The Ocean Health Index Assessment Manual

Contents

1 Introduction

1.1 The Ocean Health Index

The Ocean Health Index (OHI) project was created with a strong foundation in communication and collaboration. Following the initial publication by Halpern *et al.* 2012 in *Nature*, we have conducted global assessments annually (in 2013, 2014, and ongoing), and have conducted smaller-scale assessments for the U.S. West Coast (Halpern *et al.* 2014), Fiji (Selig *et al.* in press), and Brazil (Elfes *et al.* 2014).

We have also developed the **OHI Toolbox** and **WebApps** to enable any group to conduct independent assessments using the OHI framework and modifying it to their needs. The Toolbox enables the OHI framework to be customized to any area of interest, incorporating whatever goals, data, indicators, and priorities regarding ocean-derived benefits that are relevant and available to the chosen spatial scale. Information is presented through the WebApps, which are used for orientation, visualization, and reporting.

This manual provides information for:

1. Planning an assessment
2. Navigating the OHI WebApp to visualize data at global and regional scales
3. Modifying data and models within the Toolbox for an independent assessment
4. Guidance for frequently asked questions and troubleshooting

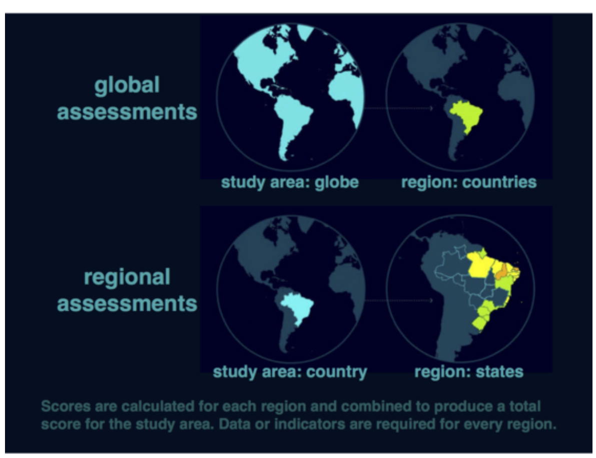
2 Introduction to OHI Regional Assessments

Assessments using the OHI framework can be most relevant to policy and management decisions when they are conducted at smaller spatial scales (e.g., countries, states, provinces, ecoregions, bays, etc.). Using ten criteria (called goals), the Index scores on a scale of 0 to 100 how well coastal regions optimize their potential ocean benefits and services in a sustainable way relative to self-established reference points (targets). Relevant goal models are developed based on the best available information, which can be either raw data or composite data, or previously developed indicators.

The process of conducting an OHI assessment is as valuable as the final results. This is because while conducting an OHI assessment you will identify gaps in knowledge and data, produce decision-relevant information, and create an ocean alliance that combines knowledge and cultural values across disciplines. Conducting an OHI assessment requires engagement from as many different groups as possible, including research institutions, government agencies, policy groups, non-governmental organizations, and the civil and private sectors.

Assessments can incorporate higher-resolution data and indicators, local priorities and preferences, and develop tailored goal models and reference points, which produce scores that better reflect local realities. If a goal is not relevant in the local context, it can be excluded entirely. Similarly, pressures and resilience measures can be refined using local data and indicators. Index scores are only as good as the data on which they are based. **Finding the best data and indicators available is crucial for obtaining meaningful findings that can help inform decision-making.**

OHI assessments most often involve several **regions** within an overall **study area**. For example, in the global assessment, there were 221 regions (nations and territories) within the study area (global coastal oceans).



Goal scores are calculated for each region separately and then combined to produce an overall Index score for the region. Index scores are combined using an area-weighted average to produce the Index score for the overall study area.

3 Overview of the OHI Toolbox App

3.1 Background

OHI WebApps are websites created to facilitate independent assessments, and one is available for nearly every coastal nation or territory: they are a 'Starter Kit'. WebApps are available through http://ohi-science.org with a three-letter identifier. For example, Ecuador's WebApp is found at http://ohi-science.org/ecu. Each WebApp displays raw data layers* and calculated OHI scores based on information extracted from global assessments. As such, they do not provide fine-scale resolution of data for each coastal nation or territory: the scores and data on which they are based are a starting point for an assessment to be conducted by an independent group. These data can be used as a default if better data for the region do not exist, but we encourage you to replace them wherever possible. (*Note: each data component that is included in the OHI is called a **data layer** because it will be combined with others to calculate the goal scores. Many data layers are rescaled from 0-1 to be combined with others on the same unitless scale.)

Boundaries for exclusive economic zones (EEZs) were identified by www.marineregions.org and the largest subcountry regions (i.e. provinces, states, districts) were identified by gadm.org. Subcountry region boundaries were extended offshore to divide the EEZ of each study area into offshore regions. These subcountry regions have been provided as a starting point, and are typically coastal states or provinces, which, in our experience, is consistent with the scale at which most policy decisions are made. However, it is possible to change the boundaries for the regions and the study area depending on your preferences.

OHI WebApps serve several purposes because they:

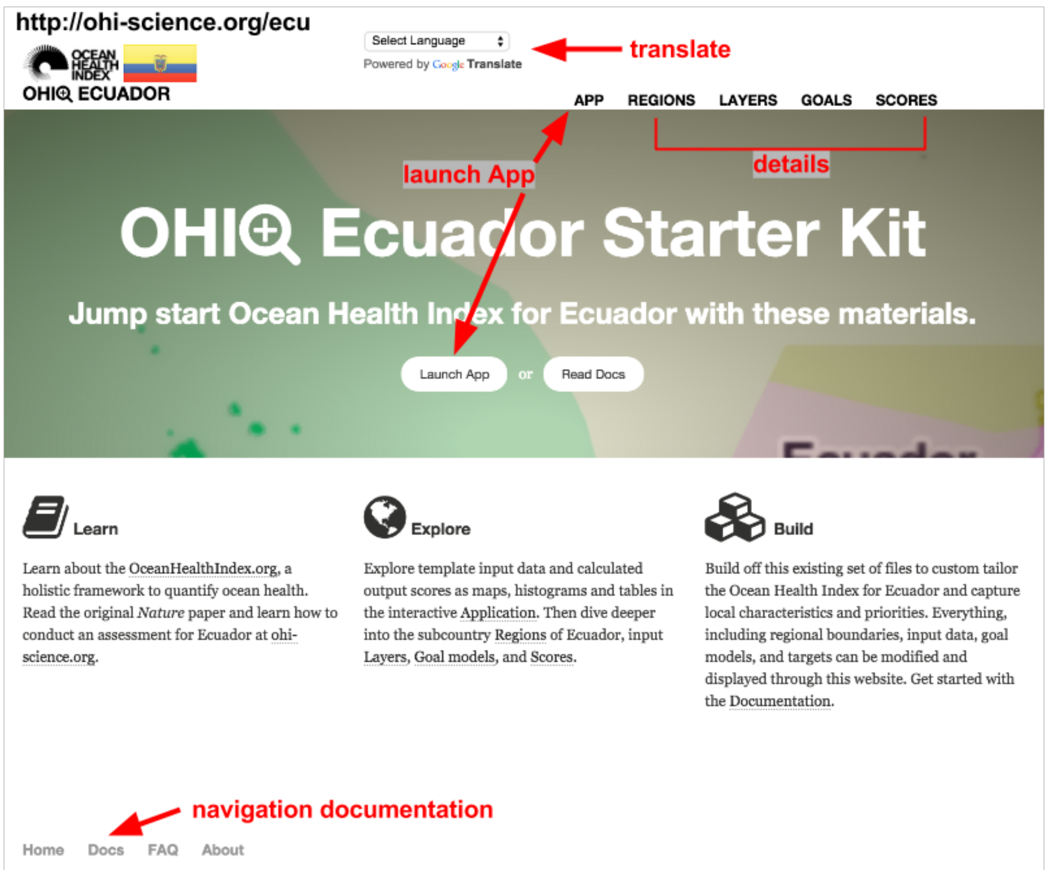
1. allow for exploration of how the Index works: what data look like and which data are used in each goal
2. are a communication platform for an assessment team, since information is presented in a manner that is accessible to group members of different disciplines and technical capacities
3. can be used to set data gathering or goal model development priorities for the assessment
4. display your assessment's data and calculated scores once you have finalized and formatted your data and modified goal models.

The information displayed on the website is stored online, in a **GitHub repository.** GitHub is an open-source development platform allows for multiple users to collaborate, track changes, and document work such as data files and code. Therefore, any changes made to the files contained within the GitHub repository will be displayed on the WebApp for all team members to view. See below for how to modify files using GitHub.

3.2 Using the WebApp

When first exploring a WebApp (for example, http://ohi-science.org/ecu), first note that it is possible to **translate** the site into any language that Google provides using the pull-down menu at the top.

The WebApp homepage provides several tabs for you to explore. The interactive **App** allows you to explore input data layers and output calculated scores for each region, and is explained fully in the following section. More detailed information is about the default **regions** and **data layers**, **goal models**, and **calculated scores** based on global data can be viewed in separate tabs, as well as through the App. A quick reference about navigating the WebApp is available through the **Docs** tab. When your team has finalized data layers and updated goal models, these data and scores will be visualized through the WebApp.


http://ohi-science.org/ecu
OCEAN HEALTH INDEX
OHI ECUADOR
Select Language
Powered by Google Translate
translate
APP
REGIONS
LAYERS
GOALS
SCORES
launch App
details
OHI Ecuador Starter Kit
Jump start Ocean Health Index for Ecuador with these materials.
Launch App
or
Read Docs
Learn
Learn about the OceanHealthIndex.org, a holistic framework to quantify ocean health. Read the original Nature paper and learn how to conduct an assessment for Ecuador at ohi-science.org.
Explore
Explore template input data and calculated output scores as maps, histograms and tables in the interactive Application. Then dive deeper into the subcountry Regions of Ecuador, input Layers, Goal models, and Scores.
Build
Build off this existing set of files to custom tailor the Ocean Health Index for Ecuador and capture local characteristics and priorities. Everything, including regional boundaries, input data, goal models, and targets can be modified and displayed through this website. Get started with the Documentation.
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3.3 The App

The App allows you to explore and visualize input data layers and calculated output scores for each region in the study area. By default, global data are presented for each subcountry region in the study area, and scores are calculated for each region using those data.

The App displays this information through two tabs: Data and Compare. The **Data** tab provides several subtabs for viewing data (*Map*, *Histogram*, *Table*), and is the default tab when the Toolbox is launched. The **Compare** tab is most useful for comparing output scores when modifications are made to the underlying data or models (this provides a way to error check) once you have begun the process of calculating your own assessment.

The App provides two Branch/Scenario options to view, identified in the upper-left corner of the Data tab. The **Branch** options refer to the versions of the GitHub repository where data are stored. Branches start off as copies of the same repository, but can be modified independently of each other, enabling progress to be made on one ('draft' branch) while not altering the vetted original ('published' branch). These branches can be merged back together at any time. The App will display the 'published branch' by default; we recommend working on the 'draft' branch until your assessment is finalized, at which point you would merge the draft branch with the published branch.

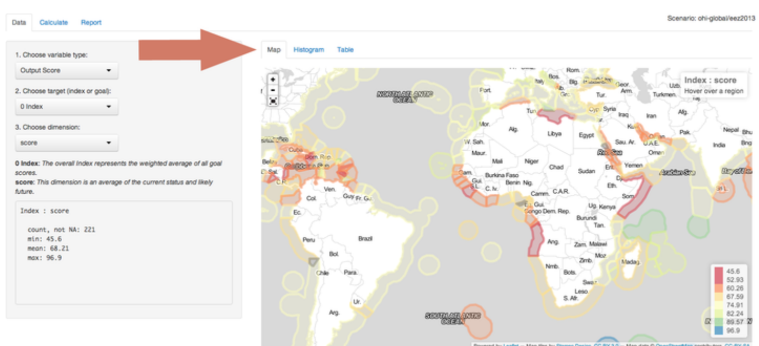
Scenario folders contain all the files needed to calculate scores. Scenario folders can differ from each other based on the years included (i.e. 2014 would be a different scenario from 2015), or they can be used to explore outcomes of policy alternatives, such as implementation of a proposed Marine Protected Area network or fisheries regulations.

3.4 The App's Data tab

3.4.1 Overview of display options

The Data tab displays input data or calculated scores for each goal parameter, and presents the information as a map, histogram, or table. These options (*Map*, *Histogram*, *Table*) are presented as subtabs located the map. The Map subtab is the default display option for the Data tab, and all data presented is based on data from global assessments.

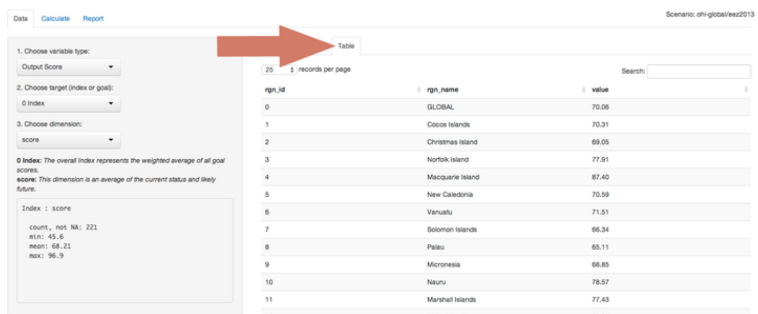
Data displayed in the Map subtab:



The map displays data for every region as reported in the scenario. A color legend is displayed in the lower right corner of the map that provides a linear colormap of the data. The range of values will change as different variables are selected.

Data displayed in the Histogram subtab:

The histogram shows the distribution of the selected variable as the number of observations per value bin (white bars) and a smoothed density function (pink shading).

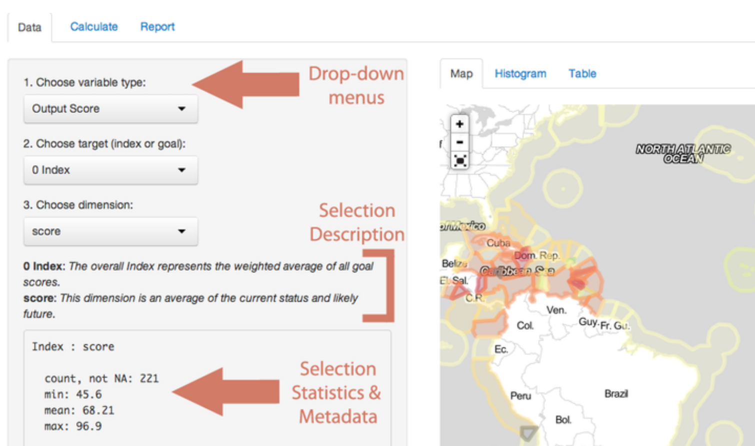


Data displayed in the Table subtab:

The table displays the target value for each region and the overall study area. It provides an identifying code (rgn_id), name (rgn_name), and value (value) for each.

