	water	wg_all
HAB	alien_species								habitat_combo_eez			mariculture		species_diver	tourism	water	wg_all
HAB	soft_bottom	alien_species							habitat_combo_eez			mariculture		species_diver	tourism	water	wg_all
HAB	soft_bottom	alien_species							habitat_combo_eez			mariculture		species_diver	tourism	water	wg_all
SPP		alien_species_cites							habitat_combo_eez			mariculture		species_diver	tourism	water	wg_all
CS									habitat_combo							water	wg_all
CW																water	wg_all
FIS										habitat_combo_eez				species_diver		water	wg_all
MAR												mariculture	msi_gov			water	wg_all
ECO											ii_goal					water	wg_all
LIV											ii_goal	ii_sector_evenness				water	wg_all
NP																	
DP																	
IGO		cites							habitat_combo							water	wg_all
LSP									habitat_combo_eez					species_diver		water	wg_all
TR																water	wg_all

Figure 40:

7.4.1 Updating resilience matrix with local habitat information

In this example we will borrow from the experience of `ohi-israel`, where they assessed habitats in the Habitats (HAB) sub-goal that were not included in global assessments `ohi-global`. Therefore, the resilience matrix needed some revision.

The habitats assessed for `ohi-israel` are:

`rocky_reef`, `sand_dunes`, `soft_bottom`

Updates are required for the following files:

- `layers.csv`
- `resilience_matrix.csv`
- `resilience_weights.csv` (only if adding new resilience layers)

7.4.1.1 Global resilience layers The first step is to determine which resilience layers from the global assessment are relevant to your assessment, and whether others need to be added. The full list of layers included in the global resilience matrix are:

```
alien_species, cites, fishing_v1, fishing_v1_eez, fishing_v2_eez, fishing_v3,  
fishing_v3_eez, habitat, habitat_combo, habitat_combo_eez, li_gci, li_sector_evenness,  
mariculture, msi_gov, species_diversity, species_diversity_3nm, tourism, water,  
wgi_all
```

Some of these layers capture general aspects of governance that apply to the protection of any habitat. These are:

```
alien_species, cites, msi_gov, water, wgi_all
```

Two layers only apply to the livelihoods and economies goal (LE), so they should be excluded from HAB resilience:

```
li_gci, li_sector_evenness
```

The remaining layers apply to certain habitats, but not others. We focus on these to determine how to adapt the HAB resilience calculation for chi-israel. They are:

```
fishng_v1, fishng_v1_eez, fishng_v2_eez, fishng_v3, fishng_v3_eez, habitat,  
habitat_combo, habitat_combo_eez, mariculture, species_diversity, species_diversity_3nm,  
tourism
```

7.4.1.2 Determining how to modify these resilience layers

- To determine whether `species_diversity_3nm` or `species_diversity` should be used:
 - `sand_dunes` should use `species_diversity_3nm`,
 - `soft_bottom` should use `species_diversity`,
 - is `rocky_reef` mainly coastal? if so it should use `tourism` and `species_diversity_3nm`.
- If the habitats can be affected by mariculture plants (e.g. eutrophication and decreased water quality can occur if mariculture plants are close by and have poor wastewater treatment), then the `mariculture` resilience score should be added.
 - are there any mariculture plants in Israel? If yes, on which habitats do they occur?
- The remaining layers are the `fishng_v...` and `habitat...` layers, which are composite indicators obtained from different combinations of the following indicators:

```
Mora, Mora_s4, CBD_hab, MPA_coast, MPA_eez,
```

where:

- `Mora` is a fisheries governance effectiveness indicator by Mora *et al* (2009)
- `Mora_s4` is another indicator from Figure S4 of the supplementary material of the same publication that focuses on regulations of artisanal and recreational fisheries
- `CBD_hab` is a score assigned based on answers to a questionnaire compiled by countries that committed to Rio's Convention on Biological Diversity (CBD) to establish their progress towards habitat biodiversity protection

- **MPA_coast** is an indicator obtained as the proportion of coastal (3nm) waters that are in a marine protected area (MPA), with the maximum being 30% of coastal waters
- **MPA_eez** is an indicator obtained as the proportion of the whole EEZ that is in a marine protected area, with the maximum being 30% of the whole EEZ.

This table shows which indicators are used by each combo layer:

Layer	Mora	Mora_s4	CBD_hab	MPA_coast	MPA_eez
fishing_v1	Mora		CBD_hab	MPA_coast	
fishing_v1_eez	Mora		CBD_hab		MPA_eez
fishing_v2_eez	Mora	Mora_s4	CBD_hab		MPA_eez
fishing_v3		Mora_s4	CBD_hab	MPA_coast	
fishing_v3_eez		Mora_s4	CBD_hab		MPA_eez
habitat			CBD_hab		
habitat_combo			CBD_hab	MPA_coast	
habitat_combo_eez			CBD_hab		MPA_eez

Questions to consider:

The first objective is to determine whether the general **fishing_v...** or **habitat_...** categories are relevant to each of the habitats. For example, fisheries regulations do not affect the conservation of sand dunes, so this habitat should not use any of the fisheries combos. If the general resilience categories are relevant to the habitat, the next step is to select one resilience layer within the **fishing_v...** and **habitat...** categories that most adequately captures the suite of combined resilience variables that affect the habitat. For example, the sand dune habitat is a strictly coastal habitat, so the most appropriate resilience layer would be the one that uses the **MPA_coast** (i.e., **habitat_combo**). The rocky reef and soft bottom, on the other hand, should definitely include fisheries and habitat regulations. So, you'll need to choose a fisheries and a habitat combo for these two habitats. To do so, consider:

- 1) For which habitats should you use both a fishery and a habitat combo, or just use a habitat combo?
 - fisheries regulations do not affect the conservation of sand-dunes, so this habitat should not use any of the fisheries combos. Also, this is a strictly coastal habitat, so choose the habitat layer that uses the **MPA_coast** instead of the **MPA_eez**, i.e. **habitat_combo** (and, as mentioned above, choose the coastal version of biodiversity, i.e. **species_diversity_3nm**).
 - The rocky reef and soft bottom, on the other hand, should definitely include fisheries regulations. So you'll need to choose a fisheries and a habitat combo for these two habitats.
- 2) Which fisheries and habitat combos for **rocky_reef** and **soft_bottom**? The choice depends on two things:
 - whether they are coastal habitats (within 3nm of the coast) or EEZ-wide habitats
 - if coastal, use the fisheries and habitat combos with **MPA_coast** (**fishing_v1**, **fishing_v3**, **habitat_combo**), and the **species_diversity_3nm** layer
 - if EEZ-wide, use the fisheries and habitat combos with **MPA_eez** (**fishing_v1_eez**, **fishing_v2_eez**, **fishing_v3_eez**, **habitat_combo_eez**), and the **species_diversity** layer
 - whether the fisheries occurring on that habitat are mainly artisanal, mainly commercial, or both
 - if only commercial fisheries, use a layer that only uses the **Mora** data **fishing_v1..**)
 - if only artisanal/small-scale fisheries, use a layer that only uses the **Mora_s4** data (**fishing_v3..**)

- if both, use a layer that uses both `Mora` and `Mora_s4` data (`fishing_v2..`)
- 3) It may also be that the existing global combo layers are not appropriate for your habitats. For example, if rocky reef is mainly coastal, and it is fished by both commercial and artisanal methods, then we need a new combo that uses `Mora`, `Mora_s4`, `CBD_hab`, and `MPA_coast` (this is the same as `fishing_v2_eez`, but we use the `MPA_coast` layer instead of the `MPA_eez`). All other combinations are already present.
 - 4) Another issue to consider is whether local data are available to improve the pressure layers (that are based on global data). For example, if there are local data on Marine Protected Areas (MPAs) and any areas with special regulations, this should be used to generate the `MPA_coast` and `MPA_eez` layers. You may know that only certain types of protected areas are closed to fisheries, and may want to only include those. Also, local datasets may be more accurate and regularly updated. **NOTE: in the global study, these are the same datasets used to calculate the status of Lasting Special Places (LSP).
 - 5) How to update `resilience_matrix.csv`?

- write the complete list of layers you want to use for each habitat. Based on the above, for example, `soft bottom` in Israel matches the combination of layers called *soft bottom, with corals* in the default `resilience_matrix.csv`. But the `rocky_reef` and `sand_dunes` don't seem to match any existing combination, so you'll probably need to delete some of the rows, e.g. the *coral only*, and replace with new ad-hoc rows.

7.5 Modifying goal models

When an existing layer is updated with new data, the Toolbox will automatically incorporate it into the goal calculations after the updated filenames are registered in `layers.csv`. However, if a new layer has been added to the layers folder and registered in `layers.csv`, the Toolbox will not use it unless it is called in a goal model. To integrate any new data layers registered in `layers.csv` you will need to modify the goal model to incorporate the data. Furthermore, in many cases, it will make sense to modify goal models based on data availability and/or local context. For example, the models for regional analyses can often be simplified because of improved data.

There are some key steps to follow when working with goal models:

1. Update `functions.R`
2. Check and possibly update `goals.csv`
3. Check if you need to update `pressures_matrix.csv` and `resilience_matrix.csv` when you change a goal model.

7.5.1 Update `functions.R`

To incorporate a new data layer into a goal model, open `functions.R` in RStudio: this script contains all the models for each goal and sub-goal. A member of your team with the ability to write R code will need to translate the updated goal model into the Toolbox format. Follow the structure of existing goal models in order to incorporate the new data layers, noting the use of certain R packages for data manipulation.

The image below shows the navigation pane in RStudio that can be used to easily navigate between goal models.

```
61
62 # separate out the region ids:
63 c$fao_id      <- as.numeric(sapply(as.character(c$fao_saup_id), "_"), function(x)x[1]))
64 c$saup_id     <- as.numeric(sapply(as.character(c$fao_saup_id), "_"), function(x)x[2]))
65 c$TaxonName   <- sapply(strsplit(as.character(c$taxon_name_key), "_"), function(x)x[1]))
66 c$TaxonKey    <- as.numeric(sapply(strsplit(as.character(c$taxon_name_key), "_"), function(x)x[2]))
67 c$catch       <- as.numeric(c$catch)
68 c$year        <- as.numeric(as.character(c$year))
69 #Create Identifier for linking assessed stocks with country-level catches
70 c$stock_id <- paste(as.character(c$TaxonName),
71                      as.character(c$fao_id), sep="_")
72
73 # b_bmsy data
74 b = SelectLayersData(layers, layer='fis_b_bmsy', narrow=T) %>%
75   select(
76     fao_id      = id_num,
77     TaxonName   = category,
78     year,
79     bmsy        = val_num)
80 # Identifier taxa/fao region:
81 b$stock_id <- paste(b$TaxonName, b$fao_id, sep="_")
82 b$bmsy     <- as.numeric(b$bmsy)
83 NP          <- as.numeric(as.character(b$fao_id))
84 CS          <- as.numeric(as.character(b$year))
85 CP          <-
86 TR          <-
87 LIV_ECO    <-
88 r_saup to rgn conversion
89 a[['fis_proparea_saup2rgn']] %>%
90   id, rgn_id, prop_area)
91   as.numeric(a$prop_area)
92   as.numeric(as.character(a$saup_id))
93   as.numeric(as.character(a$rgn_id))
94 -----
95 # the species status data with catch data
96 Catches: only taxa with catch status data
97
```

Modify *functions.R* when changing goal or sub-goal models

Shortcut to all goal sections

Figure 41: The navigation pane in RStudio can be used to easily navigate between goal models.

7.5.2 Check and possibly update `goals.csv`

`goals.csv` provides input information for `functions.R`, particularly about goal weighting and function calls. It also includes descriptions about goals and sub-goals, which is presented on the WebApp.

Changing goal weights will be done here by editing the value in the *weight* column. Weights do not need to be 0-1 or add up to 10; weights will be scaled as a proportion of the number of goals assessed. `goals.csv` also indicates the arguments passed to `functions.R`. These are indicated by two columns: *preindex_function* (functions for all goals that do not have sub-goals, and functions for all sub-goals) and *postindex_function* (functions for goals with sub-goals).

Check the information in `goals.csv`

order_color	order_hierarchy	order_calculate	goal	parent	name	name_flower	description
1	1.2	1.0	15	FP	Food Provision	Food Provision	This goal measures the amount of seafood sustainably harvested in a given region th
2	1.1	1.1	1	FIS	FP	Fisheries	This subgoal model aims to assess the amount of wild-caught seafood that can be sus
3	1.3	1.2	2	MAR	FP	Mariculture	This subgoal measures the ability to obtain maximal seafood yield from farm-raised
4	2.0	2.0	3	AO	Artisanal Fishing Opportunity	Artisanal Fishing Opportunities	This goal captures the access people have to coastal resources, whether or not they
5	3.0	3.0	4	NP	Natural Products	Natural Products	This goal model calculates overall status by weighting the status of sustainable ha
6	4.0	4.0	5	CS	Carbon Storage	Carbon Storage	This goal captures the carbon stored in natural coastal ecosystems that absorb and
7	5.0	5.0	6	CP	Coastal Protection	C	tain coastal habitats provide by mea
8	6.0	6.0	7	TR	Tourism & Recreation	T	periciencing and taking pleasure in co
9	7.2	7.0	16	LE	Coastal Livelihoods & Economics	C	dependent livelihoods and productive c
10	7.1	7.1	8	LIV	Livelihoods	L	on from the oceans in the form of jo
11	7.3	7.2	9	ECO	Economics	E	ated with marine industries.
12	8.2	8.0	17	SP	Sense of Place	S	for aspects of the coastal and na
13	8.1	8.1	10	ICO	Iconic Species	Iconic\nSpecies	is subgoal captures the species that are important to a region because they are r
14	8.3	8.2	11	LSP	Lasting Special Places	Lasting Special\nPlaces	is subgoal captures the conservation status of geographic locations that hold sig
15	9.0	9.0	12	CH	Clean Waters	Clean Waters	is goal captures the degree to which waters are polluted.
16	10.2	10.0	18	BD	Biodiversity	Biodiversity	This goal captures the conservation status of marine species.
17	10.1	10.1	13	HAB	Habitats	Habitats	This subgoal measures the condition of habitats that are important for supporting a
18	10.3	10.2	14	SPP	Species	Species	This subgoal uses to estimate how successfully the richness and variety of marine l

weight	preindex_function	postindex_function
1.0		
0.5	FIS(layers, status_year=2011)	
0.5	MAR(layers, status_years=2007:2012)	
1.0	AO(layers, year_max=2013)	
1.0	NP(scores, layers, year_max=2011)	
1.0	CS(layers)	
1.0	CP(layers)	
1.0	TR(layers, year_max=2012)	
1.0		LE(scores, layers)
0.5	LIV_ECO(layers, subgoal='LIV')	
0.5	LIV_ECO(layers, subgoal='ECO')	
1.0		SP(scores)
0.5	ICO(layers)	
0.5	LSP(layers, status_year=2013, trend_years=2008:2013)	
1.0	CW(layers)	
1.0		BD(scores)
0.5	HAB(layers)	
0.5	SPP(layers)	

Figure 42: Check the information in `goals.csv`. It provides input information for `functions.R`.