3.4.2 Overview of variable options

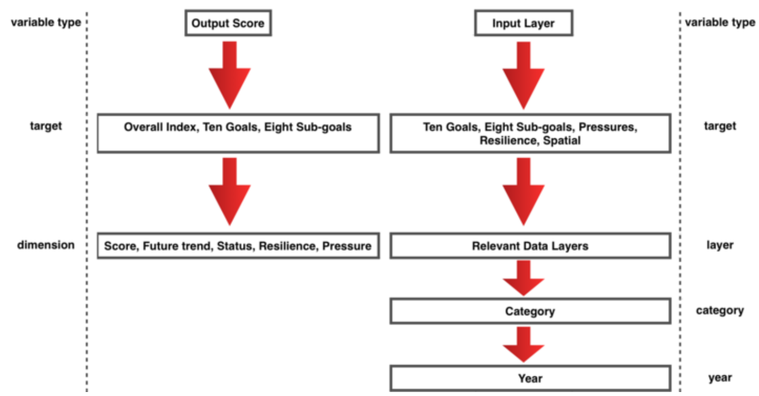
The Data tab has drop-down menus from which you choose the data to be displayed. Data selected from the pull-down menus can be viewed in Map, Histogram, or Table form as described in the section above. Descriptions, statistics and metadata for the chosen fields are also displayed below the drop-down menus on the left side of the tab.



The first selection to be made from the drop-down menus is variable type, in which the user can choose the **Output Score** that will show a calculated score (for a particular target chosen subsequently), or **Input Layer** that will show the data layer used to calculate the score of a particular target. To reiterate, Output Scores are the scores calculated using the Input Layers (data).

For example, if you select 'Output Score' as the variable type (which is the default), you will then be able to choose a target (goal or sub-goal), and the OHI dimension to be reported.

As another example, if you select 'Input Layer' as the variable type, you will be able to choose a target and a specific data layer associated with that target. If that layer has multiple categories or years available, you will be able to select a preference. Without selection, the default setting is the first category alphabetically and the most recent year.



3.5 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 data. Visualizing these differences is extremely helpful for confirming results and error checking. Instructions about how to use the Compare function are presented later in the manual, following more context about why you might want to use this functionality.

3.6 Before conducting an assessment

Before conducting an assessment, it is important to prepare the following:

- Develop a strategic plan and timeline
  - establish the need for an assessment
  - define the spatial scale of the assessment: country, state, eco-region, etc.
  - determine the resources available
  - outline a timeline with necessary meetings and workshops
  - engage decision-makers early for results to be most useful
- Assemble a qualified team with diverse skills and knowledge, including:
  - a broad scientific understanding and experience with environmental policy
  - ability to manage large data sets, make decisions, and think creatively
  - capacity to collaborate in a multidisciplinary team, remotely and in person
  - team members who can use the statistical programming language R (http://cran.r-project.org/), ArcGIS or other spatial analysis software, and are fluent in English
- Funding
  - greatly depends on the local context
  - potentially needed for a management and scientific team, workshops and meetings (including travel), communications, policy engagement, and operating costs
- Policy and management interest

- engage decision-makers early: informing policies to improve ocean health is most effective if there is early interest and engagement from government agencies and decision-making bodies
- requires ongoing communication during Index development to best inform management actions
- repeated assessments as new data become available enable tracking ocean health through time and evaluating management and policy interventions

4 Conducting an Assessment

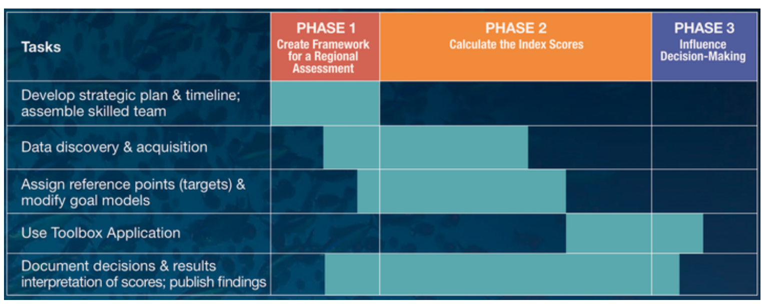
4.1 What to expect when conducting an assessment

There are key considerations and processes that will be a part of every assessment, however, the process for conducting each assessment will be unique depending on the local context. For example: what data and indicators are available will determine how goal models can be tailored to the region, and what skillsets and resources are involved will affect the time it takes to complete the assessment.

4.1.1 Timeline

The time required to complete an assessment depends on the local context and available resources, but the proportion of time required for different phases of the assessment is more predictable.

Expect strategic planning, discovering and gathering data, and developing reference points and models to comprise > 80% of the time allotted for the assessment.



4.2 Where to start

You should start by understanding the structure of the global assessment and the data involved will help you think about what should be done differently in your local context.

The best way to do this is to begin with the WebApps. As described above, most coastal countries have a WebApp that was created to facilitate planning and communication during your assessment. The WebApp presents data, goal models and calculated scores for each region (global administrative area identified by gadm.org) visually through maps, histograms, and tables. All data presented were extracted from the global analysis, and scores were calculated using global goal models. For a finer-scale assessment of ocean health in your region, these data files provided will need to be updated with available data and indicators for each region in your assessment. However, if better data are not available, you can use the data provided. Then, to dive deeper into data layers and goal models, you can explore your assessment's GitHub repository, which stores all the information presented through the WebApp.

You should also be familiar with the approaches taken by other assessments adapted from the global context, including Brazil, the US West Coast, and Fiji. You can find these studies at ohi-science.org.

While our team of scientists and managers is prepared to provide guidance for regional assessments, you should follow the steps in this training program to complete your assessment as autonomously as possible.

4.3 Points to remember

We recommend keeping in mind the following as you develop your approach:

- People are part of ocean health
  - economic and social data are included in OHI: consider how people are locally engaging with the ocean
- Goal models should be modified to capture local characteristics and priorities that can be measured with available data
  - after identifying what is important locally, identify direct or indirect measures to develop tailored goal models
- Assessments can use a mix of regional-, country- and global-scale data
  - include the finest-scale data available, but when this is not possible, rely on global-scale data
- Scores are calculated by region and then aggregated to the study area
  - comparing scores between regions is a primary reason for conducting a independent assessment
  - goal models and data layers are the same across all regions; data values will vary by region. For example, the carbon storage goal model is the same for each region, but the habitats present in each region, and the area and condition of those habitats (the data values) are specific to each region
- All data do not need to be at the same spatial or temporal scale
  - each assessment should represent the best understanding of ocean health at a point in time. For example, if fisheries data are available from 1980-2011 and tourism data are available from 2008-2012; these can both be used to represent current ocean health
- Document all decisions made, including:
  - all data sources (publications, website URL, date of access, etc).
  - processes for establishing reference points,
  - how and why models were modified, and additionally why other potential modifications were not done, as this reminds yourself of past decisions and helps explain them to others in the future)
  - that it is important for transparency, describing methods and explaining results in reports and publications, and for reproducibility (for any future comparable assessments in your study area)

4.4 Checklist: How to prepare for using the Toolbox

Most time spent conducting an assessment occurs before using the Toolbox to calculate scores. Prior to these calculations the Toolbox and WebApp can be used to understand the Index and as a tool to provide structure to its underlying framework. For example: how the data and models are used to calculate the ten goals (and, in some cases, corresponding subgoals) for each region and how these are combined to generate an overall score for each region can be explored with the Toolbox. At this point, the Toolbox provides a guideline for the data that must be collected and how it should be organized.

When going through the checklist remember too that a motivation for conducting an assessment is to be able to modify goal models and set reference points using finer-scale, local information and reference points.

The following list of tasks will not necessarily be accomplished in sequence: there is a lot of iteration of tasks as you discover data, develop reference points and models, and revisit other data possibilities. This checklist identifies decisions and steps that must be done before the Toolbox can be used to calculate regional goal scores:

- Understand the philosophy of OHI
  - what the goals represent, how they are modeled, and what types of data are included
  - what pressures and resilience data are included
  - how reference points are set
- Identify local characteristics and priorities
  - what local cultural preferences or priorities should be captured in the assessment?
  - should any goals be removed?
  - should any goals be redefined?
  - should other goals be added?
  - should goals be weighted unequally?
  - what are social and ecological pressures to the local system?
  - what social and ecological resilience measures (laws, regulations, restoration projects) are in place locally?
- Be familiar with the global inputs (data and models) used in the WebApp
  - understand the data and models used in global assessments
  - prioritize which data and models should be updated to better represent local characteristics and priorities
- Decide the spatial scale for regions within the study area
  - do the WebApp regions (states or provinces) make sense? If not, what alternate scales are more appropriate?
  - we recommend multiple regions to allow for comparisons and determine geographic priorities within the study area
  - regions should be at the smallest scale the data allow
  - at what spatial scale are data most frequently reported?
  - at what spatial scale are policy decisions made (optional)?
- Discover and gather appropriate data and indicators
  - what local data and indicators are available for goal models?
  - what local data and indicators are available for pressures and resilience?
  - are available data and indicators relevant to OHI?
  - are local data and indicators at the appropriate temporal scales?
  - how should reference points be set for local data?
  - process and format data and indicators to create data layers for the Toolbox (See 'Formatting Data for the Toolbox' section below)
  - use the Toolbox repository as a registry to organize data layers
- Update pressures and resilience information
  - determine whether all global pressures are relevant locally
  - identify local pressures not captured in the global pressures matrix
  - categorize any new local pressures layers
  - set pressure weighting/ranking based on literature, expert opinion
  - identify potential resilience measures for each of the pressures identified
  - determine what datasets may be available to measure resilience metrics
- Modify goal models mathematically:
  - how can goal models be represented mathematically using locally available data and indicators?
  - can reference points be refined using locally available data and indicators, government mandates, management targets, obligations from multilateral agreements?

4.5 The Ocean Health Index Toolbox

The OHI Toolbox is an ecosystem of data, scripts, and structure used to facilitate groups with the highly collaborative OHI assessment process at any scale. Toolbox scripts are open source, written in the software language R, and data inputted into the Toolbox are *.csv* (comma-separated-value) files, which can be created or edited using text editors or Microsoft Excel.

The Toolbox ecosystem is organized through an online collaborative platform, called **GitHub**. GitHub stores the R scripts and *.csv* files in a folder called a repository, which is found online and can also be downloaded on your computer and synced with the online version. GitHub tracks changes by all collaborators working on the project through time, and saves all versions for comparison.

The Toolbox is used to calculate final scores. But, perhaps more importantly, it can also be used to organize an assessment, including data identification and management. The Toolbox can additionally be used to compare how different management scenarios could affect overall ocean health, which can inform effective strategies for ocean resource management at a local scale.

4.6 OHI Toolbox File System

This section describes the files within your GitHub repository, which can be viewed online at with your country's three-letter code. For example, https://github.com/OHI-Science/can. You are able to view all the files in the repository online through GitHub. You are also able to download the repository from the website, but to be able to sync any modifications back to GitHub, you will need to '**clone**' this repository following the steps in the 'Installing the Toolbox' section below.

The following is an orientation to the Toolbox file system, whether you are viewing it online through GitHub, or have downloaded or cloned it to your computer.

4.6.1 Assessments and scenarios

Your **assessment**, i.e. your GitHub repository, contains a several files. The most important is your **scenario** folder: *subcountry2014* (other files are specific to GitHub and will not change). Your scenario folder contains all the files needed to calculate scores, and they are described in detail below. This scenario folder is named *subcountry2014* to indicate that it is based on data from the 2014 global assessment, with data extracted per subcountry region (i.e. state, province, district, as per gadm.org). You can rename your scenario folder to better reflect the spatial and temporal scale of your assessment after you have set up your GitHub account. Eventually, you will likely have multiple scenario folders that contain analysis for different years or for exploring policy alternatives.

In this example, **Ecuador (ecu)** is the assessment repository and *subcountry2014* is the scenario folder.

See below for a detailed overview of all the files located in the scenario folder.

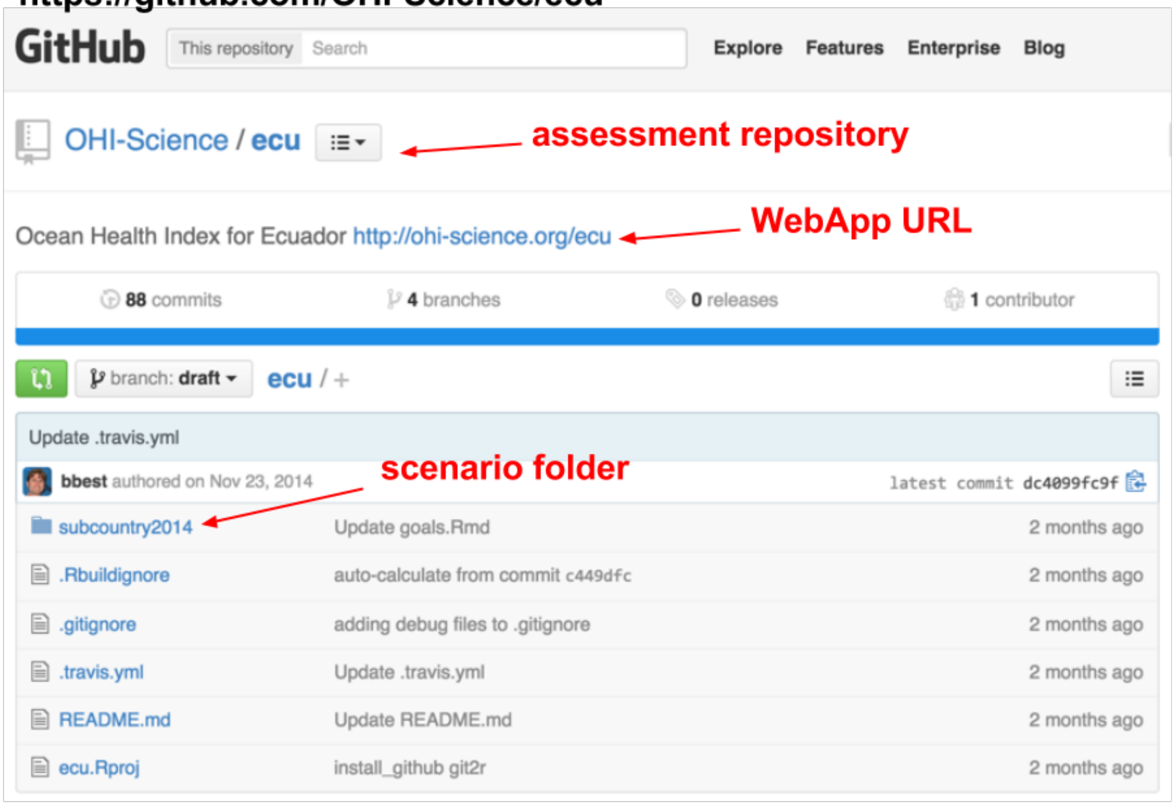
4.6.2 *layers.csv*

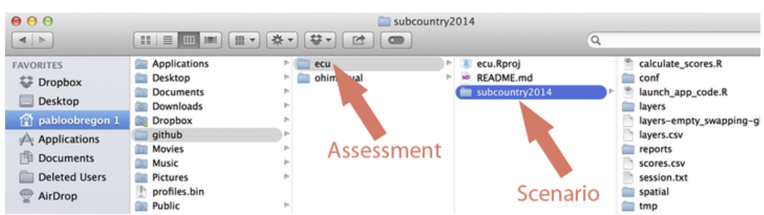
`layers.csv` is the registry that manages all data to be used in the Toolbox.