When updating layers or goal models, it is important to ensure that information called from `goals.csv` is correct:

TIP: In the ‘preindex_function’ column, you should see what the `year_max`, `status_year`, and `trend_year` say.

7.5.3 Example modification:

Suppose your team has decided to add an ‘artisanal access’ component to the Artisanal Fishing Opportunity goal because of locally available data. Once the data are obtained and properly formatted, the data layer is saved as `ao_access_art`. To include this new information in the goal model, you will need to do the following:

1. register the layer in `layers.csv`
2. update the goal model in `functions.R`
3. update the goal call in `goals.csv`

Step 1. Register in `layers.csv`

	A	B	C	D	E	F	G	H
	targets	layer	name	description	fld_value	units	filename	fld_id_num
2	AO	ao_access	Fisheries management	The opportunity for value creation	value		ao_access_china2014.csv	rgn_id
3	AO	ao_access_art	Example data	Made-up data	value		ao_access_art_china2014.csv	rgn_id
4	AO	ao_need	Purchasing power pi	The per capita purchasing power	value		ao_need_global2013.csv	rgn_id
5	CW	cw_coastalpopn_trend	Coastal human population	Coastal population trend	trend score		cw_coastalpopn_trend_global2013.csv	rgn_id
6	CW	cw_fertilizer_trend	Fertilizer consumption	Statistics on fertilizer trend	trend score		cw_fertilizer_trend_global2013.csv	rgn_id

Figure 43:

Step 2. Update the goal model

```

326 #0 = function(layers,
327   year_max=max(layers$datayear, na.rm=T),
328   year_min=min(layers$datayear, na.rm=T), max(layers$datayear, na.rm=T)-10),
329   Sustainability=1.0)({
330 
331   # cost data
332   layers_data = SelectLayersData(layers, targets='AO')
333 
334   ry = dcast(layers_data, id_num ~ year ~ layer, value.var='val_num',
335   subset = (layer %in% c('ao_need')),
336   c('id_num'~'region_id', 'ao_need'~'need')); head(ry); summary(ry)
337 
338   r = na.omit(dcast(layers_data,
339   subset = (layer %in% c('ao_access'))),
340   c('id_num'~'region_id', 'ao_access'~'access')); head(r); summary(r)
341 
342   ra = na.omit(rename(dcast(layers_data, id_num ~ layer, value.var='val_num',
343   subset = (layer %in% c('ao_access_art'))),
344   c('id_num'~'region_id', 'ao_access_art'~'access_art'))); head(ra); summary(ra)
345 
346   ry = merge(ry, ra)
347   ry = merge(ry, r); head(ry); summary(ry); dim(ry)
348 
349   # model
350   #' -within(ry, [
351   Du = (1.0 - need) * (1.0 - (access + access_art)/2)
352   status = ((1.0 - Du) * Sustainability) * 100
353   ])
354 
355   # status
356   r.status = subset(ry, year==year_max, c(region_id, status)); summary(r.status); dim(r.status)
357 
358   # trend

```

Figure 44:

Step 3. Update goal call in `goals.csv`

7.6 Removing goals

If a goal is not relevant in your region, it is possible to remove the goal completely from the calculation. There are four places where you will need to remove the reference to this goal. Failing to delete all referenced layers after the goal is deleted will result in errors. To remove goals from your assessment, you will have to do the following:

1. Remove the goal model from `functions.R`
2. Remove the goal's row from `goals.csv`
3. Remove the goal's row from `pressures_matrix.csv`
4. Remove the goal's row from `resilience_matrix.csv`

Example: Removing carbon storage (CS) goal

To completely remove the carbon storage goal from Index calculations, you will do the following.

Check goals.csv
when changing goal or
sub-goal models

J15	B	C	D	E	F	G	H	I	J	K
	order_hierar	order_calculatgoal		parent	name	name_flowe	description	weight	preindex_function	postindex_function
1	1	15 FP		Food Provisk	Food Provisk	This goal me		1		FP(layers, scores)
2	1.1	1 FIS	FP	Fisheries	Fisheries	This subgoal		0.5	FIS(layers, status_year=2011)	
3	1.2	2 MAR	FP	Marciculture	Marciculture	This subgoal		0.5	MAR(layers, status_years=2007:2012)	
5	2	3 AO		Artisanal Fish	Artisan	This goal cap		1	AO(layers, year_max=2013)	
6	3	4 NP		Natural Prod	Natural Prod	This goal mo		1	NP(layers)	
7	4	5 CS		Carbon Stora	Carbon Stora	This goal cap		1	CS(layers)	
8	5	6 CP		Coastal Prot	Coastal\nProt	This goal me		1	CP(layers)	
9	6	7 TR		Tourism & Rv	Tourism & Rv	This goal cap		1	TR(layers, year_max=2012)	
10	7	16 LE		Coastal Liveli	Coastal Liveli	This goal aim		1		
11	7.1	8 LIV	LE	Livelihoods	Livelihoods	This subgoal		0.5	LIV_ECO(layers, subgoal='LIV')	LE(scores, layers)
12	7.2	9 ECO	LE	Economies	Economies	This subgoal		0.5	LIV_ECO(layers, subgoal='ECO')	
13	8	17 SP		Sense of Plac	Sense of Plac	This goal aim		1		SP(scores)
14	8.1	10 ICO	SP	Iconic Specie	Iconic\ncySpec	This subgoal		0.5	ICO(layers)	
15	8.2	11 LSP	SP	Lasting Speci	Lasting Speci	This subgoal		0.5	LSP(layers, status_year=2013, trend_years=2008:2013)	
16	9	12 CW		Clean Water	Clean Water	This goal cap		1	CW(layers)	
17	10	18 BD		Biodiversity	Biodiversity	This goal cap		1		BD(scores)
18	10.1	13 HAB	BD	Habitats	Habitats	This subgoal		0.5	HAB(layers)	
19	10.2	14 SPP	BD	Species	Species	This subgoal		0.5	SPP(layers)	
20										
21										
22										
23										

Figure 45: A screenshot of goals.csv, used to modify goal model

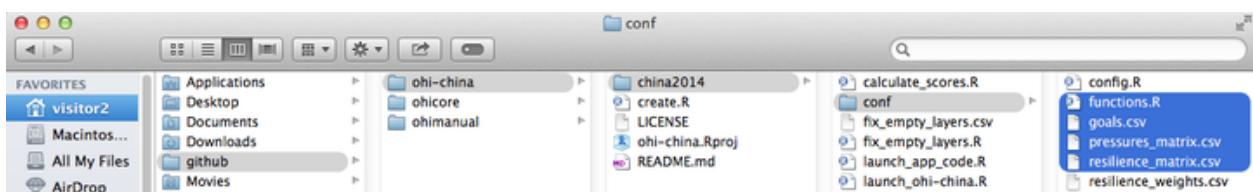


Figure 46:

- 1) Remove the carbon storage (CS) goal model from `functions.R`. Delete the highlighted text in the figure below that references the CS layers and calculates CS goal status, trend, and scores.

```

627 return(scores_AP)
628 }
629
630 CS <- function(layers){
631
632 # layers
633 lyr5 <- llist("rk" = c("hab_health" = "health",
634 "hab_extent" = "extent",
635 "hab_trend" = "trend"))
636 lyr5$names = sub("\\w+", "", names(lyr5$names)))
637
638 # cosc acco
639 # select layersData(layers, layers=lyr5$names)
640 rk = removeDots(D, dnum + category ~ Layer, value.var='val_num', subset = .(layer %in% names(lyr5[["rk"]])))
641   c("idnum"="region_id", "category"="habitat", lyr5[["rk"]]))
642
643 # limit to CS habitats
644 rk = subset(rk, habitat %in% c("mangrove", "saltmarsh", "seagrass"))
645
646 # assign extent of 0 as NA
647 rkExtent[rkextent==0] = NA
648
649 # status
650 r.status = ddply(rk[,c("region_id", "habitat", "extent", "health")], .(region_id), summarize,
651   goal = "CS",
652   dimension = "status",
653   score = min(1, sum(extent * health) / sum(extent)) * 100)
654
655 # trend
656 r.trend = ddply(rk[,c("region_id", "habitat", "extent", "trend")], .(region_id), summarize,
657   goal = "CS",
658   dimension = "trend",
659   score = sum(extent * trend) / sum(extent))
660
661 # return scores
662 scores = cbind(r.status, r.trend)
663
664 return(scores)
665
666
667 CP <- function(layers){
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```

resilience_matrix.csv													
↳	A	B	C	D	E	F	G	H	I	J	K	L	M
1	goal	component	alien_species	cites	fishing_v1	fishing_v1	eez_fishing_v1	eez_fishing_v3	fishing_v3_eez_habitat	habitat_combi_habitat	habitat_combi_gd		
2	7	component	alien_species	cites								habitat_combo_eez	
3	8												
4	9	CS	mangrove only									habitat_combo	
5	10	CW										habitat_combe	
6	11	FIS											habitat_combo_eez

Figure 50:

components within a goal differently. When that is the case, those components can have individual entries (rows) in the pressures and resilience matrix tables and will have pressures and resilience scores calculated individually for each component.

The Toolbox calls these components of a goal ‘categories’, and knows to calculate pressures and resilience for category elements separately because they are identified in three places: in `pressures_matrix.csv`, `resilience_matrix.csv`, and `config.r`. These files are all located in the `conf` folder. To calculate the pressures and resilience scores, the Toolbox uses `config.r` to identify which categories to expect in the matrix tables, and will give a warning if they do not match. `config.r` relies upon the data layers identified in the `pressures_components` and `resilience_components` variables.

In global assessments, there are several goals that have categories indicated in the matrix tables and `config.r` file:

Goal	Category	layer indicated in config.r
NP	product types	np_harvest_product_weight
CS	habitat types	cs_habitat_extent
CP	habitat types	cp_habitat_extent_rank
HAB	habitat types	hab_presence
LIV	industry sectors	le_sector_weight
ECO	industry sectors	le_sector_weight

If you have modified any of the category types in the matrix tables of the above goals, or added new category types to any goals, you will likely need to update the layer indicated in `config.r`. It is also possible to identify individual categories in other goals than those listed above. For example, in the mariculture sub-goal, you could specify the pressures on nearshore mariculture separately from offshore mariculture.

It is important that the file identified in config.r does not contain any NA values.

7.7.2 Example 1: Pressures

Here is an example of how to modify existing category types for the natural products goal.

In the China OHI+ assessment there are three natural product types (seasalt, sea chemicals, and sea medicine), which differ from those assessed in the global assessments (corals, fish_oil, ornamentals, seaweeds, sponges). After modifying and registering the appropriate data layers and updating the NP function in `functions.r`, it is time to update the natural product types in `pressures_matrix.csv`, `resilience_matrix.csv`, and `config.r`.

- to update `pressures_matrix.csv` and `resilience_matrix.csv`, make sure that each product type has a separate row, with the appropriate pressures identified and weights attributed.
 - to update `config.r`, check that the data layer identified in the `pressures_components` and `resilience_components` has the same category types.

When you run `calculate_scores.r`, the following warning will alert you that there is a mis-match between category types identified in the matrix and `config.r`:

Calculating Pressures...

The following components for NP are not in the aggregation layer np_harvest_product_weight categories (corals, fish_oil, ornamentals, seaweeds, sponges):
seasalt, sea_chemicals, sea_medicine 65

This message indicates that the `np_harvest_product_weight` layer identifies five categories (corals, fish_oil, ornamentals, seaweeds, sponges) but the `pressures_matrix.csv` indicates three (seasalt, sea_chemicals, sea_medicine).

To ensure that pressures are calculated correctly for the categories in your assessment, you will need to change the layer identified in `config.r`.

Note that more subtle examples of these mismatch between the categories identified in `pressures_matrix.csv` and `config.r` can also occur. For example, after updating the carbon storage layers and goal model in the China OHI+ assessment, the following warning message appeared when running `calculate_scores.r`:

```
Calculating Pressures...
The following components for CS are not in the aggregation layer
cs_extent categories (saltmarshes, seagrasses, mangroves):
mangrove, saltmarsh, seagrass
```

The problem here is that the categories identified in `config.r` (saltmarshes, seagrasses, mangroves) are plural, whereas the categories identified in the pressures matrix (mangrove, saltmarsh, seagrass) are singular, and the Toolbox needs exact matches. To fix this warning, you need to update the pressures matrix with the plural names.

7.7.3 Example 2: Resilience

For resilience calculations, the proper categories also need to be identified both in `resilience_matrix.csv` and `config.r`. If there is a mismatch, you will see the following message:

```
Calculating Resilience...
Note: each goal in resilience_matrix.csv
must have at least one resilience field
Based on the following components for NP:
corals
fish_oil
ornamentals
seaweeds
shells
sponges
```

With resilience, if we update only the `resilience_matrix.csv` but not `config.r`, we get the following error message instead of the warning message we saw for pressures above.

```
Based on the following components for NP:
  seasalt
  sea_chemicals
  sea_medicine
Error in subset.default(SelectLayersData(layers, layers = lyr), 
id_num == : object 'id_num' not found
In addition: Warning messages:
1: Grouping rowwise data frame strips rowwise nature
2: In left_join_impl(x, y, by$x, by$y) :
  joining factors with different levels, coercing to character vector
```

This error can be fixed by updating `config.r` with a layer identifying the appropriate categories.

7.8 Other example modifications

7.8.1 Preparing the fisheries sub-goal

Here is some background information about how to prepare fisheries data layers for the Toolbox.

Data layers used by the Toolbox:

- `fis_b_bmsy`
- `fis_meanCatch`
- `fis_preparea_saup2rgn`
- `fp_wildcaught_weight`

7.8.1.1 Description of data layers `fis_b_bmsy`

- *for species*: B/Bmsy estimate (either from formal stock assessment, or from a data-poor method such as CMSY)
- *for genus/family/broader taxa*: the toolbox will use median B/Bmsy from species in that region + a penalty for not reporting at species level. In order for the code to assign the correct penalty, the taxa need to include a numerical code of 6 digits, where the first digit behaves like an ISSCAAP code (the standardized species codes used by FAO): 6 means species, 5 means genus, 4 to 1 are increasingly broad taxonomic groups
- *data source (for CMSY)*: catch time-series (at least 10 years of catch >0), species resilience (if available)

Example data:

fao_id	taxon_name	year	b_bmsy
51	Ablennes hians	1985	1.112412
51	Ablennes hians	1986	1.222996
51	Ablennes hians	1987	1.371058

NOTE: if a species that is caught in different sub-regions belongs to the same population, you don't want to split the catch among sub-regions, instead, you want to sum catch across all sub-regions, so you can calculate B/Bmsy for the whole population. For the global analysis we grouped all species catch by FAO major fishing area (www.fao.org/fishery/area/search/en), indicated in the column `fao_id`, assuming that all species caught within the same FAO area belonged to the same stock, while we assumed that the same species, if caught in a different fishing area, belonged to a separate stock.

Use `fao_id` as an identifier that separates different fisheries 'stocks' belonging to the same species. If you don't have multiple stocks in your study area, set all `fao_id = 1`.

`fis_meanCatch`:

- average catch across all years, per species, per region
- *data source*: catch time-series (at least 10 years of catch >0), with a unique identifier for each population that you want to assess separately

Example data:

fao_saup_id	taxon_name_key	year	mean_catch
37_8	Aristeus antennatus_690051	2014	14.24398116

fao_saup_id	taxon_name_key	year	mean_catch
37_8	Atherinidae_400218	2014	27.30120156
37_8	Balistes capriscus_607327	2014	3.247883895

The *taxon_name_key* column indicates the name of the species (e.g. *Aristeus antennatus*) and its ‘taxonkey’. The taxonkey is a 6 digit numeric code used by the Sea Around Us Project, modified from FAO codes. The important element of this code is the first digit, because it reflects the taxonomic level (6=species, 5=genus, 4=family, etc.) of the reported catch. The toolbox uses this first digit to assign a score to all catch that was not reported at species level, taking the median of the B/Bmsy of assessed species, and adding a penalty that is increasingly strong for coarser taxa.

fis_proparea_saup2rgn:

- a conversion file that, for each region for which catch is reported, tells us what proportion of that region falls within each of the final OHI reporting regions.

Example data:

saup_id	rgn_id	prop_area
166	1	1.0
162	2	1.0
574	3	0.7
37	4	0.8

Specific instances:

only if catch is reported for different regions than the ones used for the OHI assessment: this should be calculated using spatial analyses of overlap of the spatial units at which catch is reported with the spatial units at which the OHI assessment will be reported. The global data was reported by subregions (*saup_id*) and in some cases multiple subregions were part of the same, larger EEZ. Since for OHI we wanted results by EEZ (*rgn_id*), in those cases we needed to combine results from the subregions to get the final score, based on their size relative to the total EEZ size (*prop_area*). *If catch is reported for the same areas for which OHI is calculated:* then all the *prop_area* are = 1. *If catch is reported for the whole area of the assessment, but you want to calculate a separate OHI score for different sub-regions:* for each OHI reporting region (*rgn_id*) you’ll repeat the same region in the *saup_id* column, and *prop_area* will be =1. This effectively means all the reporting regions will get assigned 100% of the catch and will have the same final status and trend score for the fisheries goal (but may have different pressures and resilience scores, if those layers are different in each sub-region).

fp_wildcaught_weight:

only needed if there is mariculture: for each region, this represents the relative proportion of catch coming from wild caught fisheries versus mariculture. The layer is used to weight how much the fisheries score influences the final food provision score, the higher the fisheries catch, the more the food provision score will reflect the fisheries score, and vice-versa if mariculture has a higher catch. (NOTE that, before all mariculture harvest from all species gets summed, the mariculture harvest for each species is smoothed and then multiplied by the resilience score).

7.8.1.2 Running CMSY model Sample data to run CMSY:

id	stock_id	res	ct	yr
6	Acanthistius brasilianus_41	Medium	100	1950

<i>id</i>	<i>stock_id</i>	<i>res</i>	<i>ct</i>	<i>yr</i>
23	Acanthurus dussumieri_61		0.059250269	1950
24	Acanthurus dussumieri_71		0.190749971	1950
25	Acanthurus lineatus_61	Low	12.74821966	1950

The current CMSY script produces an output that looks something like this (split into 2 tables):

<i>stock_id</i>	<i>convergence</i>	<i>effective_sample_size</i>	<i>yr</i>	<i>b_bmsy</i>	<i>b_bmsyUpper</i>
Ablennes hians_51	SC	30974	1985	1.112412	1.8
Ablennes hians_51	SC	30974	1986	1.222996	1.768895

<i>stock_id</i>	<i>yr</i>	<i>b_bmsyLower</i>	<i>b_bmsyiq25</i>	<i>b_bmsyiq75</i>	<i>b_bmsyGM</i>	<i>b_bmsyMed</i>
Ablennes hians_51	1985	1	1	1	1.093932	1
Ablennes hians_51	1986	1.014688	1.075699	1.298437	1.209005	1.160329

where *stock_id* is the unique identifier for each stock that was used in the input file, *convergence* indicates whether the model converged and how strongly ('SC' = strong convergence), *effective_sample_size* reports the number of iterations used, *yr* = year, *b_bmsy* = B/Bmsy for the corresponding year (based on the median of all the estimated values: recommended), *b_bmsyUpper* = B/Bmsy at the upper 95% bootstrapped confidence bound, *b_bmsyLower* = B/Bmsy at the lower 95% bootstrapped confidence bound, *b_bmsyiq25* = B/Bmsy at the first quartile, *b_bmsyiq75* = B/Bmsy at the third quartile, *b_bmsyGM* = B/Bmsy based on the geometric mean of estimates, *b_bmsyMed* = B/Bmsy based on the median of estimates.

How to:

1. Include resilience in the CMSY code:

In the CMSY R script, in the PARAMETERS section, replace the following:

```

start_r    <- c(0.01,10) ## disable this line if you use resilience
with

if(res == "Very low"){
  start_r <- c(0.015, 0.1)
} else {
  if(res == "Low"){
    start_r <- c(0.05,0.5)
  } else {
    if(res == "High"){
      start_r <- c(0.6,1.5)
    } else {
      start_r <- c(0.1,1)
    }
  }
}

```

Figure 51:

2. Make assumptions about fisheries regulations:

If you assume that fisheries are depleted and there isn't very much fisheries regulation, and you are using the CMSY method to assess B/Bmsy, the original model may work well. If, however, the catch of a species declined because fisheries regulations have closed or limited the fishery, or if a fishery was abandoned for economic reasons (e.g., change in consumer preferences, market price dynamics, etc.), the model may be too

pessimistic and underestimate B/Bmsy. In that case it may be best to use a version with a uniform prior on final biomass, instead of the constrained prior.

The original constrained prior on final biomass is set by this line within the code:

```
finalbio    <- if(ct[nyr]/max(ct) > 0.5) {c(0.3,0.7)} else {c(0.01,0.4)}
```

The model uses a uniform prior if that line is replaced with:

```
finalbio    <- c(0.01,0.7)
```

3. Use data at a different spatial resolution than the final assessment:

See notes above for `fis_proparea_saup2rgn`

4. Calculate B, or Bmsy:

The CMSY model calculates B/Bmsy as a ratio, it does not estimate the two variables separately.

5. Use catch per unit of effort (CPUE):

The CMSY model requires total biomass removed by fisheries, and uses catch as a proxy for that. It cannot use CPUE. Other more sophisticated stock assessment models use CPUE and may be employed. We do not provide documentation for the use of these other models.

6. Use other life-history characteristics, in addition to resilience:

The CMSY model does not use more detailed information. Other more sophisticated stock assessment models use other life-history traits such as fecundity, larval dispersal, r, K, Lmax, etc., and may be employed. We do not provide documentation for the use of these other models.

7. Create a ‘taxonkey’ to assign to each species:

When replacing the SAUP_FAO data with your own data, assign a key of 600000 to all species. For all catch that is reported at genus or coarser taxonomic level, you will have to choose an appropriate taxonkey. You can create your own key, from 100000 to 500000, based on your own judgment of how many species may be reported under that same denomination, and how different they may be (all that matters for the toolbox code is whether the number starts with a 1,2,3,4,5 or 6 with 1 being the coarsest, such as ‘miscellaneous marine animals’, or ‘crustaceans nei’).

7.8.1.3 Resources Martell, S & Froese, R (2013) “A simple method for estimating MSY from catch and resilience”. *Fish and Fisheries*, DOI: 10.1111/j.1467-2979.2012.00485.x. [Downloadable here](#)

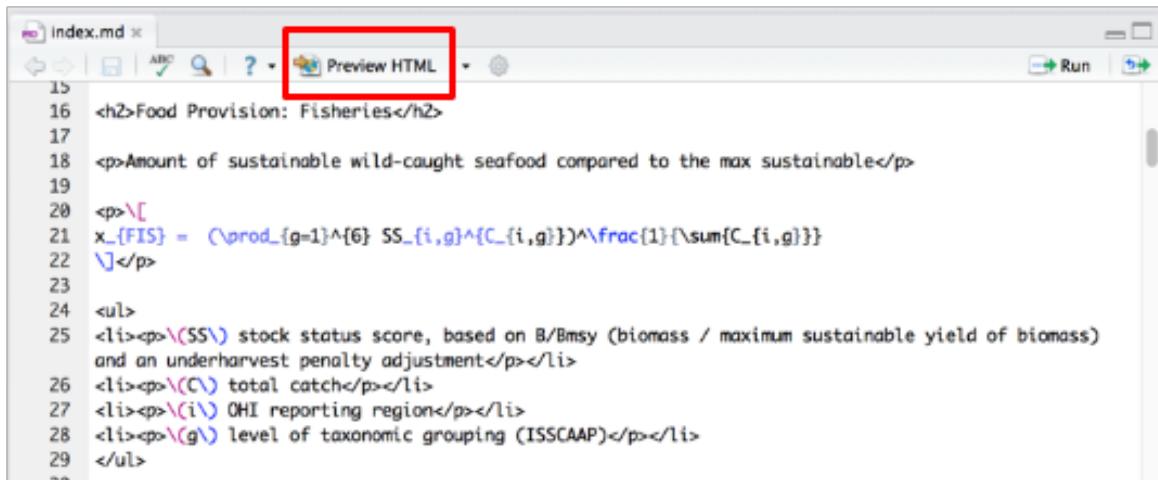
Rosenberg, A.A., Fogarty, M.J., Cooper, A.B., Dickey-Collas, M., Fulton, E.A., Gutiérrez, N.L., Hyde, K.J.W., Kleisner, K.M., Kristiansen, T., Longo, C., Minte-Vera, C., Minto, C., Mosqueira, I., Chato Osio, G., Ovando, D., Selig, E.R., Thorson, J.T. & Ye, Y. (2014) Developing new approaches to global stock status assessment and fishery production potential of the seas. *FAO Fisheries and Aquaculture Circular No. 1086*. Rome, FAO. 175 pp. [Downloadable here](#)

7.9 Updating the WebApp’s pages

The WebApp displays input layers on several pages: on the App page, Layers page, and Scores page. These input layers are displayed from `layers.csv` and the layers within the `layers` folder and the scores are displayed from `scores.csv`. While the input layers and scores will be automatically displayed on the WebApp, there is other content on WebApps pages that can be edited by your team and displayed. You will likely spend the most time updating the equations displayed on the Goals page to be consistent with the updated methods you have used in your assessment.

For the WebApp to display the pages properly, not everything on each page can be edited as it is written in a language to create the website. But it is possible to explore the files and update much of the text that is displayed while maintaining the required formatting. To do this, run `copy_webapps_templates.r` once, before further modifications on the WebApp contents. This actions creates a folder called `webapps_templates` and copies template files there.

It is best to edit the files in RStudio: you will be able to view your work as it will be displayed on the WebApp by clicking the ‘Preview HTML’.



```

15 <h2>Food Provision: Fisheries</h2>
16
17 <p>Amount of sustainable wild-caught seafood compared to the max sustainable</p>
18
19
20 <p>\[
21 x_{FIS} = (\prod_{g=1}^6 SS_{i,g}^{C_{i,g}})^{\frac{1}{\sum C_{i,g}}}
22 \] </p>
23
24 <ul>
25 <li><p>\(SS\)</p> stock status score, based on B/Bmsy (biomass / maximum sustainable yield of biomass) and an underharvest penalty adjustment</li>
26 <li><p>\(C\)</p> total catch</li>
27 <li><p>\(i\)</p> OHI reporting region</li>
28 <li><p>\(g\)</p> level of taxonomic grouping (ISSCAAP)</li>
29 </ul>
30

```

Figure 52:

7.9.1 Regions

You may have redefined the spatial boundaries of the regions used in your assessment, or you may want to update the information provided about them. This can be done with the file called `webapps_templates/regions.brew.md`.

7.9.2 Layers

Most of the information displayed on the Layers page of the WebApp is taken from the `layers.csv`, and therefore to modify any information about specific data layers, you will need to modify the `layers.csv` file within the draft branch of your repository. However, you are able to edit the header text information at the top of the Layers page if you wish. This can be done with the file called `webapps_templates/layers.brew.md`.

7.9.3 Goals

You will likely spend the most time modifying the information displayed on the Goals page, as these show and describe the models used in the assessment. Text can be modified with the file called `webapps_templates/goals.brew.md`.

To edit the goal equations themselves, you will edit the `goals.Rmd` found in the `conf` folder (example: `ecu/subcountry2014/conf/goals.Rmd`). This is an RMarkdown file, with equations written in LaTeX. When

rendered by RStudio or the WebApp, it displays nicely formatted. To update model equations, you will need to use the LaTex format. You can learn the syntax by studying how the equations from the global assessments are displayed, and from many resources online. One resource is <https://en.wikibooks.org/wiki/LaTeX/Mathematics>. Learn more about .Rmd formatting at <http://shiny.rstudio.com/articles/rmarkdown.html>.

7.9.4 Scores

The scores displayed on the Scores page of the WebApp are the calculated scores from the `scores.csv` file in the draft branch, and therefore cannot be modified. However, you are able to edit the header text information at the top of the Scores page if you wish. This can be done with the file called `webapps_templates/scores.brew.md`.

7.10 R Tutorials for OHI

Ocean Health Index R code uses several packages and best practices to facilitate understanding and collaboration. These approaches are presented here, along with examples using data included in global OHI assessments.

This document describes several packages that are used extensively in OHI assessments and introduces you to typical coding practices commonly seen in OHI scripts and functions.

Also see the accompanying R script to test examples using these packages.

7.10.1 R Very Basics:

- Have you already downloaded and installed [R](#)?
- Have you already downloaded and installed [RStudio](#)?
- Have you walked through the excellent interactive tutorials from [swirl](#)?

7.10.2 tidy functions

‘Tidy’ up your messy data using `tidy` to make it easier to work with. The ‘tidy tools’ functions in the `dplyr` package work best with tidy data.

From Hadley Wickham’s [Tidy Data paper](#): >It is often said that 80% of data analysis is spent on the cleaning and preparing data. And it’s not just a first step, but it must be repeated many over the course of analysis as new problems come to light or new data is collected. To get a handle on the problem, this paper focuses on a small, but important, aspect of data cleaning that I call data tidying: structuring datasets to facilitate analysis.

From [RStudio’s introduction to tidy](#):

The two most important properties of tidy data are: 1. Each column is a variable. 2. Each row is an observation.

Arranging your data in this way makes it easier to work with because you have a consistent way of referring to variables (as column names) and observations (as row indices). When you use tidy data and tidy tools, you spend less time worrying about how to feed the output from one function into the input of another, and more time answering your questions about the data.

`gather()` is arguably the most useful function in `tidy`, and is explained in more detail below. `spread()` and `separate()` are other useful functions in `tidy`.

Other ‘tidy’ references: * [Hadley Wickham’s *Tidy Data* paper](#): Download the pre-print version for the whys and hows of tidy data. * [Cran tidy data vignette](#): An informal and code heavy version of Hadley’s full *Tidy Data* paper. * [RStudio Blogs: Introducing tidyverse](#): Basics and philosophy of `tidyverse` * [swirl tutorial package](#): A tutorial package built directly into R. Section 2: ‘Getting and Cleaning Data’ runs you through `dplyr` and `tidyverse` basics * [R data wrangling cheat sheet](#): A quick reference guide to `tidyverse` and `dplyr` functions

7.10.2.1 `tidyverse::gather()` Description

`gather()` takes data organized in rows and collapses them into a column format (a key column and a value column), duplicating all other columns as needed. Use `gather()` when your data is organized in “wide” format, in which some of your variables are in row form, rather than column form. Another `tidyverse` function, `spread()`, is more or less the reverse of `gather()`, to reformat long data into wide data. It is more difficult to work with wide data, but may be more convenient for examining data in a table format.

Note: `gather()` essentially replaces `melt()` in `plyr` package.

Example

The sample data set (see intro) contains harvest data of a number of marine commodities, separated by country, commodity, and year. In its original form, the harvest data (in tonnes) is spread across five different harvest years. * Counter to ‘tidy data’ principles, we have multiple columns (X2007:X2011) representing a single variable (year), and multiple observations of harvest tonnage in each row. * To transform this into ‘tidy data’ we will gather the five annual harvests into a single column called ‘tonnes’ and note the year of harvest in a new column called ‘year’.

The example in the figure below shows how the original wide data is transformed into long data using the command `gather`. Here are two ways of achieving this:

1. Here, information from columns X2007 through X2011 are gathered into a single column called `year`, and the information in each column are put into a new column called `tonnes`.