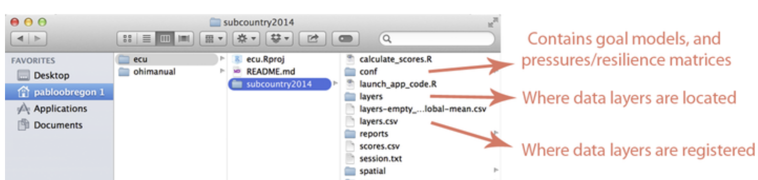
Each row of information represents a specific data layer that has been prepared and formatted properly for the Toolbox. The first columns contain information inputted by the user; other columns are generated later by the Toolbox App as it confirms data formatting and content. The first columns have the following information:

- **targets** indicates how the data layer related goals or dimensions. Goals are indicated with two-letter codes and sub-goals are indicated with three-letter codes, with pressures, resilience, and spatial layers indicated separately.

https://github.com/OHI-Science/ecu





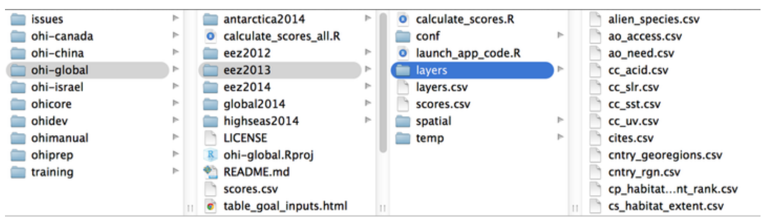


1	targets	layer	name	description	fld_value	units	filename
2	AO	ao_access	Fisheries manage	The opportunity fo	value	value	ao_access.csv
3	AO	ao_need	Purchasing powe	The per capita pu	value	value	ao_need.csv
4	CW	cw_coastalpopn_tren	Coastal human p	Coastal populatio	trend	trend score	cw_coastalpopn_tr
5	CW	cw_fertilizer_trend	Fertilizer consum	Statistics on fertili	trend.score	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 consum	Statistics on pesti	trend.score	trend score	cw_pesticide_trend
8	FIS	fis_b_bmsy	B/Bmsy estimates obtained using th		b_bmsy	B / B_msy	fis_b_bmsy.csv
9	FIS	fis_meancatch	Catch data for ea	Reported data inc	mean_catch	metric tons	fis_meancatch.csv

- **layer** is the identifying name of the data layer, which 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 Toolbox App under the drop-down menu when the variable type is 'input layer'.
- **name** is a longer title of the data layer; this is displayed on the Toolbox App under the drop-down menu when the variable type is 'input layer'.
- **description** is further description of the data layer; this is also displayed on the Toolbox App under the drop-down menu when the variable type is 'input layer'.
- **fld_value** indicates the units along with the units column.
- **units** some clarification about the unit of measure in which the data are reported
- **filename** is the *.csv* filename that holds the data layer information, and is located in the folder 'layers'.

4.6.3 *layers* folder

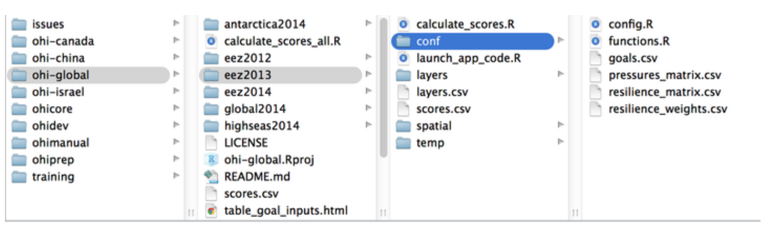
The `layers` folder contains every data layer as an individual *.csv* file. The names of the *.csv* files within the layers folder correspond to those listed in the *filename* column of the `layers.csv` file described above. All *.csv* files can be read with text editors or with Microsoft Excel or similar software.



Note that each *.csv* file within the `layers` folder has a specific format that the Toolbox expects and requires. Comma separated value files (*.csv* files) can be opened with text editor software, or will open by default by Microsoft Excel or similar software. Open a `layers/*.csv` file: note the unique region identifier (*rgn_id*) with a single associated *score* or *value*, and that the data are presented in 'long format' with minimal columns. Please see the section on *Formatting Data for the Toolbox* for further details and instructions.

4.6.4 *conf* folder

The `conf` folder includes includes R functions (*config.R* and *functions.R*) and *.csv* files containing information that will be accessed by the R functions (*goals.csv*, *pressures_matrix.R*, *resilience_matrix.csv*, and *resilience_weights.csv*).



4.6.4.1 *config.r*

`config.r` is an R script that configures labeling and constants appropriately.

4.6.4.2 *functions.r*

`functions.r` contains functions for each goal and sub-goal model, which calculate the status and trend using data layers identified as 'layers' in `layers.csv`.

4.6.4.3 *goals.csv*

`goals.csv` is a list of goals and sub-goals and their weights used to calculate the final score for each goal. Other information includes the goal description that is also presented in the Toolbox App. `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).

4.6.4.4 *pressures_matrix.csv*

`pressures_matrix.csv` maps the different types of ocean pressures with the goals that they affect.

Each column in the pressures matrix identifies a data layer that is also registered in `layers.csv`: these presssure data layers are also required to have a value for every region in the study area. Pressure layers each have a score between 0-1, and has its pressure category indicated by a prefix (for example: *po_* for the pollution category).

4.6.4.5 *resilience_matrix.csv*

`resilience_matrix.csv` maps the different types of resilience with the goals that they affect.

Like the pressures matrix, the resilience matrix also has weights depending on the level of protection. However, these weights are in a separate file: `resilience_weights.csv`.

Each column in the resilience matrix is a data layer that is also registered in `layers.csv`. Resilience layers, like the pressure layers, are also requried to have a value for every region in the study area. Resilience layers each have a score between 0-1.

4.6.4.6 *resilience_weights.csv*

`resilience_weights.csv` describes the weight of various resilience layers, which in Halpern et al. 2012 (Nature) were determined based on scientific literature and expert opinion.

4.6.5 spatial folder

The spatial folder contains a single file, *regions_gcs.js*. This is a spatial file in the JSON format; it has the appropriate study area and regions for the assessment. This file will be created by the OHI team for all regional assessments.

4.6.6 launchApp_code.R

The App can be launched through R by running the code in lauchApp_code.R.

4.6.7 layers-empty_swapping-global-mean.csv

Contains a list of data layers for which there were no data for the study area. In order for the Toolbox to run, global averages are used as template data. This file is not used anywhere in the Toolbox but is a registry of data layers that should be replaced with local data, as they are based on global averages.

4.6.8 *calculate_scores.r*

`calculate_scores.r` will run the Toolbox calculations using the *.csv* files in the *layers* folder that are registered in *layers.csv* and the configurations identified in *config.r*. Scores will be saved in *scores.csv*.

4.6.9 scores.csv

`scores.csv` is a record of the calculated scores for the assessment (Global 2013 scores). Scores are reported for each dimension (future, pressures, resilience, score, status, trend) for each reporting region, and are presented in 'long' format.

4.6.10 Relaunching the Toolbox

After the initial Toolbox setup, further launches of the Toolbox Application can be done without the software program R. Instead, PC users can double-click the `launchApp.bat` file and Mac users can double-click the `launchApp.command` file.

4.7 Discovering and Gathering Appropriate Data and Indicators

The OHI spans disciplines and integrates diverse data and sources to give a comprehensive assessment of ocean health. A hallmark of the OHI is that it uses freely-available data to create models that capture the philosophy of individual goals, and finding appropriate data requires research and creativity. There are many decisions to make when gathering from disparate sources, deciding reference points, and developing goal models.

Index scores are a reflection of data quality, and thus accessing the best data and indicators available is of highest importance.

4.7.1 Data sources

Existing data and indicators can be gathered from many sources across environmental, social, and economic disciplines, including:

- government reports
- government websites
- academic literature
- masters and PhD theses
- university websites
- non-profit organizations

All data will be rescaled to specific reference points (targets) before being combined; therefore setting these reference points at the appropriate scale is a fundamental component of any OHI assessment. This requires the regional assessment team to interpret the philosophy of each Index goal and sub-goal using the best available data and indicators.

4.7.2 Data gathering responsibilities

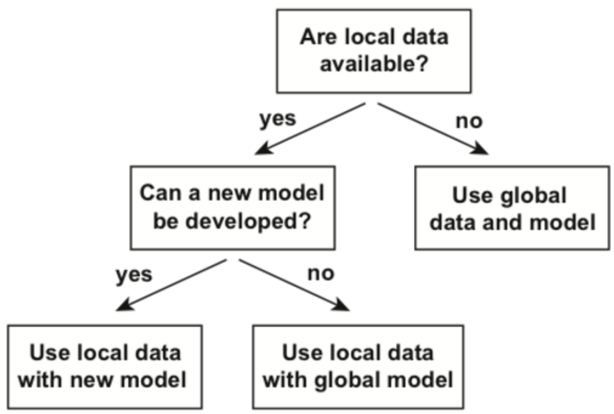
Gathering appropriate data requires searching for and accessing freely-available data. It is important that team members responsible for data discovery make thoughtful decisions about whether data are appropriate for the regional assessment, and that they also get feedback from the full team to discuss the merits of different data sources. Data discovery and acquisition can be quite an iterative process, as there are both practical and philosophical reasons for including or excluding data, in addition to requiring access to the data.

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 so that you will be able to find it again in the future.

4.7.3 The process of data discovery

In terms of philosophical considerations, the most important thing to remember when gathering data is that the data must contribute to measuring ocean health. Many data sources that enhance our knowledge of marine processes may not 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 would raw data measuring single marine attributes.

Begin by understanding and comparing the best approaches used in assessments that have been completed, including global assessments, Brazil, and the US West Coast. If finer-resolution local data were available in the study area, they could be used either in a newly developed regional goal model using locally appropriate and informed approaches, or in the existing global goal model. When local data were not available, the same global-scale data were used with the original global goal model, 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. This should be a goal-by-goal process:



Searching for data requires exploring data sources beyond any single discipline, and a good place to start is with an internet search. Internet searches can lead to published data in government and non-governmental organization reports, peer-reviewed articles, and masters and doctoral dissertations. Not everything will be freely available online but it is sometimes possible to request access.

It is good practice to keep detailed notes of attributes of each potential data layer, since there may be different options to work with. Searching for data by goal is a good approach, although some data layers will be used for multiple goals.

4.7.4 Requirements for data layers

Four requirements to remember when investigating (or 'scoping') potential data layers are:

1. relevance to ocean health
2. how to set the reference point
3. spatial scale
4. temporal scale.

Note: Once the appropriate data layers are chosen, they may need to be re-formatted in order to be readable by the toolbox (See: 'Formatting Data for Toolbox' section below).

4.7.4.1 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.

4.7.4.2 Reference point

As each data layer must 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:

- Is there a known relationship associated with these data?
- Have policy targets been set regarding these data?
- Would a historic target be appropriate?
- Could a region within the study area be set as a spatial target?

4.7.4.3 Appropriate spatial scale

Data must be available for every region within the study area.*

4.7.4.4 Appropriate temporal scale

Data must be available for at least five years to calculate the trend. Longer time series are preferable because this can be used to set temporal reference points.*

* It is not always possible to meet the spatial and temporal requirements with each data layer. In these cases it can still be possible to use these data if appropriate gap-filling techniques are used (See: 'Formatting Data for Toolbox' section below). It is important that data satisfy as many of these requirements as possible, and in cases where creative ways of working with such data are not possible, it might be better to exclude these data from the analyses and try a different approach.

4.7.5 Notes about data and regions

Final calculated scores by region will be represented on a map in addition to the flower plot. The map displays scores in the exclusive economic zone (EEZ) of the region, even if individual data layers do not all extend to the EEZ. This is a visualization that exactly maps the availble information of some data layers, but not all. Therefore, available data do not need to have been collected for all of the region's EEZ, but they need to be available for the region itself.

4.7.6 Example: US West Coast data discovery

Below are examples of some decisions made when exploring available data for the US West Coast regional assessment. Determining whether certain data could be included started with a good understanding of the data layers and models included in the global assessment, and because the US West Coast is a data-rich region, finer-resolution local data could be used in place of many of the global data layers.

4.7.6.1 Reasons data were excluded

There are a lot of existing data that contribute to our scientific understanding of ocean processes and interactions but that are not ideal for the OHI. Reasons to exclude data occur both on a practical level (do data adhere to the requirements above?) and on a philosophical level, which requires reflecting on the relationship with ocean health. Some common reasons for excluding data are listed below:

- **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, Oregon and Washington did not have these same data so they were not used.
- **There is not a clear and scientifically proven connection between the metric described by the data and ocean health**. Along the US West Coast, kelp beds are a very important habitat because of their contribution to biodiversity and coastal protection. However, kelp coverage is quite variable and is driven primarily by abiotic natural forcing (wave/storm disturbance and temperature) and thus kelp coverage is not a good metric of ecosystem health. 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 the ocean**. Sea walls and riprap provide coastal protection to many people along the US West Coast. However, these structures are not a benefit that is derived from the ocean itself, so only biogenic habitats were included in the calculation of this goal. These data can be included as a pressure due to habitat loss.
- **Data collection is biased and might misrepresent ocean health**. The US 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 ocaean health since they assess only 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.