```
data_long <- data_wide %>% gather(year, tonnes, X2007:X2011)
```

2. Here, the `-` unselects the named columns, so they will not be gathered; all other columns are gathered into columns named `year` and `tonnes`. This approach will yield the same result.

```
data_long <- data_wide %>% gather(year, tonnes, -Country, -Commodity, -Trade)
```

7.10.3 `dplyr` functions

The `dplyr` package includes a number of functions to easily, quickly, and intuitively wrangle your data. Here is a quick introduction with examples from data used in the Ocean Health Index.

From [RStudio’s introduction to dplyr](#):

The bottleneck in most data analyses is the time it takes for you to figure out what to do with your data, and `dplyr` makes this easier by having individual functions that correspond to the most common operations...

Each function does one only thing, but does it well.

The most important `dplyr` functions to understand for data processing will be `group_by()`, `mutate()`, and `summarize()`. Also important, `dplyr` introduces the ability to perform subsequent functions in a logical and intuitive manner, using the `%>%` chain operator.

Wide data: 15 rows of 8 columns.

The data (tonnes of harvest) is spread out across multiple columns, separated by year.
Each row represents multiple observations.

```
data_wide <- data_long %>%
  spread(year, tonnes)
```

Country	Commodity	Trade	year	tonnes
1 Australia	Agar agar nei	Export	X2007	208
2 Australia	Coral and the like	Export	X2007	616
3 Australia	Fish body oils, nei	Export	X2007	448
4 Australia	Fish liver oils, nei	Export	X2007	...
5 Australia	Mother of pearl shells	Export	X2007	189
6 Australia	Ornamental fish nei	Export	X2007	5
7 Australia	Ornamental saltwater fish	Export	X2007	...
8 Australia	Other seaweeds and aquatic plants and products thereof	Export	X2007	1348
9 Australia	Shells nei	Export	X2007	NA
10 Vietnam	Agar agar nei	Export	X2007	0 0
11 Vietnam	Coral and the like	Export	X2007	2400
12 Vietnam	Fish body oils, nei	Export	X2007	2800
13 Vietnam	Fish liver oils, nei	Export	X2007	26000
14 Vietnam	Ornamental fish nei	Export	X2007	30000
15 Vietnam	Other seaweeds and aquatic plants and products thereof	Export	X2007	50560

Country	Commodity	Trade	X2007	X2008	X2009	X2010	X2011
1 Australia	Agar agar nei	Export	208	122	1	0 0	0 0
2 Australia	Coral and the like	Export	616	446	294	353	426
3 Australia	Fish body oils, nei	Export	448	382	1517	1282	1555
4 Australia	Fish liver oils, nei	Export	69	98	113
5 Australia	Mother of pearl shells	Export	189	215	135	342	204
6 Australia	Ornamental fish nei	Export	5	...	8	48	26
7 Australia	Ornamental saltwater fish	Export	115	88	82
8 Australia	Other seaweeds and aquatic plants and products thereof	Export	3348	2698	1988	3248	2458
9 Australia	Shells nei	Export	NA	NA	0	0	0
10 Vietnam	Agar agar nei	Export	0 0	2	2	1	0 0
11 Vietnam	Coral and the like	Export	2400	2600	3500	3000	3000
12 Vietnam	Fish body oils, nei	Export	8200	29000	26000	30000	50560
13 Vietnam	Fish liver oils, nei	Export	7	5	15	3	53
14 Vietnam	Ornamental fish nei	Export	74	84	121	288	189
15 Vietnam	Other seaweeds and aquatic plants and products thereof	Export	298	608	468	808	808

```
data_long <- data_wide %>%
  gather(year, tonnes, -Country, -Commodity, -Trade)
```

Long data: 75 rows of five columns.

Each column represents a single variable.
Each row represents a single observation.

Figure 53: wide data to long data using `gather()` and `spread()`

- `%>%` (chaining operator): allows sequential chaining of functions for cleaner, easier-to-read code
- `dplyr::select()`: selects variables to be retained or dropped from dataset
- `dplyr::filter()`: filters data set by specified criteria
- `dplyr::arrange()`: sorts dataset by specified variables
- `dplyr::mutate()`: adds variables or modifies existing variables
- `dplyr::summarize()`: uses analysis functions (sum, mean, etc) to summarize/aggregate specified variables
- `dplyr::group_by()`: groups data by specified variables, allowing for group-level data processing.

Other `dplyr` references:

- [RStudio blogs: Introducing dplyr](#): philosophy, examples, and basics of `dplyr`
- [Cran dplyr vignette](#): Walkthrough of `dplyr` with examples
- [dplyr and pipes: the basics](#): More examples of `dplyr` functions, and more depth on `%>%`
- [swirl tutorial package](#): A tutorial package built directly into R. Section 2: ‘Getting and Cleaning Data’ runs you through `dplyr` and `tidyverse` basics
- [R data wrangling cheat sheet](#): a quick reference guide to `tidyverse` and `dplyr` functions

7.10.3.1 `%>%` operator Description

The `%>%` operator allows you to ‘pipe’ or ‘chain’ a number of function calls, in which the output dataframe of one function is fed directly into the next function as the input dataframe. This lets you avoid creating temporary variables to store intermediate values, and lets you avoid nesting multiple functions. Using `%>%` makes your code more elegant, streamlined, and easy to read since you are able to write your code on multiple indented lines. From [dplyr and pipes: the basics](#):

OK, here’s where it gets cool. We can chain `dplyr` functions in succession. This lets us write data manipulation steps in the order we think of them and avoid creating temporary variables in the middle to capture the output. This works because the output from every `dplyr` function is a data frame and the first argument of every `dplyr` function is a data frame.

Usage

```
data_out <- f(data_in, args)
# standard function call

data_out <- data_in %>% f(args)
# function call using %>% operator. data_in is passed as first argument
# of function().

data_out <- data_in %>%
  f1(args1) %>%
  f2(args2) %>%
  f3(args3) %>% ...
# Output of function can be passed to another function immediately,
# without need for temporary storage. Indented format for legibility,
# see how pretty it looks?
```

Example

```
### Bad! Nested functions: read from inside out - hard to decipher
h_recent_totals1 <- arrange(mutate(filter(group_by(harvest, country, commodity),
year >= 2009), harvest_tot = sum(tonnes, na.rm = TRUE)), country, commodity)

### Better: Line by line. Easier to read, but have to wait for the end to see
### what it does. Temp variables add more places for errors and bugs.
h_temp <- group_by(harvest, country, commodity)
h_temp <- filter(h_temp, year >= 2009)
h_temp <- mutate(h_temp, harvest_tot = sum(tonnes, na.rm = TRUE))
h_recent_totals2 <- arrange(h_temp, country, commodity)

### Best! Chained format intuitively links together the functions. Saves
### typing, fewer opportunities for errors, easier to debug. The %>% operator
### automatically indents each following line for easy reading.
h_recent_totals3 <- harvest %>%
  group_by(country, commodity) %>%
  filter(year >= 2009) %>%
  mutate(harvest_tot = sum(tonnes, na.rm = TRUE)) %>%
  arrange(country, commodity)
```

7.10.3.2 dplyr::select() Description

`select()` allows you to choose specific columns/variables from your dataset, and drop all others. Alternately, you can select specific variables to drop, leaving others in place. `rename()` is a relative of `select()` that allows you to rename variables, while leaving all variables in place.

Examples

The sample dataset includes the annual harvest, in tonnes, of a number of commodities exported by two countries. Type of trade provides no information (it is all Export), so that variable can be dropped. The names of all the variables should be converted to lower-case, to match the OHI style guide. See the figure below.

```
### Example 1:
harvest <- harvest %>%
```

```

select(Country, Commodity, year, tonnes)
### Selects the named variables, and drops all others. Useful to choose a
### subset of key variables from a complicated data set.

### Example 2 (same result as example 1):
harvest <- harvest %>%
  select(-Trade)
### Using the '-' drops 'Trade' column and leaves other variables intact.
### Useful if you would like to clear out temporary variables.

harvest <- harvest %>%
  rename(country = Country, commodity = Commodity)
### Drops no variables. Syntax: rename(new_var_name = old_var_name) w/o quotes.

```

Using the chain operator, we can string these two functions into one smooth, easy-to-read flow:

```

harvest1 <- harvest %>%
  select(-Trade) %>%
  rename(country = Country, commodity = Commodity)

```

The `harvest` data is fed into `select()`, and the output is fed into `rename()`. The final output of this complete

The diagram illustrates the data transformation process. It starts with the original `harvest` data, which is then processed by the `select(-Trade)` function. This results in a table where the `Trade` column is removed, as indicated by the red arrow and the label "Eliminate unneeded column". Finally, the `rename()` function is applied to this intermediate table, resulting in the final output table.

Country	Commodity	Trade	year	tonnes
1 Australia	Agar agar nei	Export	X2007	200
2 Australia	Coral and the like	Export	X2007	616
3 Australia	Fish body oils, nei	Export	X2007	448
4 Australia	Fish liver oils, nei	Export	X2007	...
5 Australia	Mother of pearl shells	Export	X2007	189
6 Australia	Ornamental fish nei	Export	X2007	5
7 Australia	Ornamental saltwater fish	Export	X2007	...
8 Australia	Other seaweeds and aquatic plants and products thereof	Export	X2007	3348
9 Australia	Shells nei	Export	X2007	NA
10 Vietnam	Agar agar nei	harvest (before)	Export	0 0
11 Vietnam	Coral and the like	Export	X2007	2400
12 Vietnam	Fish body oils, nei	Export	X2007	8200

flow is assigned to the new variable `harvest1`.

country	commodity
1 Australia	Agar agar nei
2 Australia	Coral and the like
3 Australia	Fish body oils, nei
4 Australia	Fish liver oils, nei
5 Australia	Mother of pearl shells
6 Australia	Ornamental fish nei
7 Australia	Ornamental saltwater fish
8 Australia	Other seaweeds and aquatic plants and products thereof
9 Australia	Shells nei
10 Vietnam	Agar agar har
11 Vietnam	Coral and the like
12 Vietnam	Fish body oils, nei

7.10.3.3 dplyr::filter() Description

`filter()` allows you to select observations (rows) that match search criteria, using values in specified variables (columns). Drops all observations that do not match the criteria. * Use logical operators & and | to filter on multiple criteria simultaneously

Example

```

harvest_vnm <- harvest %>%
  filter(country == 'Vietnam')
### Single criterion filter: keeps only data with country matching 'Vietnam'.

```

```

h_vnm_recent <- harvest %>%
  filter(country == 'Vietnam' & year >= 2009)
### filter with multiple criteria: selects 'Vietnam' data from 2009 or later.

```

7.10.3.4 dplyr::arrange() Description

`arrange()` sorts observations (rows) based upon a specified variable or list of variables. Does not actually change the data in any way, only the appearance. Useful for inspecting your data after each processing step.

Example

```

harvest_sorted <- harvest %>%
  arrange(country, commodity, year)
  ### Sorts commodity harvest values for each country, chronologically

harvest_sorted <- harvest %>%
  arrange(country, commodity, desc(year))
  ### Sorts harvest values by most recent year (descending order)

```

7.10.3.5 dplyr::mutate() Description

`mutate()` is a powerful and useful tool for processing data. You can add new variables or modify existing variables, using all variety of functions to perform operations on the dataset. `mutate()` works well with `group_by()` to perform calculations and analysis at a group level rather than dataset level.

Example

From the sample data set (see figure below), we would like to:

- Remove the ‘X’ from the ‘year’ values.
- Translate the text codes in ‘tonnes’ into numbers and NAs. These codes are specific to FAO’s data reporting format: ... is the same as NA, and 0 0 means greater than zero, but less than half a tonne.
- Convert these text fields into numeric fields so they can be analyzed properly.

The figure shows two dataframes side-by-side. On the left is 'harvest (before)' and on the right is 'harvest1 (after)'. Both dataframes have columns: country, commodity, year, and tonnes. The 'year' column contains X2007 for most rows, while the 'tonnes' column contains various text codes like '200.0', '616.0', '448.0', etc., or codes like '...', '0 0', 'NA', '0.1', etc. A red arrow points from the 'before' dataframe to the 'after' dataframe, indicating the transformation.

	country	commodity	year	tonnes
1	Australia	Agar agar nei	X2007	200
2	Australia	Coral and the like	X2007	616
3	Australia	Fish body oils, nei	X2007	448
4	Australia	Fish liver oils, nei	X2007	...
5	Australia	Mother of pearl shells	X2007	189
6	Australia	Ornamental fish nei	X2007	5
7	Australia	Ornamental saltwater fish	X2007	...
8	Australia	Other seaweeds and aquatic plants and products thereof	X2007	3348
9	Australia	Shells nei	X2007	NA
10	Vietnam	Agar agar nei	X2007	0 0
11	Vietnam	Coral and the like	X2007	2400
12	Vietnam	Fish body oils, nei	X2007	8288
13	Vietnam	Fish liver oils, nei	X2007	7

	country	commodity	year	tonnes
1	Australia	Agar agar nei	2007	200.0
2	Australia	Coral and the like	2007	616.0
3	Australia	Fish body oils, nei	2007	448.0
4	Australia	Fish liver oils, nei	2007	NA
5	Australia	Mother of pearl shells	2007	189.0
6	Australia	Ornamental fish nei	2007	5.0
7	Australia	Ornamental saltwater fish	2007	NA
8	Australia	Other seaweeds and aquatic plants and products thereof	2007	3348.0
9	Australia	Shells nei	2007	NA
10	Vietnam	Agar agar nei	2007	0.1
11	Vietnam	Coral and the like	2007	2400.0
12	Vietnam	Fish body oils, nei	2007	8288.0
13	Vietnam	Fish liver oils, nei	2007	7.0

Figure 54: Using `mutate` to alter data in a data frame