4.7.6.2 Creative approaches to using data

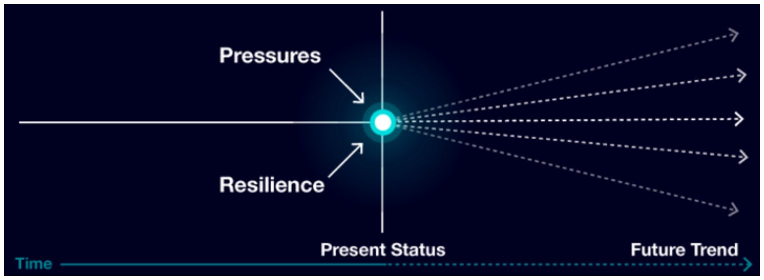
- **Time series data are not long enough to calculate a trend or a reference point (when a historical reference point is most appropriate)**. For the US West Coast, available data measure the current extent of seagrass habitats, however, these only exist for one time point in most areas so could not be used to calculate the trend or set a historical reference point. As these were the best data available for habitat coverage, we built a model to calculate the status and trend of seagrass habitats using other data that were available over time. A reasonable approach was to model the pressures exerted on seagrasses over time as a proxy for seagrass health.

4.8 Updating pressures and resilience

4.8.1 Introduction

'Pressures' and 'Resilience' are two of the four dimensions with which each goal/sub-goal is evaluated (the other two are 'Present Status' and 'Future Trend').

- **Pressures** are the sum of the ecological and social pressures that negatively affect goal scores.
- **Resilience** is the sum of the ecological factors and social initiatives (policies, laws, etc) that can positively affect goal scores by reducing or eliminating pressures.



For more general information on how OHI scores are calculated, see: http://www.oceanhealthindex.org/About/Methods/.

Updating the pressure and resilience matrix for a new regional assessment will require the user to:

- Understand the pressures and resilience measures included in completed global assessment and determine whether they are relevant locally.
- Identify and categorize new local pressures not captured in the pressures matrix.
- Identify and categorize new local resilience measures (laws, regulations) not captured in the resilience matrix.
- Set pressure and resilience weighting/ranking based on scientific literature and expert opinions.

Before updating the pressure and resilience matrices however, please also consider the following:

The Ocean Health Index framework calculates pressures by first grouping them into five ecological categories (pollution, habitat destruction, fishing pressure, species pollution, and climate change) and one social category. The reason behind the ecological categories was largely due to data availability at the global level and was designed to minimize sampling bias. For example, we found that there was more pollution data available than habitat destruction data, but just because people have monitored pollution more does not mean it is a larger pressure than habitat destruction. Ecologial and social pressures are assessed separately and then combined with equal weighting, which could be changed if there is local information on how to do so.

Ecological and social resilience are similarly assessed separately and then combined with equal weighting, which could also be changed based on expert opinions. Any new resilience measure must be associated with a pressure layer. This is because resilience in the Ocean Health Index framework acts to reduce pressures in each region. Therefore, resilience measures must not only be directly or indirectly relevant to ocean health, but must be in response to a pressure layer affecting a goal.

Note that goals often interact with each other through pressures. The pressure created by one goal may affect a second goal without being affected itself. For example, raising fish in the mariculture goal can cause genetic escapes, which is a pressure (the *sp_genetic* layer). This pressure affects only the wild-caught fisheries and species sub-goals, but does not affect mariculture itself.

4.8.2 Explore local pressures

Begin by exploring the pressures included in the global pressures matrix in the GitHub repository (`subcountry2014/conf/pressures_matrix.csv`; more on the filesystem below). As illustrated below, pressures are either ecological or social, and are grouped into 6 categories: pollution, habitat destruction, fishing pressure, species pollution, climate change, and social pressures.

In the example below, the clean waters goal is affected by four data layers within the pollution category, as well as one in the social category.

	TOTAL PRESSURES																				
	ECOLOGICAL																				SOCIAL
	Pollution						Habitat destruction			Species pollution		Fishing pressure					Climate change				Social
	Chemicals po_chemicals	Chemicals: 3nm po_chemicals_3nm	Pathogens po_pathogens	Nutrients po_nutrients	Nutrients: 3nm po_nutrients_3nm	Trash po_trash	Subtidal softbottom hd_subtidal_sb	Subtidal hardbottom hd_subtidal_hb	Intertidal hd_intertidal	Invasive species sp_alien	Genetic escapes: sp_genetic	Commercial high bycatch fp_com_hb	Commercial low bycatch fp_com_lb	Artisanal low bycatch fp_art_lb	Artisanal high bycatch fp_art_hb	Targeted harvest fp_targetharvest	Sea surface temperature cc_sst	Ocean acidification cc_acid	Ultra violet cc_uv	Sea level rise cc_slr	World Governance Indicators ss_wgi
CLEAN WATERS		3	3		3	3															1

Pressures (columns in `subcountry2014/conf/pressures_matrix.csv`), are matched with different goals and subgoals (rows) to indicate which pressures will be included when goal scores are calculated. In some cases the goals are further divided into components (e.g. habitats are divided by habitat type, natural products by product type).

The first step in updating the pressures matrix for your regional assessment is to determine if there any pressures that should be excluded from your study? For example, if there is no mariculture in your study area, perhaps there are also no genetic escapes (*sp_genetic* layer).

Next, brainstorm local pressures that are not captured in `pressures_matrix.csv`. Which pressures stand out in your study area? Pressures included in the `pressures_matrix.csv` are ultimately determined by available data, and thus there were pressures that were important but could not be included in the global assessment because of data availability (including altered sediment regimes, noise and light pollution, toxic chemicals from point sources, and nutrient pollution from atmospheric deposition and land-based sources other than fertilizer application to agricultural land). There are likely pressures important to your study area that were not captured in the global pressures matrix.

Table of pressures layers and descriptions

layer	name
cc_acid	Ocean acidification
cc_slr	Sea level rise
cc_sst	Sea surface temperature (SST) anomalies
cc_uv	UV radiation
fp_art_hb	High bycatch caused by artisanal fishing
fp_art_lb	Low bycatch caused by artisanal fishing
fp_com_hb	High bycatch caused by commercial fishing
fp_com_lb	Low bycatch caused by commercial fishing
fp_targetharvest	Targeted harvest of cetaceans and sea turtles
hd_intertidal	Coastal population density as a proxy for intertidal habitat destruction
hd_subtidal_hb	High bycatch artisanal fishing practices as a proxy for subtidal hard bottom habitat destruction
hd_subtidal_sb	High bycatch commercial fishing practices as a proxy for subtidal soft bottom habitat destruction
po_chemicals_3nm	Land-based chemical pollution
po_nutrients_3nm	Coastal nutrient pollution
sp_alien	Alien species
sp_genetic	Introduced species as a proxy for genetic escapes
ss_wgi	Weakness of governance indicated with the WGI

layer	name
po_chemicals	Ocean-based chemical pollution
po_nutrients	Ocean nutrient pollution
po_pathogens	Access to improved sanitation as a proxy for pathogen pollution
po_trash	Trash pollution

Some background on the reasoning behind nutrient and chemical pollution in the global `pressures_matrix.csv`: Nutrient and chemical pollution were calculated from the global cumulative impact maps (spatial data). These data were clipped to each global region's EEZ: 200 km from the coast.

- For some goals, the data clipped to the EEZ affects goals that occur far from shore, so `po_chemicals` applies to goals relevant offshore: FIS, MAR, ECO, and SPP.
- However, some goals are really only relevant nearshore, so we clipped the spatial data again, to 3nm from shore and used this as a separate input. So `po_chemicals_3nm` applies to goals nearshore: AO, CS, CP, TR, ICO, LSP, HAB.

These distinctions don't always apply for smaller-scale assessments. For example, in the US West Coast study (Halpern et al. 2014), only a single `po_chemicals` layer was used: we did not distinguish between offshore and 3nm.

4.8.3 Determine how the pressure affects goals

Next, you will need to:

- Map which goals are affected by a given pressure layer.
- Determine the appropriate rank weighting (how important the pressure is for the delivery of the goal/component).
- Decide in which pressure category the new pressure belongs.

These decisions should depend on expert opinions and previous scientific studies, even if they do not occur in your study area.

The original pressure matrix weights for instance were determined by Halpern *et al.* 2012 (*Nature*) based on scientific literature and expert opinion (3=high, 2=medium, and 1=low pressure; stressors that have no impact drop out rather than being assigned a rank of zero, which would affect the average score). Pressures are ranked rather than being represented as a binary (yes/no) measure because the range of consequence of different pressures on each goal can be quite large, and to classify all those pressures as a simple 'yes' would unduly give too much influence to the weakest stressors. For example, food provision is most heavily impacted by unsustainable, high-bycatch fishing, but pollution does have some impact on fish stocks. Without a weighting system, these stressors would be treated equally in their impact on the food provision goal.

Most likely, the new pressure will fit into one of the existing categories. However, depending on the type of pressures in your study area, it is possible that a new pressure category could be created.

4.8.4 Identify available pressures data

Like the global study, what pressures you are able to include in your regional study will also depend on data availability. Remember that each column in `pressures_matrix.csv` is a data layer, which requires data for each region in your study area. Begin with a list of local pressures that are important, and then refine if data are not available.

In addition to data for the local pressures you identify, it will likely be possible to find better, local data to replace the global template data layers from the pressures matrix. In this case, you will first find local data and then update the pressure data layer as you would with any other data layer. See the 'modifying and creating data layers' section below for how to do this.

4.8.5 Explore local resilience

As with the pressures matrix, begin by exploring the resilience measures included in the global resilience matrix (`subcountry2014/conf/resilience_matrix.csv`). As illustrated below, resilience is also grouped into ecological and social categories, and includes ecological components, goal-specific regulations, and social components.

In the example below, only one regulatory measure is relevant for the clean waters goal, along with one social integrity measure.

		TOTAL RESILIENCE																		
		Ecological Resilience																Social Resilience		
		Regulatory														Ecological Integrity		Social Integrity		
goals and subgoals	component	alien_species	CITES signatories cites	Fishing v1 fishing_v1	Fishing v1 EEZ fishing_v1_eez	Fishing v2 EEZ fishing_v2_eez	Fishing v3 fishing_v3	Fishing v3 EEZ fishing_v3_eez	Habitat habitat	Habitat combo habitat_combo	Habitat combo EEZ habitat_combo_eez	CBD mariculture mariculture	MSI governance msi_gov	CBD tourism tourism	CBD water water	Species diversity species_diversity	Species diversity 3nm species_diversity_3nm	Global Competitive Index li_gci	Sector Evenness li_sector_evenness	World Governance Indicators wgi_all
CLEAN WATERS															1					1

Goal-specific regulations intend to address ecological pressures, and are measured as laws, regulations, and other institutional measures related to a specific goal. Governance is a function of institutional structures that address the intended objective, implementing such governance, and whether stated objectives have been effectively met. Social integrity is intended to describe those processes internal to a community that affect its resilience. It is a function of a wide range of aspects of social structure within a region, and may not be strictly marine related, but can judge how well-governed areas are and therefore how well a region may be able to respond to or prevent environmental challenges.

The first step in updating the resilience matrix for your regional assessment is to determine if there any resilience measures that should be excluded from your study?

Next, brainstorm local resilience measures that are not captured in `resilience_matrix.csv`. What are important regulatory, ecological and social resilience measures in your study area? Resilience measures included in `resilience_matrix.csv` are also determined by available data, and thus it is possible to improve upon the resilience measures when doing an assessment at a spatial scale smaller than the global analysis.

Table of resilience layers and descriptions

layer	name
alien_species	Alien species
cites	Resilience from commitment to CITES
fishing_v1	CBD survey: coastal fishing v1
fishing_v1_eez	CBD survey: ocean fishing v1
fishing_v2_eez	CBD survey: ocean fishing v2

layer	name
fishing_v3	CBD survey: coastal fishing v3
fishing_v3_eez	CBD survey: ocean fishing v3
habitat	CBD survey: habitat
habitat_combo	CBD survey: coastal habitat
habitat_combo_eez	CBD survey: ocean habitat
li_gci	GCI: competitiveness in achieving sustained economic prosperity
li_sector_evenness	Sector evenness as a measure of economic diversity
mariculture	CBD survey: mariculture
msi_gov	MSI sustainability and regulations
species_diversity	Ocean ecological integrity
species_diversity_3nm	Coastal ecological integrity
tourism	CBD survey: tourism
water	CBD survey: water
wgi_all	Strength of governance indicated with the WGI

* *CBD = Centre for Biological Diversity; GCI = Global Competitiveness Index; MSI = Mariculture Sustainability Index; WGI = World Governance Indicators.*

Ecological integrity in the global assessment was measured as the relative condition of assessed species in a given location, and therefore is only relevant to a subset of goals (wild-caught fisheries, artisanal opportunity, natural products, iconic species, and species). Local measures of this component would potentially allow for more goals to be affected.

4.8.6 Identify regulatory resilience measures for any new ecological pressures

As you explore any new local resilience measures to be included, remember that any new pressure in the ecological resilience category with a rank of 2 or 3 will need a corresponding resilience measure.

4.8.7 Determine how the resilience measure affects goals

Next, you will need:

- Map which goals are affected by a given resilience layer.
- Determine the appropriate rank weighting, (how important the resilience is in counteracting a pressure).
- Decide in which resilience category the new pressure belongs.

These decisions should depend on local expert knowledge and previous scientific studies, even if they do not occur in your study area.

4.8.8 Identify available resilience data

Resilience layers are intended to describe the measures that set rules and regulations to address ecological pressures, and are measured as laws and other institutional measures related to a specific goal. Data to address these resilience components should fall into one of three categories:

1. Existence of rules and regulations: Are there institutional structures in place to appropriately address the ecological pressure?
2. Implementation and Enforcement: Have these structures been appropriately implemented and are there enforcement mechanisms in place?
3. Effectiveness and Compliance: How effective has the structure been at mitigating these pressures and is their effective compliance with these structures?

Social measures may not be strictly marine related, but can judge how well-governed areas are and therefore how well a region may be able to respond to or prevent environmental challenges.

4.9 Formatting Data for the Toolbox

4.9.1 Introduction

The Ocean Health Index Toolbox App 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). Data layers (data input) each have their own .csv file that are combined within the Toolbox in model calculations. These data layers are used for calculating goal scores, meaning that they are inputs for status, trend, pressures, and resilience. In the global analysis, there were over 100 data layer files included, and there will be nearly as many in regional applications, no matter what the spatial scale. This document describes and provides examples of how to format data for the Toolbox App.

Ocean Health Index goal scores are calculated at the scale of the reporting unit, which is called a '**region**' and then combined using a weighted average to produce the score for the overall area assessed, called a '**study area**'. The OHI Toolbox App expects each data file 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*. 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).

Example of data in the appropriate format:

4.9.2 Gapfilling

It is important that data prepared for the Toolbox App 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

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	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

rgn_id	product	year	tonnes
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

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 easily enables transparency and reproducibility.

4.9.2.1 Temporal gapfilling Temporal gaps are when some data are available for a region, but there are missing years. The Toolbox requires data for each year for every region. It is important to make an informed decision about how to temporally gapfilling 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.

Many times, creating a linear model is the best way to estimate data and fill temporal gaps. If data do not fit a linear framework, other models may be fit to help with gapfilling. Here we give an example assuming linearity.

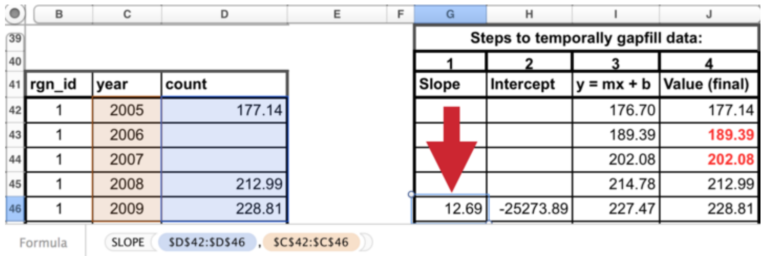
Using a linear model can be done in most programming languages using specific functions, but here we show this step-by-step using functions in Excel for Region 1.

Temporal gapfilling example (assumes linearity):

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).



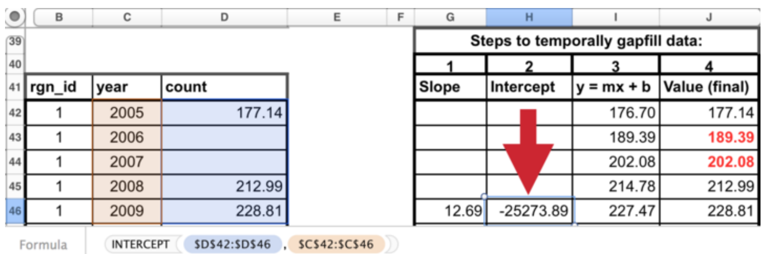
rgn_id	year	count
1	2005	177.14
1	2006	
1	2007	
1	2008	212.99
1	2009	228.81

Steps to temporally gapfill data:			
1	2	3	4
Slope	Intercept	y = mx + b	Value (final)
		176.70	177.14
		189.39	189.39
		202.08	202.08
		214.78	212.99
12.69	-25273.89	227.47	228.81

Formula SLOPE ($D$42:$D$46 , $C$42:$C$46)

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.



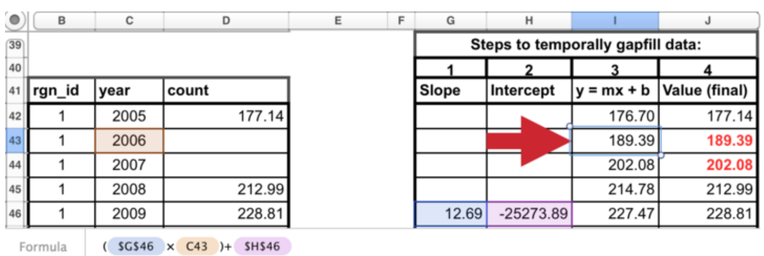
rgn_id	year	count
1	2005	177.14
1	2006	
1	2007	
1	2008	212.99
1	2009	228.81

Steps to temporally gapfill data:			
1	2	3	4
Slope	Intercept	y = mx + b	Value (final)
		176.70	177.14
		189.39	189.39
		202.08	202.08
		214.78	212.99
12.69	-25273.89	227.47	228.81

Formula INTERCEPT ($D$42:$D$46 , $C$42:$C$46)

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 $\mathbf{y = mx + b}$ equation, to calculate the unknown 'count' for a given year (189.39 in 2006, and 202.08 in 2007).



rgn_id	year	count
1	2005	177.14
1	2006	
1	2007	
1	2008	212.99
1	2009	228.81

Steps to temporally gapfill data:			
1	2	3	4
Slope	Intercept	y = mx + b	Value (final)
		176.70	177.14
		189.39	189.39
		202.08	202.08
		214.78	212.99
12.69	-25273.89	227.47	228.81

Formula ($G$46 × C43)+ $H$46

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.

4.9.2.2 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.

To fill gaps spatially, assumptions must be made that one region is like another, and data from another region will 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

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

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

No temporal gapfilling is required in this example.

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 region 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, 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

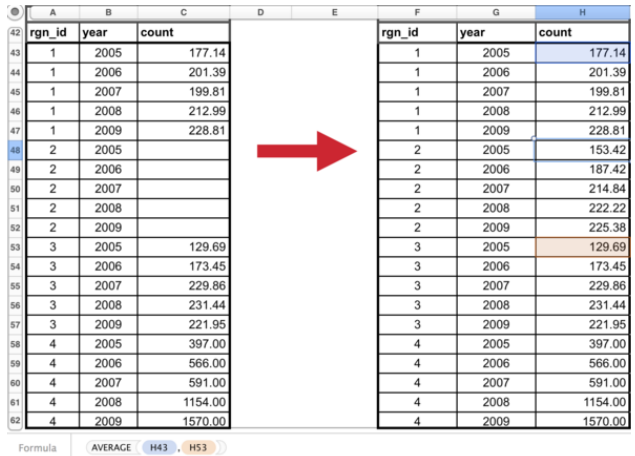
There is no absolute answer of how to best gapfill rgn_id 2. Here are a few reasonable possibilities:

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.

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



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

4.9.3 Long formatting

The Toolbox expects data to be in 'long' or 'narrow' formatting. 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:

		Year									
Region	DataLayer	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	0.8615	1	1
C	governance_indicator						0.8779	1	1	0.8986	1
D	governance_indicator						0.8537	0.5373	0.7044	1	1

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 `reshape` package has the `melt` command, which will melt the data from a wide format into a narrow format. It also can `cast` the data back into a wide format if desired. R documentation:

- http://cran.r-project.org/web/packages/reshape2/reshape2.pdf
- http://www.slideshare.net/jeffreybreen/reshaping-data-in-r
- http://tgmstat.wordpress.com/2013/10/31/reshape-and-aggregate-data-with-the-r-package-reshape2/

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),]
```

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 more easy to read for humans (R and the Toolbox can read these data without this final step):

Example of data in the appropriate format:

GDP_USDx1000.csv

Region	Year	value
A	2000	8
A	2001	7
A	2002	30
A	2003	26
A	2004	69
A	2005	39
A	2006	108
A	2007	92
A	2008	261
A	2009	151
B	2000	13
B	2001	9
B	2002	13
B	2003	14
B	2004	10
B	2005	12
B	2006	14
B	2007	10
B	2008	6
B	2009	5

governance_indicator.csv

Region	Year	value
A	2000	
A	2001	
A	2002	
A	2003	
A	2004	
A	2005	0.854599407
A	2006	0.540059347
A	2007	0.706231454
A	2008	1
A	2009	1
B	2000	
B	2001	
B	2002	
B	2003	
B	2004	
B	2005	0.856410256
B	2006	0.779487179
B	2007	0.861538462
B	2008	1
B	2009	1

With 'narrow' format, each row of data provides complete and unique information, and does so with as few columns as possible. Data layers in this format can be easily combined with other data layers: the range of years available can be different for each data layer, and there are minimal column names.

5 Installing the Toolbox for a Regional Assessment

5.1 Getting started

OHI Toolbox software is written in R, and work with simple *.csv* files to store data and registeries. Template files and scripts are kept together in a folder, a **GitHub repository**, online. GitHub is an open-source development platform that enables easy collaboration and versioning (see: http://en.wikipedia.org/wiki/GitHub).

At this point, you should already be familiar with your repository's filesystem (see Section 4.5 above). To efficiently modify input data files, set parameters and modify goals, you will need to download your repository onto your computer. In GitHub vocabulary, this is called to 'clone' your repository. This will put a complete copy of the repository on your computer, enabling you to work offline.

We recommend establishing a GitHub user account, which will allow you to syncronize your modifications with the online repository. Your website (accessed from ohi-science.org) will also display these modifications visually. Using GitHub faciliates collaboration within your team and also allows us to provide support when you need it. However, it is possible to work independently without GitHub (after the initial download), although you will not be able to synchronize your work with your website, and we cannot offer much support in this case.

5.2 Accessing repositories with GitHub

5.2.1 Overview

We recommend that groups interested in conducting OHI assessments do so using GitHub, which is an online interface for version-control software called *git*. GitHub has powerful versioning capabilities, which allows changes to be archived and tracked by each user. This 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.

Conducting an OHI regional assessment using GitHub will therefore enable collaboration and transparency, and will provide access to the latest developments in the Toolbox software.

It is also possible to conduct a regional assessment without GitHub. We do not recommend this because it is more difficult for you to track progress and decisions, and for us to help or advise you. However, if this is preferable, see the instructions in the 'Accessing repositories without GitHub' section below. You can always switch back to GitHub later on.

In addition to cloning your GitHub repository to your computere, you will need to download and install some free software in order to have syncing capabilities between your local version of the repository and the online version. Syncing will require **git** software and the **GitHub** application. Once installed, you will be able to work with data layers (*.csv* files) using any software program you prefer (Excel, R, Matlab, text editors), and the *GitHub* application will enable you to syncronize your updates to the online repository. We highly recommend processing data (*.csv* files) in a programming language (particularly R), to aid in reproducibility and transparency. When editing goal models, you will need to install **R**, and **RStudio** (optional, but highly recommended). *RStudio* has the added benefit of being able to directly sync with the online GitHub repository, which means you would not have to use the *GitHub* app.

To get started on an OHI assessments using GitHub, follow the steps below.

5.2.2 Create a GitHub account

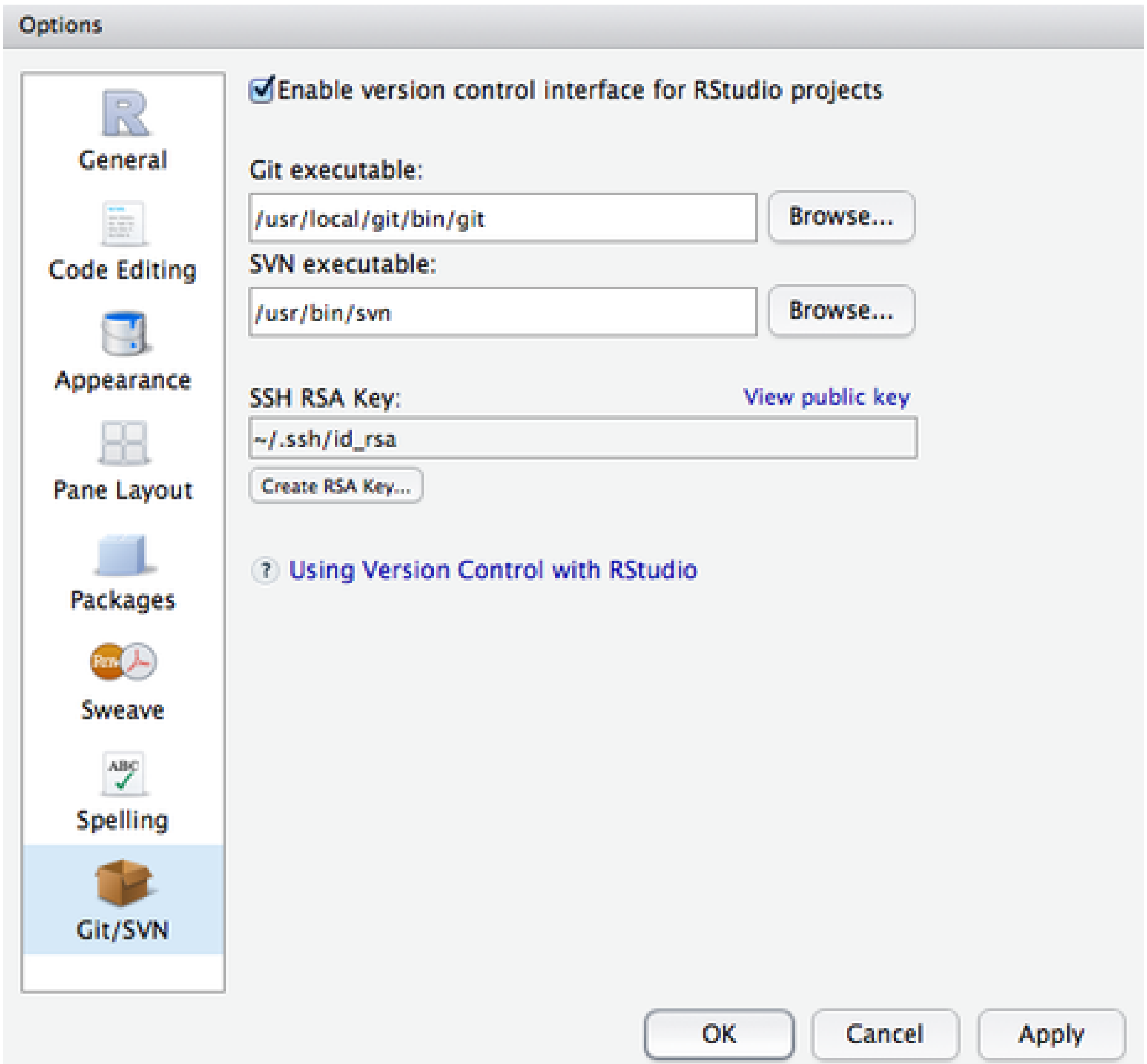
GitHub is an online interface for *git*, and to use it you must create a GitHub account at http://github.com. You will use this username and password when you install *git* and access your GitHub repository (next two steps below).

5.2.3 Install *git* software

git is version-control software that you will need to install on your computer. Note that there are specific settings to select for **Windows** and **Mac**.

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, do the following things in *RStudio* and in *Terminal*:
>
> - *RStudio*
>
> Within RStudio, update your preferences for 'Git executable':


Options
Enable version control interface for RStudio projects
General
Code Editing
Appearance
Pane Layout
Packages
Sweave
Spelling
Git/SVN
Git executable:
/usr/local/git/bin/git
Browse...
SVN executable:
/usr/bin/svn
Browse...
SSH RSA Key:
View public key
~/.ssh/id_rsa
Create RSA Key...
Using Version Control with RStudio
OK
Cancel
Apply

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

- *Terminal*

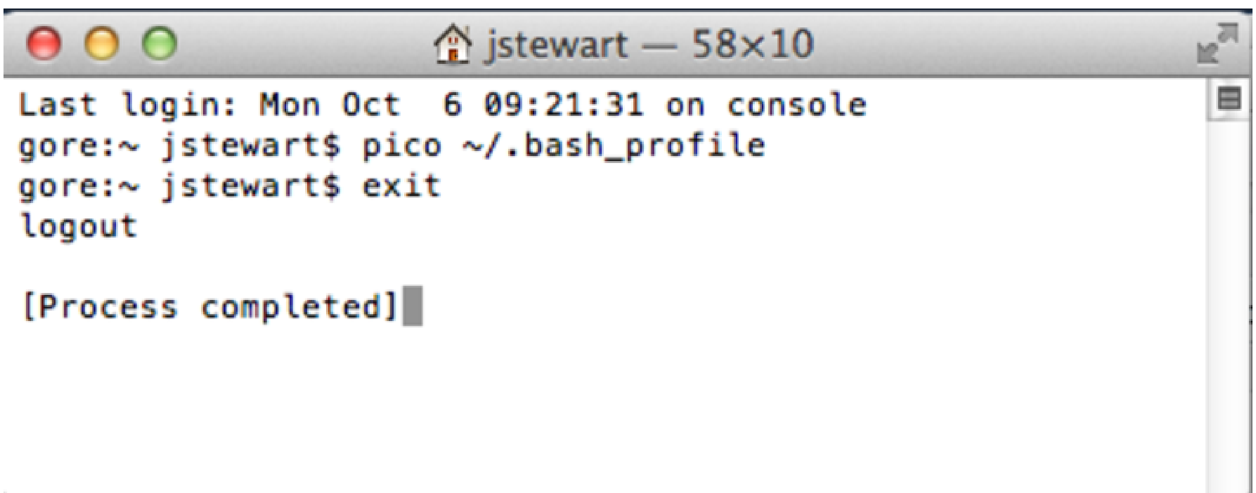
From Terminal, add a line to your 'bash profile' (launch Terminal from Applications > Utilities > Terminal).

First type: `pico ~/.bash_profile`

Add this line:

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

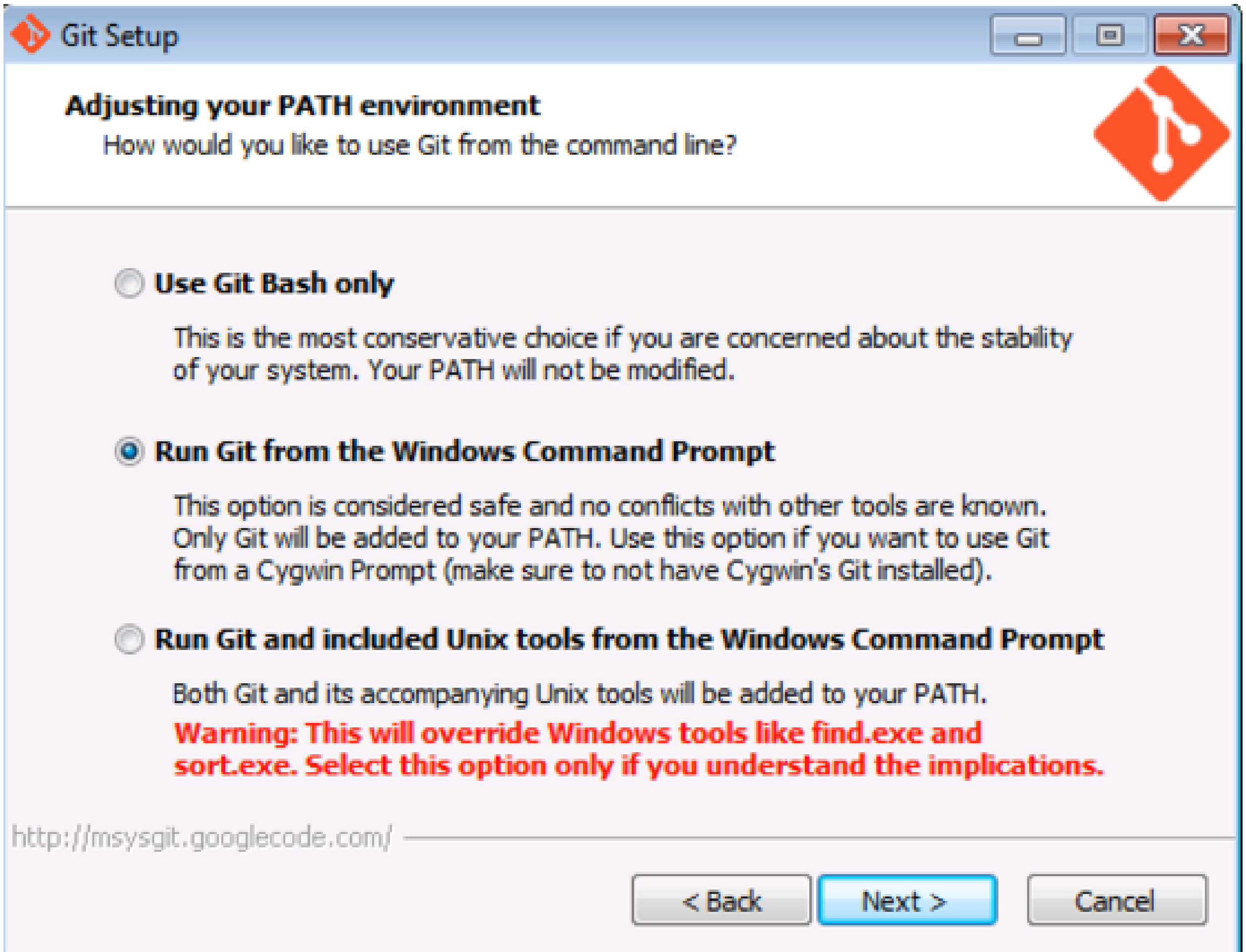
To exit pico, type `control-X`, then `y` and then return. Type `exit` before quitting Terminal.



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 compatibility with RStudio.


Git Setup
Adjusting your PATH environment
How would you like to use Git from the command line?
Use Git Bash only
This is the most conservative choice if you are concerned about the stability of your system. Your PATH will not be modified.
Run Git from the Windows Command Prompt
This option is considered safe and no conflicts with other tools are known. Only Git will be added to your PATH. Use this option if you want to use Git from a Cygwin Prompt (make sure to not have Cygwin's Git installed).
Run Git and included Unix tools from the Windows Command Prompt
Both Git and its accompanying Unix tools will be added to your PATH.
Warning: This will override Windows tools like find.exe and sort.exe. Select this option only if you understand the implications.
http://msysgit.googlecode.com/
< Back
Next >
Cancel

5.2.4 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. You will use the command line:

- **Mac**: launch the Terminal application (Applications > Utilities > Terminal)
- **Windows**: go to command line in Windows (Start > Run > cmd)

You will see cursor where you are able to type (the mouse may not work here). Type the following and press return at each step. Make sure all spaces and symbols are identical to the example below.

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 johndoe@example.com
```