```
library(stringr)  ### to access 'str_replace()' string functions
```

```

harvest1 <- harvest %>%
  mutate(
    year    = str_replace(year, fixed('X'), ''), # remove the 'X'
    tonnes = str_replace(tonnes, fixed('...'), NA), # replace '...' with 'NA'
    tonnes = str_replace(tonnes, fixed('0 0'), 0.1), # replace '0 0' with '0.1'
    tonnes = ifelse(tonnes == '', NA, tonnes)) %>%
  mutate(
    tonnes = as.numeric(as.character(tonnes)),
    year   = as.integer(as.character(year)))

```

Notes: * In this example, no new variables were added. Multiple variables can be changed with one call to `mutate()`. Multiple modifications to ‘tonnes’ happen sequentially, so order is important. * The `as.numeric(as.character(...))` gets around the fact that these text variables are stored as ‘factor’ class, rather than ‘character’ class. `as.character()` forces them into character class, and then the `as.numeric()` can convert the character strings to numeric where applicable. Similar for `as.integer(...)`

7.10.3.6 dplyr::summarize() (or summarise()) Description

`summarize()` combines multiple values of a variable into a single summary value. `summarize()` works well with `group_by()` - for grouped data, each group will be summarized and reported separately. For ungrouped data, the summary covers the entire dataset.

- `summarize()` compresses the dataset and drops individual observations. To maintain individual observations, consider creating a summary variable using `mutate()` instead.
- NA values can be problematic - use `na.rm=TRUE` or similar methods.

Example

To determine the total harvest of each country, for each commodity:

```
h_summary <- harvest %>%
  group_by(country, commodity) %>%
  summarize(harvest_tot = sum(tonnes, na.rm = TRUE)) %>%
  ungroup()
```

7.10.3.7 dplyr::group_by() Description

`group_by()` allows you to easily group a dataset by one or more variables/columns.

By itself, it does nothing to change your data. But once your dataset has been sorted into useful groups, other `dplyr` functions will operate on each group separately, rather than operating on the entire dataset. *

The function `groups(data)` reports back the current grouping status of dataframe `data`.

- `group_by()` alters the grouping, but does not alter the sort order.
- `arrange()` does not alter the current grouping - it will sort by groups first, then sorts within each group.
- Multiple calls to `group_by()` will reset the groupings each time (by default), rather than adding additional layers of groups.
- Once you have finished with your operation at the group level, it is a good practice to use the `ungroup()` function to remove the groupings, to avoid unintended consequences due to forgotten `group_by()` calls.

Example

If you want to find the total tonnage harvested for each commodity for each country, you would want to group by country and by commodity, and then perform a `sum()` function on the grouped data. Two options presented here: `summarize()` to collapse data to just the summary, and `mutate()` to add a new column that includes the summary values.

```
h_tot_sum <- harvest %>%
  group_by(country, commodity) %>%
  summarize(harvest_tot = sum(tonnes, na.rm = TRUE))
  ### Summarize information by collapsing each group to a single summary value
  ### (total tonnage by commodity by country). Note ungroup() at end.

h_tot_mut <- harvest %>%
  group_by(country, commodity) %>%
  mutate(harvest_tot = sum(tonnes, na.rm = TRUE)) %>%
  arrange(country, commodity) %>%
  ungroup()
  ### Summarize information by creating a new variable to contain summary
  ### value; report value for every observation. Note ungroup() at end.
```

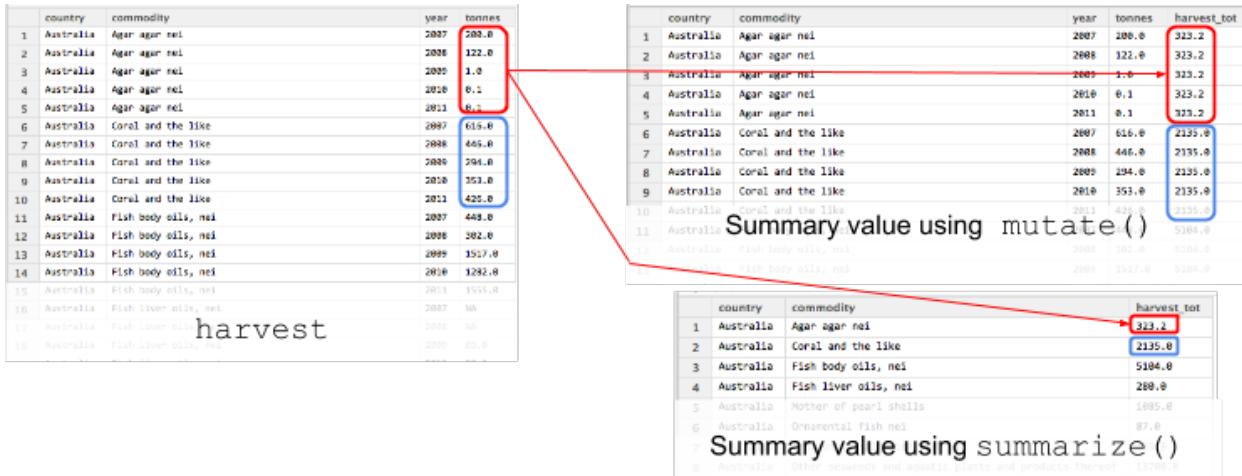


Figure 55: group_by to find group-level information

7.10.4 Coding style

Code unto others as you would have them code unto you.

Why style? ask Hadley Wickham, developer of many wonderful R packages:

Good style is important because while your code only has one author, it'll usually have multiple readers. This is especially true when you're writing code with others. In that case, it's a good idea to agree on a common style up-front. Since no style is strictly better than another, working with others may mean that you'll need to sacrifice some preferred aspects of your style.

The Ocean Health Index is founded upon principles of open-source science, so our code should be not just available, but legible to others. For OHI+, we expect people to modify code to implement new goal models, and we may need to provide support in developing and debugging their code.

Certain coding techniques are more efficient than others (e.g. in R, looping across elements in a vector is much slower than operating on the entire vector at once), but rarely does OHI code push any performance envelopes. Much more of our time is spent writing code, translating old code into new models, and debugging. Transparent, readable code will save more time in the future than a perfectly-optimized but opaque algorithm.

Readable code is:

- collaborative
- easier for others to understand and debug
- easier for others to update and modify
- easier for ‘future you’ to interpret what ‘past you’ meant when you wrote that chunk of code.

Check out Hadley Wickham’s [style guide](#):

- How many of these suggestions are second-nature to you? how many are you guilty of breaking?
- Note that these are guidelines, not rules; non-stylish code can still work.

7.10.4.1 Best practices for coding in OHI assessments:

- use a consistent format for variable names, filenames, function names, etc.
 - `lower_case_with_underscores` (preferred) or `camelCase` (ok I suppose)
 - * not `periods.in.between`
 - use names that are brief but intuitive
- Comment clearly for your own purposes, and for others.
 - Comment on the purpose of each important block of code.
 - Comment on the reasoning behind any unusual lines of code, for example an odd function call that gets around a problem.
- Take advantage of R Studio section labels functionality:
 - If a comment line ends with four or more `-`, `=`, or `#` signs, R Studio recognizes it as a new section.
 - Text within the comment becomes the section name, accessible in the drop-down menu in the bottom left of the RStudio script window.
- use `<-` to assign values to variables (not necessary, but preferred)
- use `%>%` to create intuitive chains of related functions
 - one function per line
 - break long function calls into separate lines (e.g. multiple mutated variables)
- use proper spacing and formatting for legibility
 - don't crowd the code - use spaces between math operators and after commas
 - use indents to indicate nested or sequential/chained code
 - break sequences or long function calls into separate lines logically - e.g. one function call per line
- use functions to add intuitive names to chunks of code
- Use ‘tidy data’ practices - take advantage of `tidyverse`
 - clean up unused columns using `select(-colname)`
- if you are working on an older script, spend a few extra minutes to update it according to these best practices
 - technical debt - you can do it quickly or you can do it right. Time saved now may cost you or someone else more time later.

7.10.4.2 Writing functions <http://nicercode.github.io/guides/functions/> Why write functions?
* name a chunk of code for easier reading
* easily reuse a chunk of code

What makes a good function:
* It's short
* Performs a single operation
* Uses intuitive names

7.10.4.3 Directories and files

* Store files in a folder called 'github' in your home directory; access it with `~/github` so that user

8 Toolbox Troubleshooting

The Toolbox prints messages during its processing to help guide error checking and debugging. Here are a few troubleshooting tips. This section will be updated frequently; please share any problems that you encounter.

8.1 General Software Errors

8.1.1 rpostback-askpass error

Sometimes when RStudio won't push committed changes to GitHub, RStudio displays an `rpostback-askpass` error:

```
error: unable to read askpass response from 'rpostback-askpass'  
fatal: could not read Username for 'https://github.com': Device not configured
```

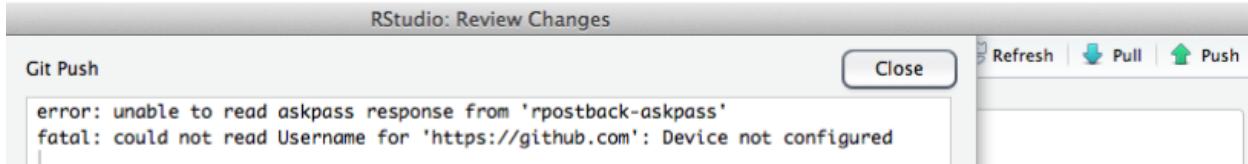


Figure 56: Error screen window: ‘error: unable to read askpass response’.

Here's how we fixed it: we updated `git.exe` to the latest version, 2.2.1, edited the search path to point to the new version, made sure the `git credential.helper` was configured to be able to access the OS X keychain, and pushed a test commit from terminal to store the username and password in the keychain, where it can be accessed from other apps like RStudio. Easy peasy!

1. To check your current version of `git.exe`, type this at the terminal command line:
 - `$ git --version` should return something like:
 - `git version 2.2.1` (check online to see if this is the latest version)
2. To update, go to <http://git-scm.com/download/mac>, download the latest `git` for OS X, install it.
3. In terminal, type `git --version` and verify that it reports the new version. If it shows the new version, great! Skip to Step 5.
 - Don't be sad if it doesn't! If you still see the old version, the installer put the new version into a different directory, which has a lower priority in the search path, so now to update the search path. The default Apple `git` seems to install the `git.exe` into `/usr/bin/` directory, this particular updater seems to install into `/usr/local/git/bin/` directory. The search path needs to be updated to look for `git.exe` in the new directory first.
4. To change the search path, open up the paths file in `nano` editor using `sudo`:
 - `$ sudo nano /etc/paths`
 - At the top line of the paths file, add the directory for the updated `git`: `'/usr/local/git/bin'` (without

```

GNU nano 2.0.6           File: /etc/paths
/usr/local/bin
/usr/local/bin
/usr/bin
/bin
/usr/sbin
/sbin