You can check settings with the following:

```
git config --list
```

Quit the Terminal after typing:

```
exit
```

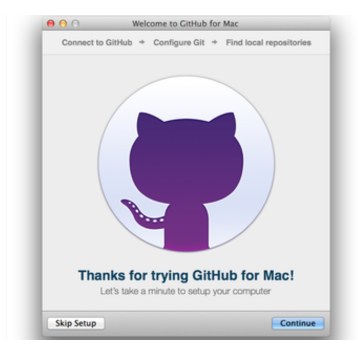
5.2.5 Install the GitHub application

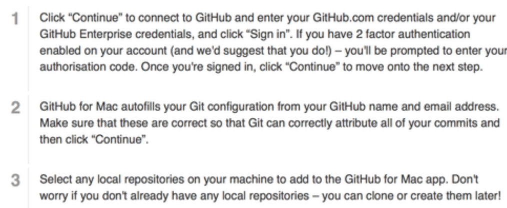
There are several options to clone the repository to your local machine. We recommend using the GitHub application. See [http://github.com] for instructions on how to clone using the command line or RStudio support if you are interested in other options.

GitHub App

(a) For Mac (freely available at https://mac.github.com/):

Once the the GitHub App is installed and opened, the following page will appear:





1 Click "Continue" to connect to GitHub and enter your GitHub.com credentials and/or your GitHub Enterprise credentials, and click "Sign in". If you have 2 factor authentication enabled on your account (and we'd suggest that you do!) – you'll be prompted to enter your authorisation code. Once you're signed in, click "Continue" to move onto the next step.

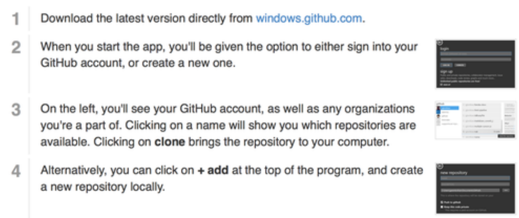
2 GitHub for Mac autofills your Git configuration from your GitHub name and email address. Make sure that these are correct so that Git can correctly attribute all of your commits and then click "Continue".

3 Select any local repositories on your machine to add to the GitHub for Mac app. Don't worry if you don't already have any local repositories – you can clone or create them later!

Follow the instructions for cloning on a Mac (copied from: https://mac.github.com/help.html)

(b) For Windows:

Follow the instructions for cloning on Windows (copied from: https://windows.github.com/help.html)



1 Download the latest version directly from windows.github.com.

2 When you start the app, you'll be given the option to either sign into your GitHub account, or create a new one.

3 On the left, you'll see your GitHub account, as well as any organizations you're a part of. Clicking on a name will show you which repositories are available. Clicking on **clone** brings the repository to your computer.

4 Alternatively, you can click on **+ add** at the top of the program, and create a new repository locally.

5.2.6 Cloning your repository to your computer

Clone a repository by clicking the 'Clone in Desktop' button on your online repository's homepage (https://github.com/ohi-science/{[}assessment{]}):

You will be asked where to save this repository. The placement of the repository is critical for easy collaboration.

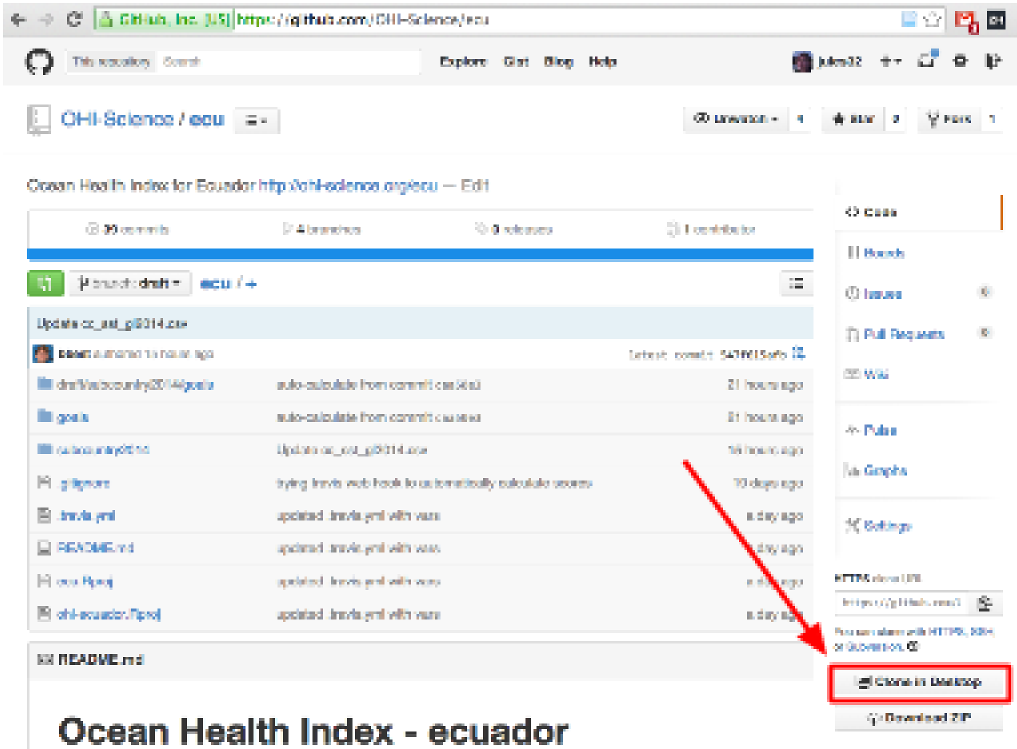
Please create a folder called `github` in your root directory and save the repository there. If teammembers save files in different places, those different filepaths can create a lot of problems when collaborating, particularly between Macs and Windows machines. The directory for an assessment (`~/github/[assessment]`) will therefore be:

- on a Mac: `/Users/[User]/github/[assessment]` (example: `/Users/[User]/github/ecu`)
- on Windows: `C:\Users\[User]\Documents\github\[assessment]` (example: `C:\Users\[User]\Documents\github\`

The entire folder will now be saved on your computer. You are able to explore and modify these files as needed.

5.2.7 Updating permissions

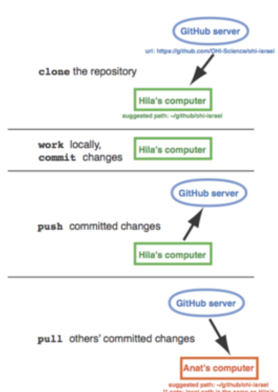
You will need permission to sync any changes you make back to the repository. OHI-Science is the 'owner' of all Ocean Health Index repositories stored on GitHub, and individual users contribute to these repositories when they have permission. To obtain editing privileges, please provide your GitHub username in an email to lowndes@nceas.ucsb.edu. You will need to do this one time only.



5.2.8 Working locally

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 regional 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.

The example below illustrates GitHub's collaborative workflow with the `ohi-israel` repo owned by `OHI-Science`:



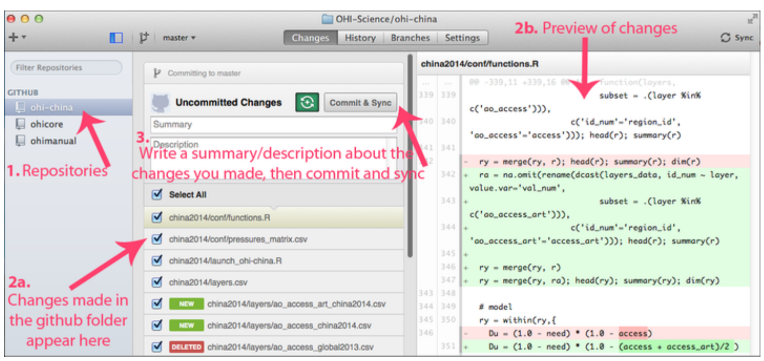
All changes within your local repository will be tracked by GitHub regardless of the software you use to make the changes. This means that you can delete or paste files in the Mac Finder or Windows Explorer and edit *.csv* files in Excel or a text editor, and still sync these changes with the online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

We recommend syncing with either the GitHub app or with RStudio. Both methods require you to commit your changes, before pulling any updates and pushing your modifications. The GitHub app combines the pulling and pushing into one step, called syncing.

5.2.9 Using GitHub App to syncronize your repository

The GitHub App will track your modifications and can be used to commit and sync any changes made locally to your repository. Once you are done working on the pertinent files and wish to commit and sync the changes to the online server on the Github server, open the Github App. The following example is with the ohi-china repository:

1. Make sure you select the correct repository, located on the left column of the github app window.
2. Select the different files to which changes have been made (2a), and preview those changes on the right column of the github app window (2b).
3. Once all the changes have been reviewed, write a summary/description in the respective message bars in the Github App window, then click on commit and sync (Note: If a `Commit` button appears instead of the `Commit & Sync` button, you can either click `Commit` and then click the `Sync` button located on the top-right corner of the githup app window, or you can alternatively click the `+` button next to the `Commit` button, and then click the the `Commit & Sync` button that appears).

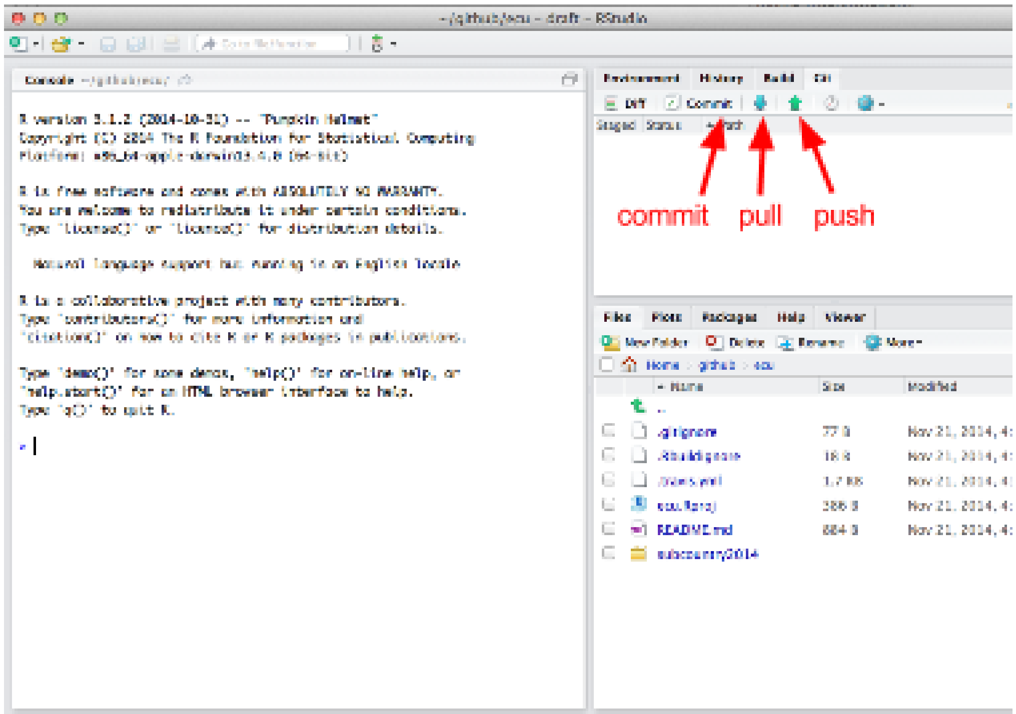


Your changes should now visible on Github online.

5.2.10 Using RStudio to syncronize your repository

RStudio (for installation, see below) can sync files with GitHub directly, and can be used instead of the GitHub app. Like the GitHub app, it will capture the changes made to any files within the repository, no matter which software was used to modify them. The advantage for using RStudio to sync instead of the GitHub app is when you are working with R scripts already. In RStudio, you sync by pulling and pushing separately; in the GitHub app these two are done together.

Launch your project in RStudio by double-clicking the `[assessment].Rproj` file. From RStudio, Commit locally, associating a message with each set of changes.



When you modify or add a file, the file will appear in the 'Git' window. In the example below, the file `test.R` was created.

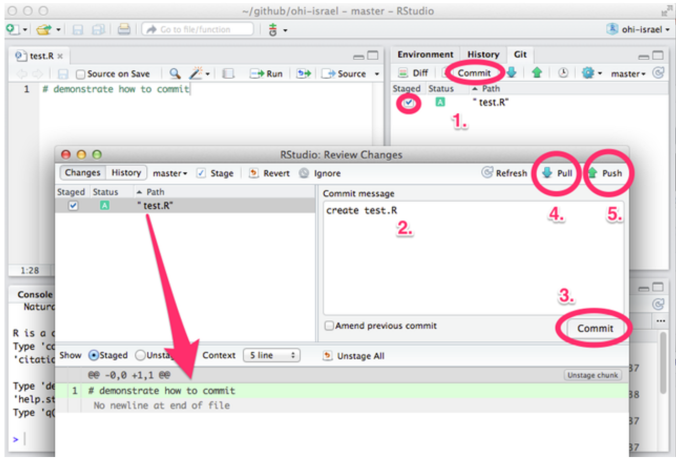
1. Clicking the 'Staged' box and the 'Commit' button opens a new window where you can review changes.
2. Type a commit message that is informative to the changes you've made.

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

5.2.11 Install the latest version of R and RStudio

Make sure you have the most current version of R and RStudio. Download **R** at http://cran.r-project.org/ and install on your computer. If you already have R installed, check the website for updates. There are



frequent updates to the R software, and the current version is identified on the websited. Compare what is available from their wesite with what you already have on your computer by typing `sessionInfo()` into your R console. (This will also identify packages you have installed).

While not required, we highly recommend working with **RStudio**, which is an interface that makes working with R much easier, and it also interfaces with GitHub so you are able to syncronize without using the GitHub app. RStudio does not get updated as often as R does, but it is good to check for updates regularly.

5.3 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. (Details below.)
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 App pulls updates from the data branches (draft and published) every time a new connection is initiated (ie browser refreshes).

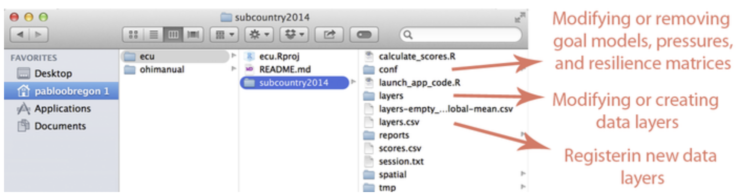
6 Using the Toolbox

As your team finalizes which data should be included in the assessment and develops goal models, you can incorporate this information into your repository. Data files can be updated with any software, but goal models will be updated in R. With any modifications you sync to the online repository, the Toolbox will automatically recalculate goal scores. Calculations can also be done locally by running `subcountry2014/calculate_scores.R`.

This section gives instruction and examples for the most common modifications you will make to your repository:

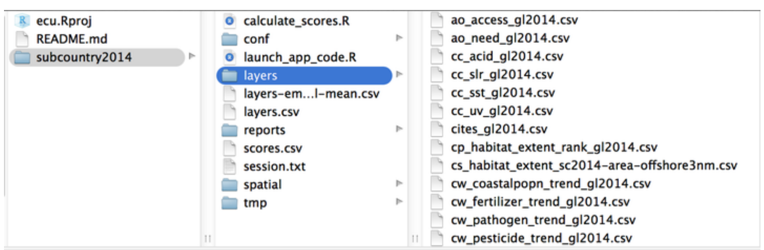
- **modifying pressures and resilience matrices**
- **modifying and creating data layers for status, trend, pressures and resilience**
- **modifying goal models**
- **removing goals**

The files you will modify are identified in the figure below:



6.1 Modifying and creating data layers

Data layers are *.csv* files and are located in the `[assessment]/[scenario]/layers` folder. All template layers provided in your repository are the global values from the 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.
- 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 subcountry region 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 serveral times), national GDP was down-weighted by the proportion of coastal population in each region compared with the total coastal population.

Both types of data layers are at coarse-resolution and should be exhanged for 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 the `[assessment]/[scenario]/conf` folder)

6.1.1 Create data layers with proper formatting

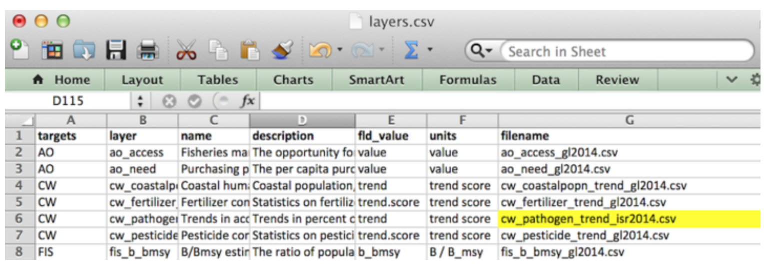
The OHI Toolbox expects each data layer to be in its own *.csv* file and to be in a specific format, with data available for every region within the study area, with data organized in 'long' format (as few columns as possible), and with a unique region identifier (rgn_id) associated with a single score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

6.1.2 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 regional assessment (example: `_israel2014.csv`). Modifying the layer name provides an easy way to track which data layers have been updated regionally, and which rely on global data. Template layers (`_gl2014.csv` and `_sc2014.csv`) can then be deleted.

6.1.3 Register data layers in *layers.csv*

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



	A	B	C	D	E	F	G
1	targets	layer	name	description	fld_value	units	filename
2	AO	ao_access	Fisheries ma	The opportunity fo	value	value	ao_access_gl2014.csv
3	AO	ao_need	Purchasing p	The per capita purc	value	value	ao_need_gl2014.csv
4	CW	cw_coastalp	Coastal hum	Coastal population,	trend	trend score	cw_coastalpopn_trend_gl2014.csv
5	CW	cw_fertilizer_	Fertilizer con	Statistics on fertiliz	trend.score	trend score	cw_fertilizer_trend_gl2014.csv
6	CW	cw_pathoge	Trends in acc	Trends in percent c	trend	trend score	cw_pathogen_trend_isr2014.csv
7	CW	cw_pesticide	Pesticide cor	Statistics on pestici	trend.score	trend score	cw_pesticide_trend_gl2014.csv
8	FIS	fis_b_bmsy	B/Bmsy estir	The ratio of popula	b_bmsy	B / B_msy	fis_b_bmsy_gl2014.csv

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); other columns are generated later by the Toolbox App as it confirms data formatting and content:

- **targets:** Add the 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 used 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 project website.
- **description:** Add a longer description of the new data layer this will be displayed on your project website.
- **fld_value:** Add the appropriate units for the new data layer (which will be referenced in subsequent calculations).
- **units:** Add a description about the *units* chosen in the *fld_value* column above.
- **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*.

6.1.4 Check pressures and resilience matrices

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

6.2 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 into the Toolbox's `pressures_matrix.csv` (located in the `[assessment]/[scenario]/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. But 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.

6.2.1 Create the new pressure layers and save in the `layers` folder

If you will 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*.

Assume that these new layers have scores from 0 to 1, with values for each region in your study area, and have been saved in `layers` folder.

6.2.2 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*.

layers.csv

	A	B	C	D	E	F	G	H
1	targets	layer	name	description	fld_value	units	filename	fld_id_num
60	TR	tr_sustainabili	Sustainability in	Tourism Comp	score	score	tr_sustainability_global2013.cs	rgn_id
61	TR	tr_unemploym	Percent unemployment		percent	percent unemplc	tr_unemployment_global2013.	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 acidificati	Modeled distri	pressure_scor	pressure score	cc_acid_global2013.csv	rgn_id
65	pressures	cc_slr	Sea level rise	Modeled sea le	pressure_scor	pressure score	cc_slr_global2013.csv	rgn_id

6.2.3 Register the new layers in `pressure_matrix.csv`**

`pressures_matrix.csv` maps 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.

6.2.3.1 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.

6.2.3.2 Identify the goals affected and set the weighting This step also requries 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=high pressure, 1=low pressure).

pressures_matrix.csv

	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_chemicals_	po_pathogens	po_nutrients	po_nutrients_	po_trash	hd_subtidal_sl	hd_subtidal_h	hd_intertidal
2	FIS			3	2	1			1			2	2	1
3	MAR			3	2	2				3				
4	AO						1			1		1	3	1
5	NP	corals		1	2	1			2				3	
6	NP	fish_oil		1	2	2			1			2		
7	NP	ornamentals		1	2	2			1				3	
8	NP	seaweeds		1	2	2			2					1
9	NP	shells		1	2				1			2		1
10	NP	sponges		1	2				1			3		
11	CS	mangrove		2	2		1			1				3
12	CS	saltmarsh		2	2		1			2				3
13	CS	seagrass		2	2		2			3				3
14	CP	coral		2	2		1			2			3	
15	CP	mangrove		2	2		1			1				3
16	CP	saltmarsh		2	2		1			2				3
17	CP	seaice_shoreline		2	2									
18	CP	seagrass		2	2		2			3				3
37	LSP						2			2	3		2	3
38	CW						3	3		3	3			
39	HAB	coral		2			1			2			3	
40	HAB	mangrove		2			1			1				3
41	HAB	saltmarsh		2			1			2				3
42	HAB	seaice_edge		2										
43	HAB	seagrass		2			2			3				3
44	HAB	soft_bottom		2			2			2		3		
45	SPP			2		2			3		1	3	2	2

6.2.4 Modify the resilience matrix (if necessary)

Resilience in the Ocean Health Index is 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. See below for instructions and examples about modifying resilience matrices.

6.3 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/pressures the resilience affects and what weight they should have. Then, you can transfer this information into `resilience_matrix.csv` (located in the `[assessment]/[scenario]/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 Ocean Health Index 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_ee	fishing_v2_ee	fishing_v3	fishing_v3_ee	habitat	habitat_combo	habitat_combo	li_gci	li_sector_ever	mariculture	msi_gov	species_diver	species_diver	tourism	water	wgi_all
AO				fishing_v1						habitat_combo							species_diversity_3nm			wgi_all
HAB	coral only	alien_species						fishing_v3_eez			habitat_combo_eez			mariculture		species_diversity		tourism	water	wgi_all
HAB		alien_species									habitat_combo_eez			mariculture		species_diversity		tourism	water	wgi_all
HAB	soft_bottom	alien_species				fishing_v2_eez					habitat_combo_eez			mariculture		species_diversity		tourism	water	wgi_all
HAB	soft_bottom	alien_species			fishing_v1_eez						habitat_combo_eez			mariculture		species_diversity		tourism	water	wgi_all
SPP		alien_species	cites			fishing_v2_eez					habitat_combo_eez			mariculture				tourism	water	wgi_all
CS										habitat_combo									water	wgi_all
CW																			water	wgi_all
FIS						fishing_v2_eez					habitat_combo_eez					species_diversity				wgi_all
MAR														mariculture	msi_gov				water	wgi_all
ECO												li_gci								wgi_all
LIV												li_gci	li_sector_evenness							wgi_all
NP																				
CP										habitat_combo									water	wgi_all
ICO			cites			fishing_v2_eez					habitat_combo_eez					species_diversity			water	wgi_all
LSP									habitat										water	wgi_all
TR																			water	wgi_all

6.3.1 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 several files:

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

6.3.1.1 Template resilience layers

The full list of layers included in the template 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 will apply to certain habitats, but not others. We focus on these to determine how to adapt the HAB resilience calculation for `ohi-israel`. They are:

> `fishing_v1`, `fishing_v1_eez`, `fishing_v2_eez`, `fishing_v3`, `fishing_v3_eez`, `habitat`, `habitat_combo`, `habitat_combo_eez`, `mariculture`, `species_diversity`, `species_diversity_3nm`, `tourism`

6.3.1.2 Determining how to modify these resilience layers

- If the new habitat occurs only along the coast, we should use `tourism` and `species_diversity_3nm`, otherwise, only use `species_diversity`.
  - `sand_dunes` should use `tourism` and `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 `fishing_v...` and `habitat..` layers, these are composite indicators that we call 'combo' layers, obtained from different combinations of the following datasets:

  `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 questionnaire compiled by countries that committed to Rio's Convention on Biodiversity (CBD) to establish their progress towards habitat biodiversity protection
- `MPA_coast` is 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 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 data-sets 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:

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) Are the existing combo layers appropriate or do you need an ad-hoc version for any of the Israel habitats?