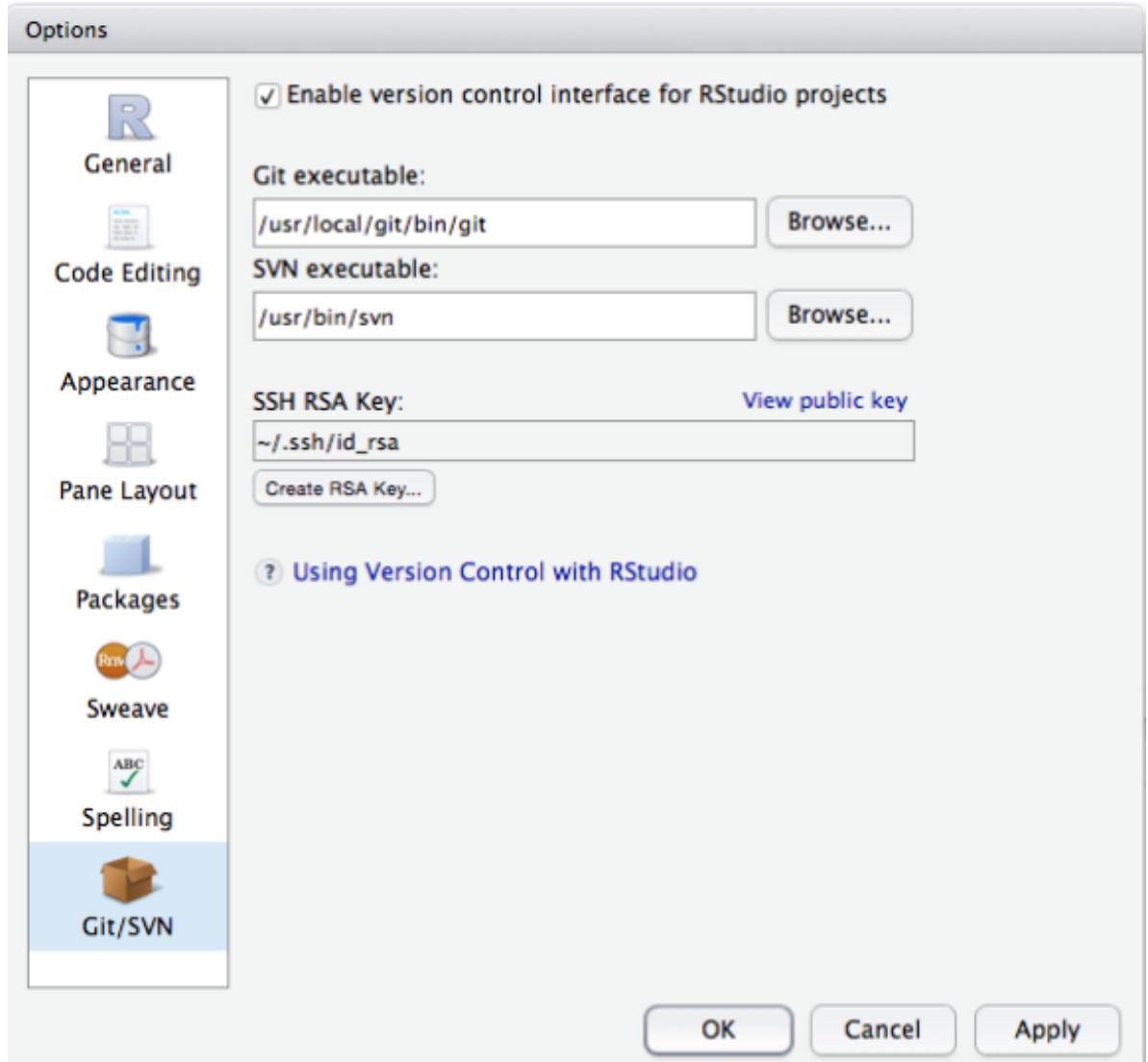
^G Get Help ^O WriteOut ^R Read File ^Y Prev Page ^K Cut Text
^X Exit      ^J Justify ^W Where Is ^V Next Page ^U Uncut

```

the quotes) so it looks like the top line here:

- Then hit **control-X** to exit, then **Y** in response to the save prompt.
5. Make sure your `git config` is up to date, including `credential.helper`:
 - `$ git config --global -l` should return something like:
 - `user.name="Casey O'Hara"`
 - `user.email=ohara@nceas.ucsb.edu`
 - see https://github.com/OHI-Science/ohiprep/wiki/Setup#git_identity for help on updating user.name and user.email
 - `credential.helper=osxkeychain`
 - (if you need to configure the credential helper: <https://help.github.com/articles/caching-your-github-password-in-git/>)
 - 6. Now while you are in Terminal, it is important to sync with a repository to establish your security credentials. You must clone a repository and push a ‘test’ commit, and then once you are prompted for your username and password your information will get stored in the keychain. Here are the steps:
 - Change your working directory to your local github directory: `$ cd github`
 - (Tip: you can check if you’re in the right folder by entering `pwd`, short for “print working directory”; or you could look at the line of code preceding the “\$.”)
 - Clone into a repository with a URL *for which you have permissions*. As an example, the following steps use a repository called ‘ZAF’ but you should use your own URL with a three-letter country code in place of ‘ZAF’:
 - `$ git clone https://github.com/omalik/zaf.git`
 - Change your working directory to the folder you just created (here, ‘ZAF’): `$ cd zaf`
 - Push a test commit to repository ‘ZAF’:
 - `$ touch test.md`
 - `$ git add test.md`
 - `$ git commit -m "testing"`
 - `$ git status`
 - `$ git push`
 - Check your status again: `$ git status`
 - (TIP: You can check your status with `$ git status` and you can use ‘ls’ to see if your new changes have registered in this repository.)

7. Now that *git* is updated and your username and password are set, make sure RStudio knows the location of the new *git.exe*. In RStudio, select **Tools > Global Options...**, select the **Git/SVN**, and browse to the new **Git executable** (it should appear as `/usr/local/git/bin/git` if you updated your *git* version



as above).

Next time you push a commit from RStudio, it should remember the username and password from your test commit in Step 6, and you should be good to go.

8.1.2 Git not detected on system path

After downloading and installing git, sometimes RStudio is unable to locate git and will show the following error:

It is important to make sure you do in fact have git installed on your computer first. You can do this by opening up terminal (Mac OSX) or the cmd line (Windows) and typing:

- `$ which git` for Mac/Linux,
- `$ where git` for Windows

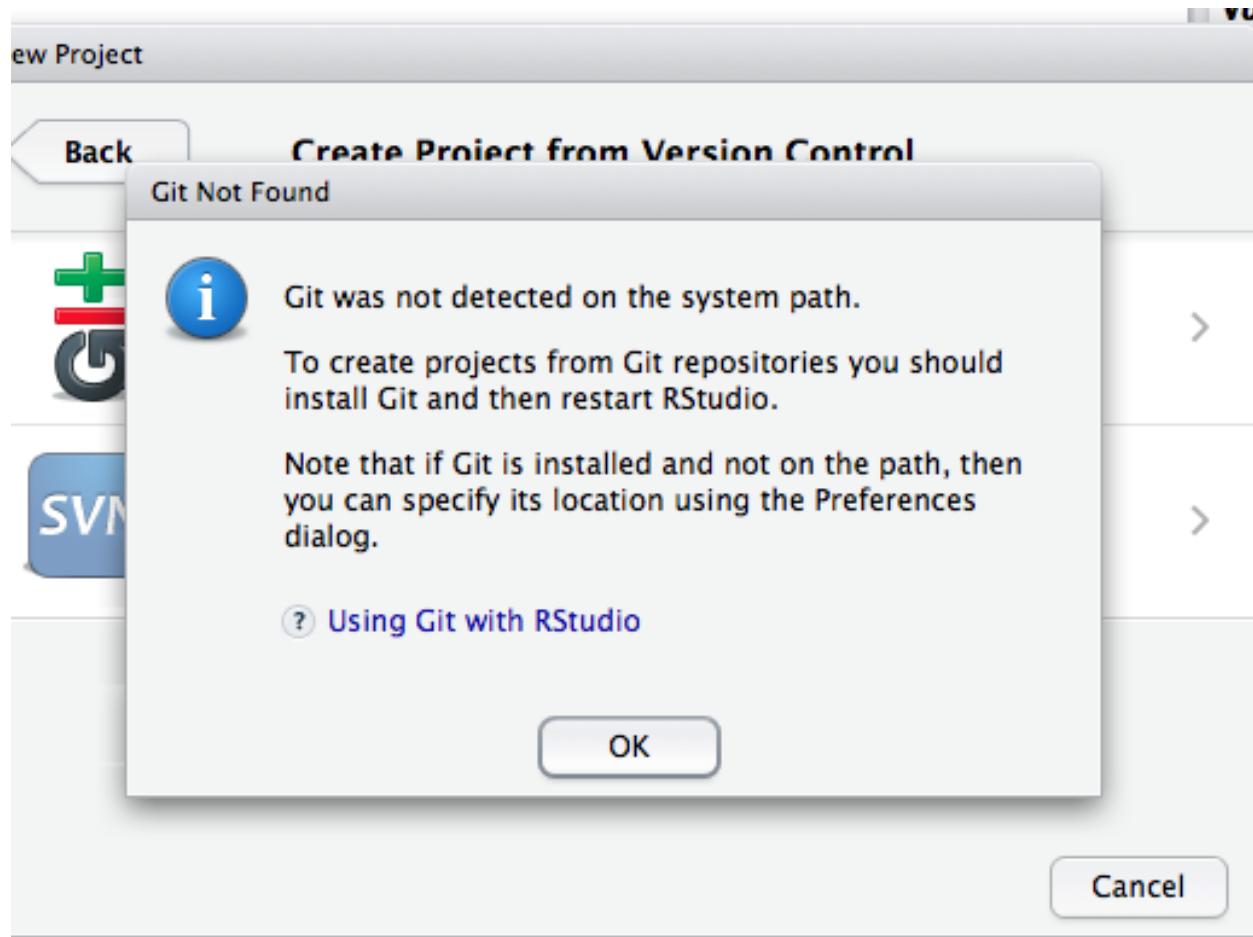


Figure 57: Error screen window:‘Git was not detected on the system path’

These commands will tell you where the `git.exe` file is located. Typically it will look something like this: `/usr/local/git/bin/git` or `/usr/bin/git` or some variation of those.

Once confirming the location of `git.exe` you need to tell RStudio where it is. Open up RStudio, got to Preferences and select the Git/SVN option:

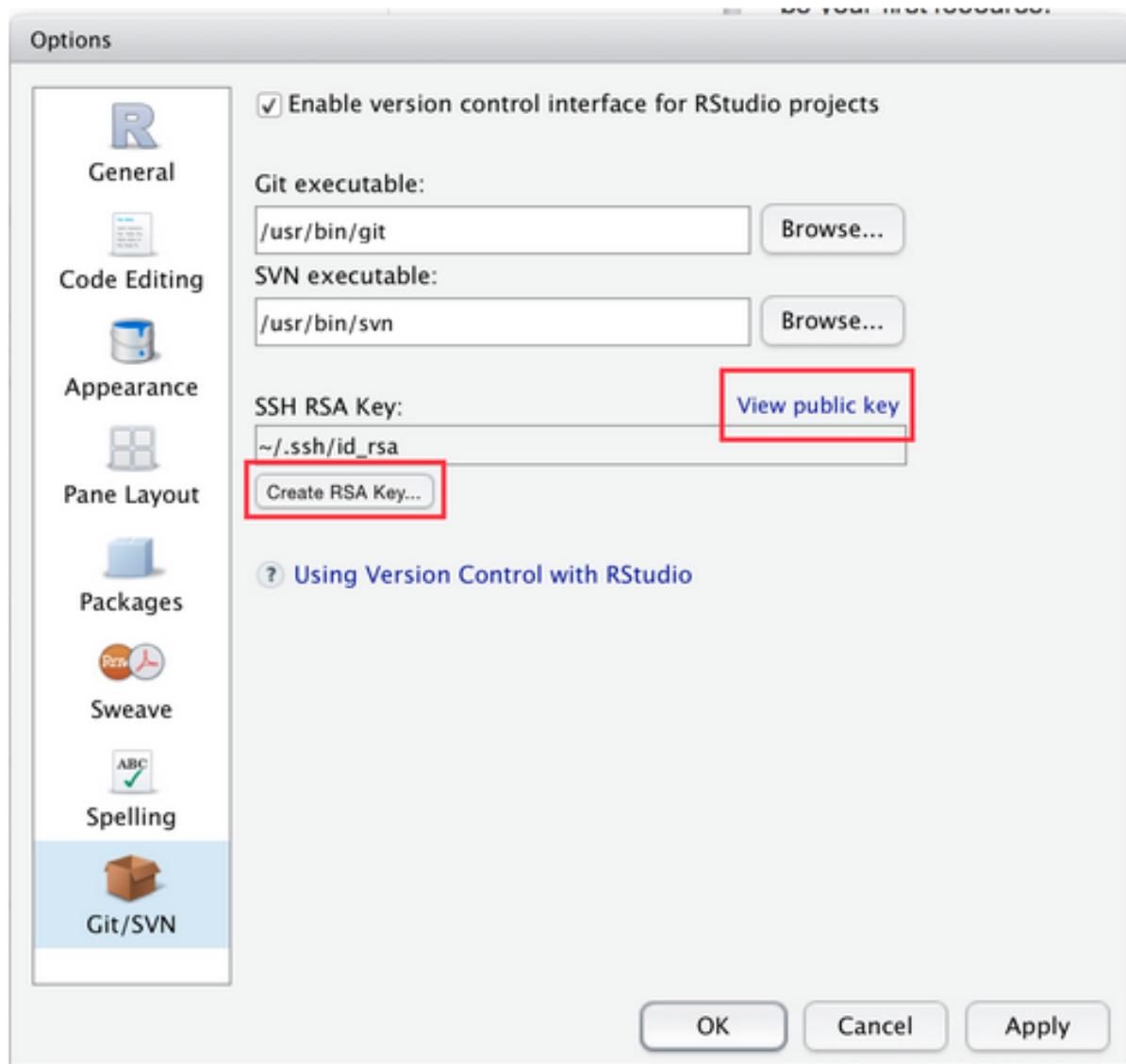


Figure 58:

In the Git executable area, fill in the path to your `git.exe`. If RStudio does not let you manually enter your path, select `Browse...` and navigate to the `git.exe` file. If you are not able to navigate to the file it is likely a hidden file.

On a Mac, to make hidden files visible, close RStudio and do the following:

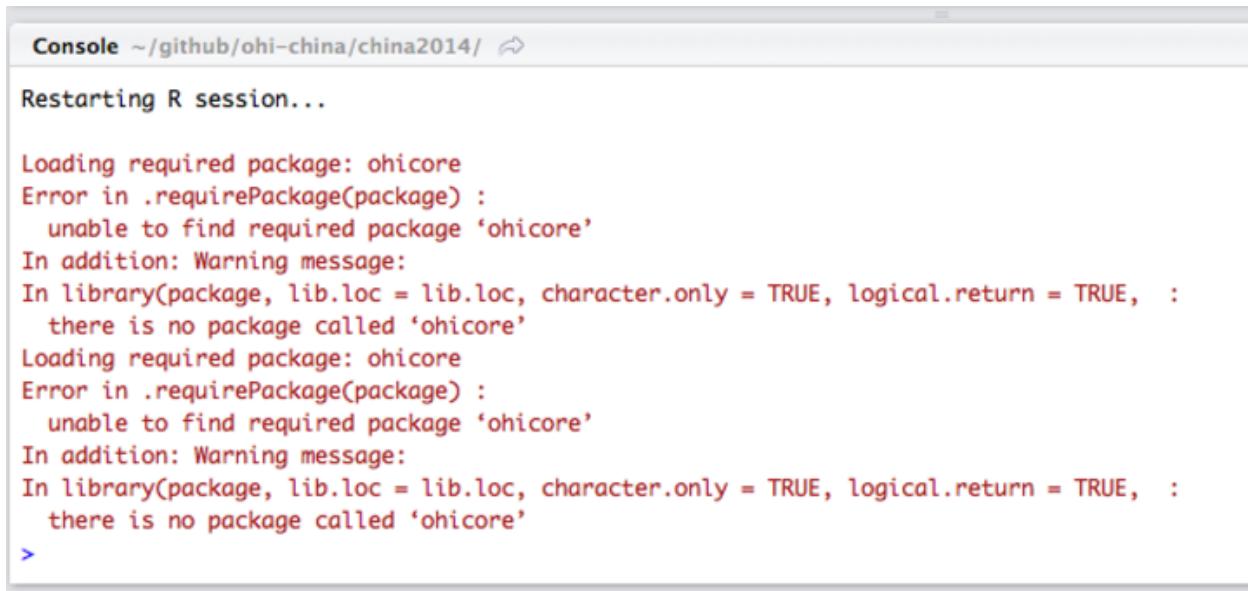
- Open Terminal found in Finder > Applications > Utilities.
- In Terminal, paste the following: `defaults write com.apple.finder AppleShowAllFiles YES`.
- Press return.
- Hold the 'Option/alt' key, then right click on the Finder icon in the dock and click Relaunch.

And then reopen RStudio, go to Preferences -> Git/SVN -> Browse... and you should be able to navigate to the `git.exe`

You will then need to create an RSA Key. You can do this by clicking on ‘Create RSA Key...’ at the bottom of the Git/SVN panel, then ‘View public key’. Copy the key you see, and add it to your GitHub account by using the instructions provided [here](#).

8.1.3 Loading RWorkspace on Restart

When you restart your R Session (**Session > Restart R** on a Mac), if you see that it is trying to load `ohicore`, it may give you an error:



The screenshot shows the RStudio Console window. The title bar says "Console ~/github/ohi-china/china2014/". The console output is as follows:

```
Restarting R session...

Loading required package: ohicore
Error in .requirePackage(package) :
  unable to find required package 'ohicore'
In addition: Warning message:
In library(package, lib.loc = lib.loc, character.only = TRUE, logical.return = TRUE,  :
  there is no package called 'ohicore'
Loading required package: ohicore
Error in .requirePackage(package) :
  unable to find required package 'ohicore'
In addition: Warning message:
In library(package, lib.loc = lib.loc, character.only = TRUE, logical.return = TRUE,  :
  there is no package called 'ohicore'
>
```

Figure 59:

You do not want it to load `ohicore` or to save anything in your workspace. You will need to change the default setting from your **.Rproj** file. Steps to do this:

1. Go to Project Options, either in the pull-down menu or by double-clicking the **.Rproj** file:

2. Change all options to **No**:

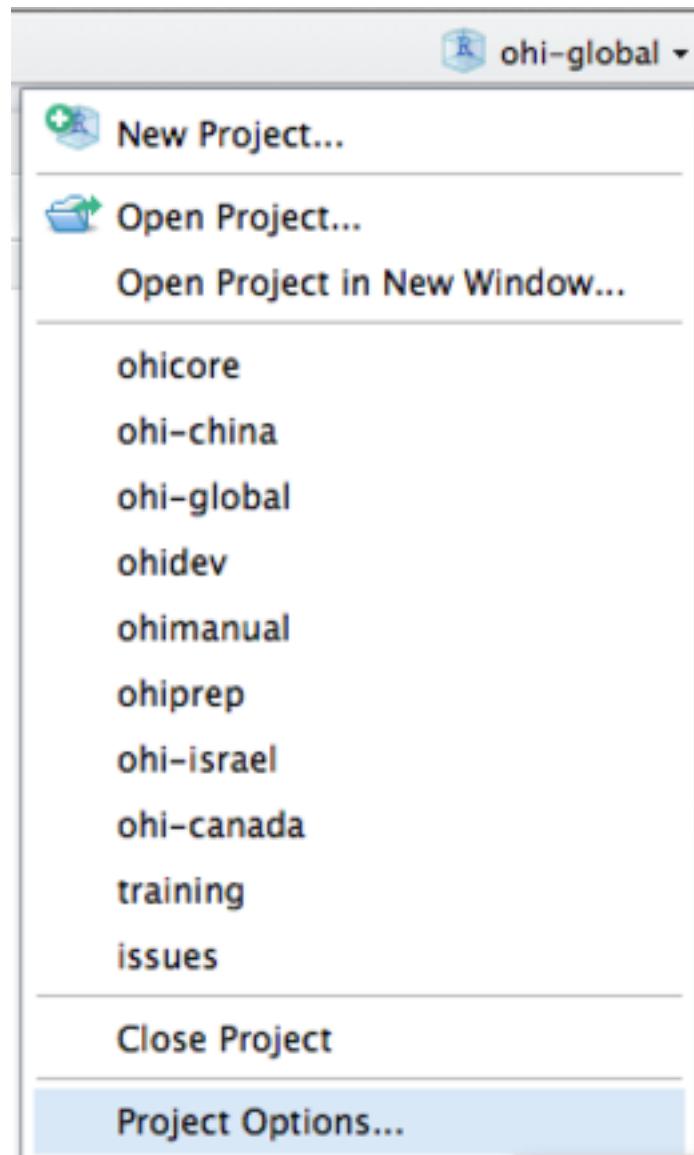


Figure 60:

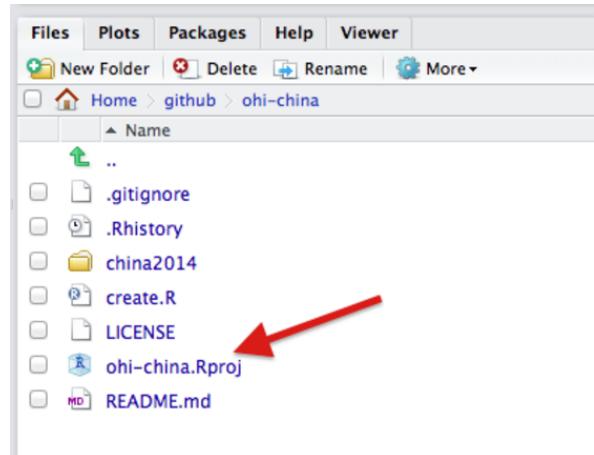


Figure 61:

8.2 Errors when Using the Toolbox

8.2.1 Useful Errors when Calculating Scores

TIP: You can use the `layers` function in `calculate_scores.R` to error-check whether you have registered your files in `layers.csv` correctly or not. If you haven't, you will get an error message regarding 'missing files'.

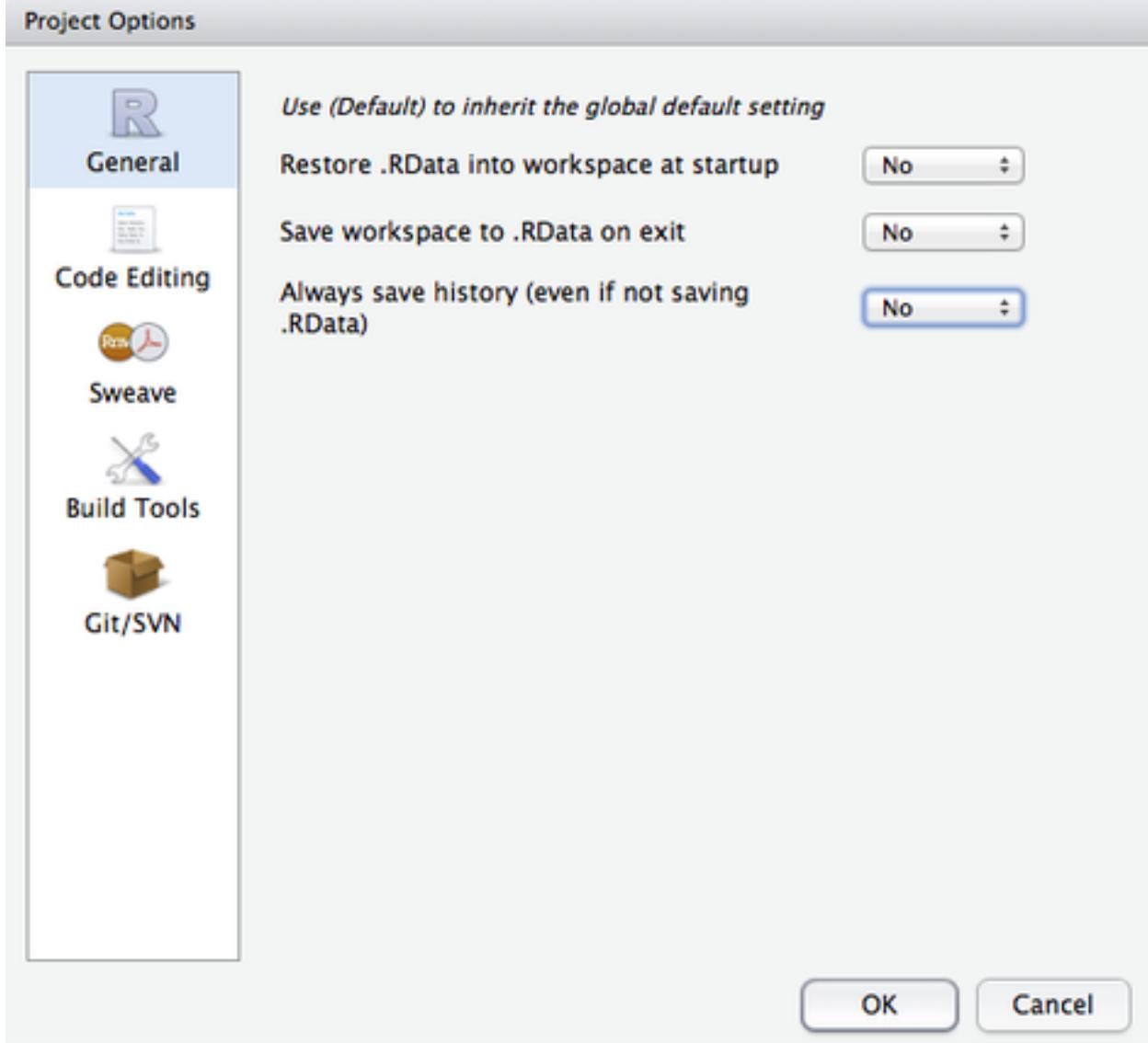


Figure 62:

The screenshot shows an RStudio interface with several tabs open: config.R, calculate_scores.R, data_prep.r, and cp_extent_chn2015_zb.csv. The Environment pane displays a table of data frames, including 'layers' which has 6 rows. A red arrow points from the 'layers' table in the Environment pane to the 'layers.csv' file in the File Explorer pane. A large red callout box contains the text: "These errors mean your data layers have not been registered in 'layers.csv' correctly."

```

# load required libraries
suppressWarnings(require(ohicore))

# set working directory to the scenario directory, ie containing conf and la
setwd('~/github/chn/province2015')

# load scenario configuration
conf = Conf('conf')

# run checks on scenario layers
CheckLayers('layers.csv', 'layers', flds_id=conf$config$layers_id_fie

# load scenario layers
layers = Layers('layers.csv', 'layers')

# calculate scenario scores
scores = CalculateAll(conf, layers, debug=F)
write.csv(scores, 'scores.csv', na='', row.names=F)

```

8.2.2 Calculating Pressures...

8.2.2.1 ‘The following components for [goal] are not in the aggregation layer [layer]...’ Example:

```

Running Setup...
Calculating Pressures...
The following components for NP are not in the aggregation layer np_harvest_product_weight categories (fish_oil,
Error in data.frame(names(P), P) :
  arguments imply differing number of rows: 0, 1

```

Figure 63:

This error means you should update your pressures matrix because it expects there to be components that your region does not have.

	A	B	C	D	E	F	G
1	goal	component	component_n	po_chemicals	po_chemicals	po_pathogens	po_nutrients
2	FIS			1			1
3	MAR			2			
4	AO				1		
5	NP	corals		1			2
6	NP	fish_oil		2			1
7	NP	ornamentals		2			1
8	NP	seaweeds		2			2
9	NP	shells					1
10	NP	sponges					1

Figure 64:

	A	B	C	D	E
1	goal	component	component_n	po_chemicals	po_chemicals
2	FIS				1
3	MAR				2
4	AO				
5	NP	corals			1
6	NP	fish_oil			2
7	NP	ornamentals			2
8	NP	seaweeds			2
9	NP	shells			
10	NP	sponges			

8.2.2.2 ‘Error in matrix...’ Example: >

This error means there is an empty column in `pressures_matrix.csv`, and the Toolbox cannot handle empty columns.

8.2.3 Calculating Resilience ...

8.2.3.1 ‘Error in match(x, table, nomatch = OL) : object id_num not found’

This error means you should check that there is at least one entry for each goal (for each row) in `resilience_matrix.csv`.

Figure 65:

9 Frequently Asked Questions (FAQs)

This document provides answers to some frequently asked questions about conducting regional assessments using the Ocean Health Index. A few questions are related to general concepts in the Ocean Health Index, but mostly those topics are covered at <http://www.oceanhealthindex.org/About/FAQ/>. Here, the FAQ are primarily technical questions regarding regional assessments and using the OHI Toolbox. This document will be updated continually as we have more questions. Questions are arranged by theme, and have the format Q: (question) and A: (answer).

9.1 Overall

9.2 Conceptual

Q: Are regional assessment scores comparable with global assessment scores?

A: Regional Index scores cannot be directly compared to global Index scores, or to other regional Index scores calculated through separate efforts. This is because data and indicators (both what they measure and their quality), reference points (set using local knowledge and priorities), and specific goal models are often different for the areas being compared.

However, because scores for each goal are scaled to a reference point, qualitative comparisons can be made. For example, a score of 71 in the US West Coast compared to 66 in Brazil says that the US West coast is closer to fully meeting its sustainable goals (i.e., meeting regional reference points). Furthermore, use of the same Ocean Health Index framework across regional assessments permits fruitful discussion and general comparisons even if data inputs differ. Ocean Health Index assessments at any scale always work within a standardized definition of ocean health, using information to capture the philosophy of the ten goals that have been identified (and undergone scientific peer-review) prior to compiling relevant data. Use of the ten-goal framework is important both to ensure that all aspects of ocean health are captured and to allow better comparison across regional assessments than would be possible if the different regions used different methods.

Q: How does the Index account for ecosystem benefits?

A: The OHI is not an index of ecosystem services. The Index prefers to describe benefits from a healthy ocean and emphasize their relevance, but the ideas are closely related. The ten goals roughly fall into areas of ecosystem services such as food provisioning (**Food Provision**), regulatory services (**Carbon Storage**), cultural services (**Tourism and Recreation, Special Places**), supporting services (**Clean Waters, Biodiversity**), and other values (**Livelihoods and Economies**).

(Source: OHI Baltic workshop)

Q: Where is climate change measured in the Index?

A: Four different aspects of climate change – increases in sea surface temperature (SST), sea level rise (SLR), ultraviolet radiation (UV), and ocean acidification (OA) – are included as pressures to many goals in the Index,

including Natural Products, Carbon Storage, Coastal Protection, Sense of Place, Livelihoods & Economies and Biodiversity. Mitigation of climate change through carbon storage is one of the ten goals.

Q: Why are food provision and artisanal fishing opportunities goals separated?

A: These goals measure different aspects of how people relate to fishing. The catch of fish made by artisanal (=small-scale, subsistence type) fisheries is captured in the food provision goal. Jobs, wages and income from both the food provision and artisanal fishing goals are captured in the livelihoods & economies goal. The purpose of the artisanal fishing opportunity goal is to evaluate the opportunity for people to pursue this fishing in relation to their need to do so.

Q: Can 10 goals really capture all the ocean's values? Shouldn't we talk about ocean's values in more detailed terms?

A: This question speaks of the interdisciplinary nature of OHI. It is a part of the design of the model. It takes experts from all fields many years to develop the 10 goals, and each goal includes different aspects. Ten goals can easily become 100. For example, the economy goal can be divided into individual goals of tourism, transportation, production, value added (eg. fish to burger) etc. However, getting solid scores for 100 goals could take more than a year or two, and trying to communicate all the information to stakeholders and managers will be cumbersome. But we can communicate with people across fields about 10 goals (and their pressures and resilience) without being overwhelming.

Ten goals may seem simplified. But they are useful for talking to people across fields without compromising scientific validity.

Q: How are the goals weighted to calculate the final score?

A: By default, we weighed them equally because we don't have solid, better information to do otherwise, even though we understand that each goal may/should have different weights depending on regional conditions and needs. We didn't put emphasis on goal weighing because ten individual goal scores are more important than one total score, and can tell more about the status of ocean health. If you are interested in seeing how weighing affects the total index score, you can try the following:

- Scenario studies. The OHI framework is flexible so that you can change the weights and see how scores change
- Studies on people's preferences or management needs to weigh goals differently

Q: How should we compare regional scores, spatially or temporally?

A: Temporal comparison is good for repeated measurements in one location, so that managers can see how goal conditions change and whether their policies take effect. Spatial comparison is used to compare regional differences in your country.

For OHI+, the most helpful comparison is temporal comparison. Management goals are different spatially, and data are different. We can't compare spatially unless they use the same model and data. The goal of OHI is to help local agencies adapt and improve ocean resources management. Therefore it may be an unnecessary burden to compare spatially. Without worrying about comparisons, different regions can still learn from one another.

Q: We calculate trends based on 5 years of data. Wouldn't it be more scientifically valid to have a 20 or 30 year trend?

A: Yes you can use more years of data if available. But 5 years is a good compromise between scientific validity and meaningfulness for local stakeholders. On one hand, we have to do it scientifically vigorous with a solid reference. But on the other hand, a 5-yr trend is more helpful and actionable to stakeholders than a 30-yr trend.

Q: Is OHI an internatinally recognized mointoring system? What other partnership does OHI have?

A: OHI is gaining recognition from world governance organizations, NGOs, and local governments. There is only limited amount of funds for conservation. If we work together, we can reach maximum return on investment. We partner with UCSB, who is on the scientific frontier. They innovate science and technology, develop toolbox, fill data gap, and provide technical support for local OHI assessments. Conservation International focuses on external partnerships. CI is always looking at multilateral agreements. Some of our active partnerships include:

- The United Nation. Many countries follow UN leads.
- World Bank and The Nature Conservancy, who has good research on economics, and is interested in incorporating OHI in their monitoring systems that are already in place.
- World Wildlife Fund, who is interested in using OHI in all of their 14 global sites.
- Clinton Climate Initiative.

How to draw spatial boundary: ecosystem or jurisdictional boundary?

A. We recommend jurisdictional boundary. It comes down to who will care, and who will take responsibility for the results and act on the results.

There seems to be overlapping between goals, for example, habitats data re used for CS, CP, and HAB. Is that double counting?

A. No. There is no complete overlap of data. Different habitat data are used for different goals. For example, habitats good for CS aren't necessarily appropriate for CP.

OHI is also human benefits-driven, not ecologically-driven. It happens that CS, CP, and HAB are affected by similar factors, but they provide non-overlapping benefits. It is the design of OHI to show the connectivity among goals. If certain habitats are good for multiple goals, there is strong incentive to focus energy and resources to protect those habitats.

9.3 Timing and Resources

Q: How much does it cost to produce a regional assessment?

A: Regional assessments can be completed at varying costs depending on the local context. (Funds are needed for a management and scientific team, workshops and meetings (including travel), communications, policy engagement, and operating costs. Therefore, securing funding is an important component to satisfactorily complete the assessment. We encourage the development of a local proposal or strategic action plan that details a timeline of activities and the resources needed to accomplish them.

Q: How many people are required in a team?

A: rather than a specific number of individuals, what is required are specific skillsets. For example, if the scientific analysts were capable of effectively conducting the R analysis, then a dedicated R analyst would not be required. In current assessments, teams range between 2 and 8 people.

Q: How long does it take to calculate OHI at a regional scale?

A: The duration of an OHI assessment depends on a number of factors, such as the budget and number of people involved, the scale of the study area and whether new regions will need to be created, how easily data can be acquired, how much local data can be incorporated, how many goal models need to be changed. Additionally, decisions about setting reference points require input from experts. For independent assessments (OHI+), we have found that the average time has ranged from 1.5 to 3 years (See **Task Timeline** in the **Conceptual Guide**).

Q: How much time will modifications by an R analyst take?

A: This will depend on if you are changing any models, and potentially data layers—but a lot of changing data layers just requires registering them properly in `layers.csv` (and maybe `pressures_matrix.csv` and

resilience_matrix.csv if they are pressures or resilience files) and having the `functions.R` file call those layers. That is more ‘bookkeeping’ than actual R programming.

Q: How much time will modifications by a GIS analyst take?

A: this will depend on how many layers you are processing: you are clipping spatial data? That will take some time because there are quite a few files, but maybe not too long since it is pretty small scale and once there is a clipping mask created I think you apply it to other files.

Q: Which goals require a GIS analyst?

A: All goals using spatial data could potentially require a GIS analyst. These goals are commonly: habitat-based goals and sub-goals: (Coastal Protection, Carbon Storage, Habitats—a sub-goal of Biodiversity), Food Provision, Sense of Place, Species—a sub-goal of Biodiversity, Clean Waters

9.4 Structure

Q: Can we remove or add goals to the OHI?

A: A lot of deliberation went into defining the ten goals, and they seem to do a pretty good job of covering many if not most ocean uses, so additional goals may not be necessary. But it could be that they eclipse or replace an existing goal.

9.5 Reference points

Q: Can planning targets can be used as the reference points?

A: Yes, planning targets can be used as reference points. This won’t be appropriate for every goal, but there are cases where this seemed best (example: iconic species sub-goal in the global assessment, mariculture sub-goal in the US West Coast assessment).

Q: What is sector evenness?

A: Sector evenness (also called a diversity index) is an economic concept that is included in OHI to enable comparison across many different sectors included in the Livelihoods & Economies goal. This goal evaluates jobs, wages and revenues for nine marine employment sectors. The distribution of employment across these nine sectors is an effective indicator of resilience. If total employment within a community is primarily based in one or two sectors, the overall economic system will be excessively vulnerable to downturns in those sectors. Conversely, if employment is spread relatively evenly throughout all nine sectors, the overall system will be more robust and resistant to such disturbances. Overall revenue within the community will remain more stable during such downturns, and workers displaced by a downturn in their sector may be able to find employment in another sector without leaving the community.

9.6 Appropriate data layers

Q: Shipping and port activity are hardly affected by the health of the ecosystem. Why are these included in the Index?

A: Shipping and port activity are included as pressures only

Q: Can oil spills be included in OHI?

A: Yes, oil spills could be included as a pressure and in the Clean Waters goal.

Q: Is seasonal (non-permanent) sea ice included in OHI habitats?

A: No, sea ice only includes permanent sea ice.

Q: Can seaweeds be included in the Carbon Storage goal?

A: Because they store carbon for less than 100 years, seaweeds and corals are not included in the carbon storage goal. While the pelagic oceanic carbon sink (phytoplankton) plays a large role in the sequestration of anthropogenic carbon, the pelagic ocean mechanisms are not amenable to local or regional management intervention. Phytoplankton contribute to carbon fixation when they die and sink to the sea bottom at sufficient depth, because it is effectively out of circulation. However, if those phytoplankton are eaten, the carbon is cycled back into the system and not sequestered. Something that could potentially be included in the carbon storage goal is mollusc shells, if they are added to a landfill and not recycled in the sea. So if information on mariculture production and waste disposal are available, this could be an interesting addition to carbon storage at a regional scale.

Q: Is coastal engineering included in Coastal Protection? What if it reduces erosion?

A: We did not include an assessment of the protection afforded by man-made structures, such as jetties and seawalls, because these structures cannot be preserved without maintenance, may have other negative side effects (e.g. alter sedimentation rates causing erosion in new locations), thus they do not constitute long-term sustainable services. Coastal engineering (jetties, harbours, marina and breakwater) is not natural, and is mostly seen as a pressure. It will also be evident in the status of due to decreased natural habitat. It gets tricky when structures are built to help reduce coastal erosion—they are still manmade and therefore not a natural benefit that the ocean provides. But if available data allow, it might be possible to include tradeoff effects: maybe in areas where natural habitats are degraded and man-made structures have been built to reduce erosion, we could reduce the pressure that would otherwise be applied.

Q: How is seawater used for cooling on-shore power plants incorporated into OHI?

A: The use of cooling water for on-shore power plants would be a pressure on the ocean, since it causes entrapment of fishes, larvae, etc, and usually is circulated back into the ocean at higher temperatures (and maybe other chemicals, minerals, etc). Since the energy is coming from land-based activities, there isn't a service that the ocean is providing that 'benefits' people, it is only a pressure from the OHI perspective.

Q: How is freshwater production through desalination incorporated into OHI?

A: Desal would be incorporated into OHI in several places. The benefit is that there is freshwater produced, which could be incorporated into the Natural Products goal (or potentially into its own goal). Data required would be the volume of freshwater created based on the volume of seawater involved and spatial extent. Setting the reference point would not be based on how much can be produced, but some other targets perhaps set by government (percentage of the population served). Similar to the mariculture sub-goal and tourism goals, any negative effects caused by desal that affect other goals (example: species) do not influence the ability to obtain desalination targets now and in the future. Therefore, the sustainability coefficient only measures the ability to sustain that goal, but not the impacts on other goals: instead, they are taken into account as pressures when calculating the other goals. Desal should be included as a pressure similar to cooling on-shore power plants since the discharge brine is dense, doesn't plume very well and there are chemicals involved.

Q: Where do energy activities fit in to OHI?

It depends. Energy could be part of a **Natural Products** goal, for instance, such as wave energy – but then the question is, what is the reference point? It is partially accounted for in **Livelihoods & Economies** through sectoral jobs data. The infrastructure is also something to consider. It could also be a pressure or resilience factor if there is a measurable footprint of the activity. You may want to consider for resilience, do you have governance measures that promote more sustainable practices in the energy industry?

9.7 Food Provision

Q: Could the culture of marine fish in closed pools on-shore be included in the Mariculture sub-goal?

A: This should not be included because onshore aquaculture does not require a marine environment.

Q: Can aquaculture farms that receive seawater supply and return seawater back to the sea be included in the food provision goal?

A: This would be more appropriately included in the Mariculture sub-goal, and with finer-scale data additional pressures due to the intake pipes and the processed brine back into the marine system could be incorporated as well. Natural Products

Q: If natural products are all produced through on-land aquaculture, should this goal be removed?

A: In this case you would probably have good reason to exclude the natural product goal due if this was defendable through discussions with experts and any reports/papers on the topic. This would also depend on the origin of these natural products—are they from the region's waters? Habitat-based goals

**Q: I have fish that are used as feed for other fish (e.g., sprat) in my country. Can I include them in this goal?

A: It would be more appropriate to include them in Natural Products rather than Food Provision. This is because they are not being consumed directly. Fish such as sprat, for example, may be used to feed pigs in addition to other fish, and therefore you would need to know how much (tonnage) is being produced, and where it is going to be able to accurately distinguish these categories to avoid double-counting.

(Source: OHI Baltic Workshop, February 2015)

Q: How is coral health calculated?

A: Coral health was estimated by compiling point data from multiple studies of percent live coral cover. In other words, estimates of coral cover within transects of certain sites were repeated in time and we used that rate of change in time as an indication of health of the reefs in the whole region. The difficulty lies in 1) having enough different locations sampled that you can say something about the whole region and 2) finding studies that did repeated measures in time, in the same location, over at least 20 years. In the Global 2013 assessment, there were so few datasets that satisfied this condition that we had to pool observations from different locations.

Q: Is it possible to calculate habitat goals when there is only one year of habitat data?

A: With only one year of habitat data, it is not possible to calculate the trend (which requires 5 years of data). Instead, it might be best to use the available habitat data to calculate the current status and then to overlay pressures for the last 5 years to calculate trend.

9.8 Livelihoods & Economies

Q: Benefits gained from Wild-caught fisheries, Mariculture, Tourism & Recreation are included in specific goals. Why are these counted again in Livelihoods & Economies?

A: The quantity of fish, mariculture, and participation in T&R are considered separately in goals whereas the monetary component is captured in L&E.

Q: Why are revenue data from shipping, boat building, ports and harbors included as revenue? Do these activities rely on a healthy ocean?

A: These sectors are included in the Ocean Health Index because the demand for some of those boats (fishing boats, sailboats, yachts) is dependent on a healthy ocean.

Q: Why isn't oil and gas industries included in revenue?

A: The Natural Products goal does not include non-living items such as oil, gas, and mining products, because these practices are not considered to be sustainable. They are also done at such large scales that including them would essentially make OHI an index for oil and mining—and they are not truly an ocean product. Because these products are not included in terms of quantity extracted, it did not seem appropriate to include information regarding jobs, wages or revenue.

9.9 Tourism & Recreation

Q: How do I calculate the sustainability term for TR?

A: The best way is to use a local indicator or measure of tourism sustainability or competitiveness, otherwise use the TTCI value from the Global 2013 assessment for the study area (applied evenly across all regions).

9.10 Natural Products

Q: Where do Natural Products come from?

A: In the global assessments, Natural Products data come from the UN's Food and Agriculture Administration (www.fao.org/fishery/statistics/software/fishstatj/en). These data are compiled and reported by product for each country, and available by downloading the FishStatJ software.

9.11 Species

Q: Can species and iconic species model scores be penalized if there are local flagship species that have not been evaluated?

Global data are based on IUCN assessments. For these evaluations, IUCN chooses a taxon (e.g. sharks) and a group of world experts assess it comprehensively. Locally identified species identified in a regional assessment may not be in the IUCN database because they do not belong to one of the taxa that have been selected for assessment, or because the experts that did the assessment did not know that information existed. In either case, there is no connection between what IUCN reports and what assessments are done locally. Therefore, it might not be fair to penalize a study area for missing species. For biodiversity, it is unrealistic to expect that all species are assessed, so it seems unfair to penalize for unassessed species. In the fisheries goal, there are penalties for species that are exploited but not assessed, because if there are landings data, it means they are somewhat measurable, and so it is reasonable to expect they should be at least monitored.

It might be reasonable to penalize unassessed iconic species. It is a smaller list of species that are specifically identified as being of interest, for one reason or other. This would work for species that have some form of assessment - unless that information already exists, it might be unrealistic to try to produce the data layer required to develop a new model.

9.12 Sense of Place

Q: Data are only available for marine protected areas, not terrestrial protected areas. Can we still calculate the Lasting Special Places sub-goal?

A: Yes, it is possible to calculate only the marine component of this sub-goal: this is not ideal but OHI is flexible to work with the data available.

Q: Should we calculate each category used in our assessment (e.g., antiquities, MPAs, beaches of special interest) independently, and then give the same weight (e.g., a third of the goal score) to the three categories, or should we instead pool the actual areas of the 3 categories?

A: Whether you group them together or calculate each category separately depends on reference points. Maybe you want 10% of offshore water to be in MPAs, but only 5% of coastlines to be beaches and 3% Antiquities, for example; in this case, you would calculate them separately and then add them together. But if you want 10% of your country's coast to have any combination of these things, you would keep them together.

(Source: OHI Israel assessment discussions, 2014-2015)

9.13 Pressures

Q: How are single ecological pressures (si in Equation S8) calculated?

A: Data included in pressures calculations are accessed in the same manner as any other data layer, and rescaled from 0-1 with an appropriate reference point. For further information, see HowTo_GatherAppropriateData and HowTo_CalculatePressures from ohi-science.org.

Q: Does the pressures matrix need to be changed?

A: It is likely that the pressures matrix will not need to be changed. The weights assigned in the matrix were set using information from the literature and by experts; the matrix was created by Halpern et al. 2012.

Q: How is commercial high and low bycatch calculated?

A: Commercial high and low bycatch are categorical values that were set based on fishing gear type. This began as a list of gear types used, producing a range of potential bycatch frequencies (from local reports when possible), which can be rescaled.