- if rocky reef is mainly coastal, and it is fished by both commercial and artisanal methods, then we need a new combo, specifically, we need a 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) Are there local data to be used?

- 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. **NOTE: 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.

6.4 Modifying goal models

In the discussion on data layers above, when an existing layer is still used as before but has a new *filename*, nothing further needs to be done for the Toolbox to incorporate this updated layer. However, if a new layer has been added to the `layers` folder and registered in `layers.csv` (and potentially added to the pressures or resilience matrices), the Toolbox will still not use it unless it is incorporated into a goal model.

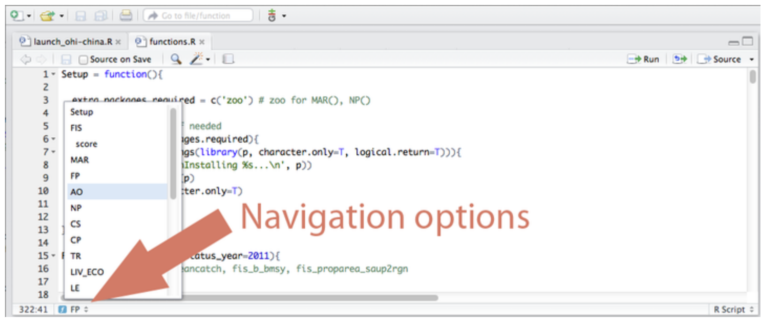
There are several steps to follow when working with goal models:

1. Update `functions.r`
2. Check and possibly update `goals.csv`

6.4.1 Update *functions.r*

To incorporate a new data layer into a goal model, open `functions.R`: 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 incorpoarte the new data layers, noting the use of certain R packages for data manipulation.

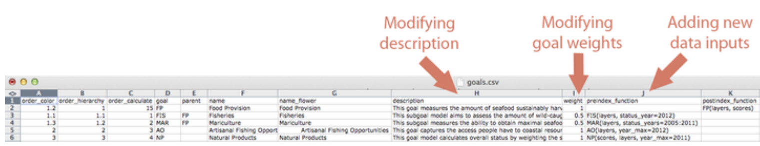
The image below shows the navigation pane in RStudio that can be used to easily navigate between goal models.



6.4.2 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 project website.

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 goal totals. `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).



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

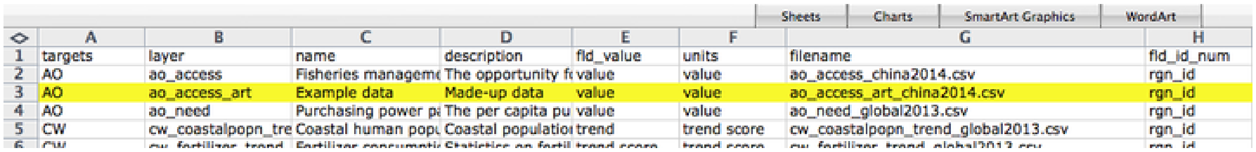
- check the years
- etc…

6.4.3 Example modification:

Suppose in your study area, there are new data to include in the artisanal fishing opportunity goal to refine understanding of this goal. Your team has decided to add an 'artisanal access' component to the goal model because of locally available data. Once this data is 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:

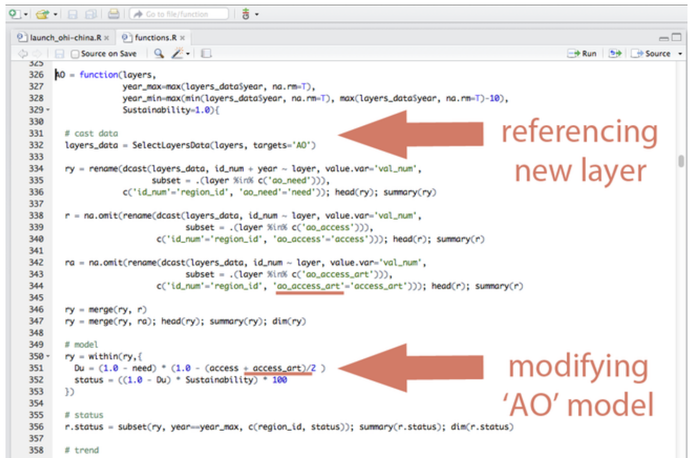
1. register the layer in `layers.csv`
2. update the goal model in `functions.r`
3. update the goal call in `goals.csv`

1. register in `layers.csv`



	A	B	C	D	E	F	G	H
1	targets	layer	name	description	fld_value	units	filename	fld_id_num
2	AO	ao_access	Fisheries manageme	The opportunity fo	value	value	ao_access_china2014.csv	rgn_id
3	AO	ao_access_art	Example data	Made-up data	value	value	ao_access_art_china2014.csv	rgn_id
4	AO	ao_need	Purchasing power pa	The per capita pu	value	value	ao_need_global2013.csv	rgn_id
5	CW	cw_coastalpopn_tre	Coastal human popu	Coastal populatio	trend	trend score	cw_coastalpopn_trend_global2013.csv	rgn_id

2. update goal model



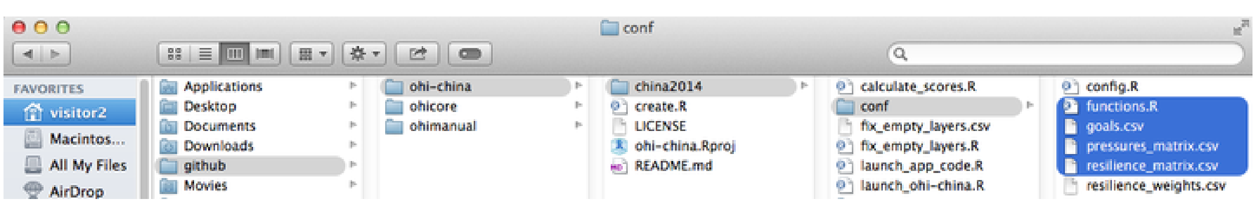
3. update goal call in goals.csv

[develop]

6.5 Removing goals

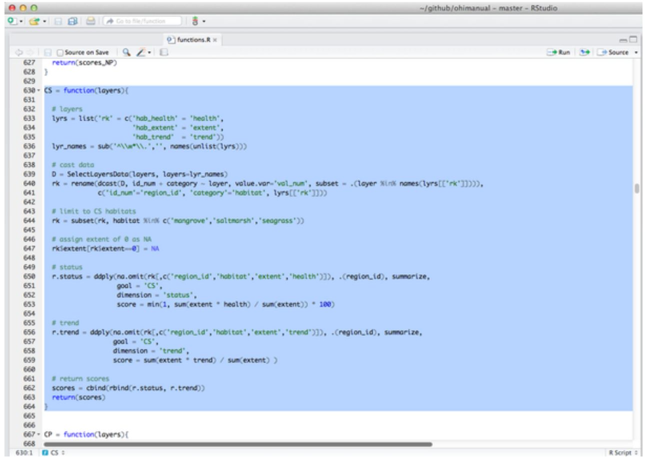
If a goal is not relevant in your region, it is possible to remove the goal completely from the calculation. There are four places where you will need to remove the reference to this goal. Failing to delete all referenced layers after the goal is deleted will result in errors.

1. `functions.r`
2. `goals.csv`
3. `pressures_matrix.csv`
4. `resilience_matrix.csv`



Example: Removing carbon storage (CS) goal

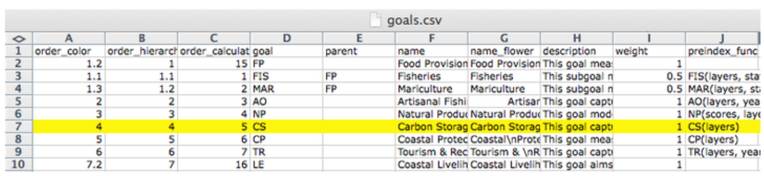
To completely remove the carbon storage goal from Index calculations, you will do the following.



```r
  return(scores_NP)
}

CS = function(layers){

  # layers
  lyrs = list('rk' = c('hab_health' = 'health',
                       'hab_extent' = 'extent',
                       'hab_trend'  = 'trend'))
  lyr_names = sub('^\\w*\\.','', names(unlist(lyrs)))

  # cast data
  D = SelectLayersData(layers, layers=lyr_names)
  rk = rename(dcast(D, id_num + category ~ layer, value.var='val_num', subset = .(layer %in% names(lyrs[['rk']]))),
              c('id_num'='region_id', 'category'='habitat', lyrs[['rk']]))

  # limit to CS habitats
  rk = subset(rk, habitat %in% c('mangrove','saltmarsh','seagrass'))

  # assign extent of 0 as NA
  rk$extent[rk$extent==0] = NA

  # status
  r.status = ddply(na.omit(rk[,c('region_id','habitat','extent','health')]), .(region_id), summarize,
                   goal = 'CS',
                   dimension = 'status',
                   score = min(1, sum(extent * health) / sum(extent)) * 100)

  # trend
  r.trend = ddply(na.omit(rk[,c('region_id','habitat','extent','trend')]), .(region_id), summarize,
                  goal = 'CS',
                  dimension = 'trend',
                  score = sum(extent * trend) / sum(extent) )

  # return scores
  scores = cbind(rbind(r.status, r.trend))
  return(scores)
}


CP = function(layers){
```

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.

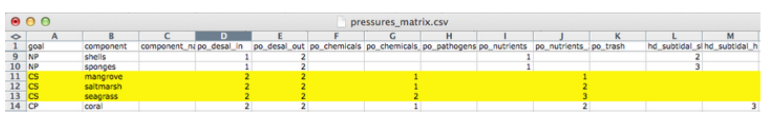
2) Remove the CS row from `goals.csv`. Delete the highlighted row in the figure below that contains the CS goal.



goals.csv

	A	B	C	D	E	F	G	H	I	J
1	order_color	order_hierarch	order_calculat	goal	parent	name	name_flower	description	weight	preindex_func
2	1.2	1	15	FP		Food Provision	Food Provision	This goal mea:	1	
3	1.1	1.1	1	FIS	FP	Fisheries	Fisheries	This subgoal n	0.5	FIS(layers, sta
4	1.3	1.2	2	MAR	FP	Mariculture	Mariculture	This subgoal n	0.5	MAR(layers, st
5	2	2	3	AO		Artisanal Fishi	Artisar	This goal capt	1	AO(layers, yea
6	3	3	4	NP		Natural Produc	Natural Produc	This goal mod	1	NP(scores, laye
7	4	4	5	CS		Carbon Storag	Carbon Storag	This goal capt	1	CS(layers)
8	5	5	6	CP		Coastal Protec	Coastal\nProte	This goal mea:	1	CP(layers)
9	6	6	7	TR		Tourism & Rec	Tourism & \nR	This goal capt	1	TR(layers, year
10	7.2	7	16	LE		Coastal Livelih	Coastal Livelih	This goal aims	1	

3) Remove all CS rows from `pressures_matrix.csv`. Delete the highlighted rows in the figure below that contain CS pressures.



pressures_matrix.csv

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	goal	component	component_na	po_desal_in	po_desal_out	po_chemicals	po_chemicals_	po_pathogens	po_nutrients	po_nutrients_	po_trash	hd_subtidal_s	hd_subtidal_h
9	NP	shells		1	2				1			2	
10	NP	sponges		1	2				1			3	
11	CS	mangrove		2	2		1			1			
12	CS	saltmarsh		2	2		1			2			
13	CS	seagrass		2	2		2			3			
14	CP	coral		2	2		1			2			3

4) Remove all CS rows from `resilience_matrix.csv`. Delete the highlighted rows in the figure below that contain CS resilience.

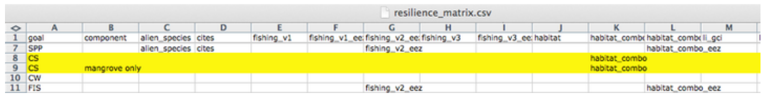
6.6 Other example modifications

6.6.1 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_proparea_saup2rgn`
- `fp_wildcaught_weight`



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_ee	fishing_v2_ee	fishing_v3	fishing_v3_ee	habitat	habitat_combo	habitat_combo	li_gci
7	SPP		alien_species	cites			fishing_v2_eez					habitat_combo_eez	
8	CS										habitat_combo		
9	CS	mangrove only									habitat_combo		
10	CW												
11	FIS						fishing_v2_eez					habitat_combo_eez	

6.6.1.1 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
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 stastus 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).

6.6.1.2 Running CMSY model Sample data to run CMSY:

id	stock_id	res	ct	yr
6	Acanthistius brasilianus_41	Medium	100	1950
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):

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

stock_id	yr	b_bmsyLower	b_bmsyiq25	b_bmsyiq75	b_bmsyGM	b_bmsyMed
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: reccomended), 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)
      }
    }
  }
```

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 prefereces, market price dynamics, etc.), the model may be too pessimistic and understimate 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').

6.6.1.3 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

6.7 Notes about R

The Toolbox is written in R, and relies heavily on a few R packages created to faciliate data handling and manipulation. The primary R package used is called `dplyr` by Hadley Wickham. The `dplyr` package allows for 'chaining' between functions, which is represented with a `%>%`. See: https://github.com/hadley/dplyr#dplyr for documentation.

7 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).

7.1 Overall

7.2 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: 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.

7.3 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: This depends on many things: 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.

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

7.4 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.

7.5 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.

7.6 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 and 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.

7.7 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: 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.

7.8 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, mariculature, 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.

7.9 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.

7.10 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.

7.11 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.

7.12 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.

7.13 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?

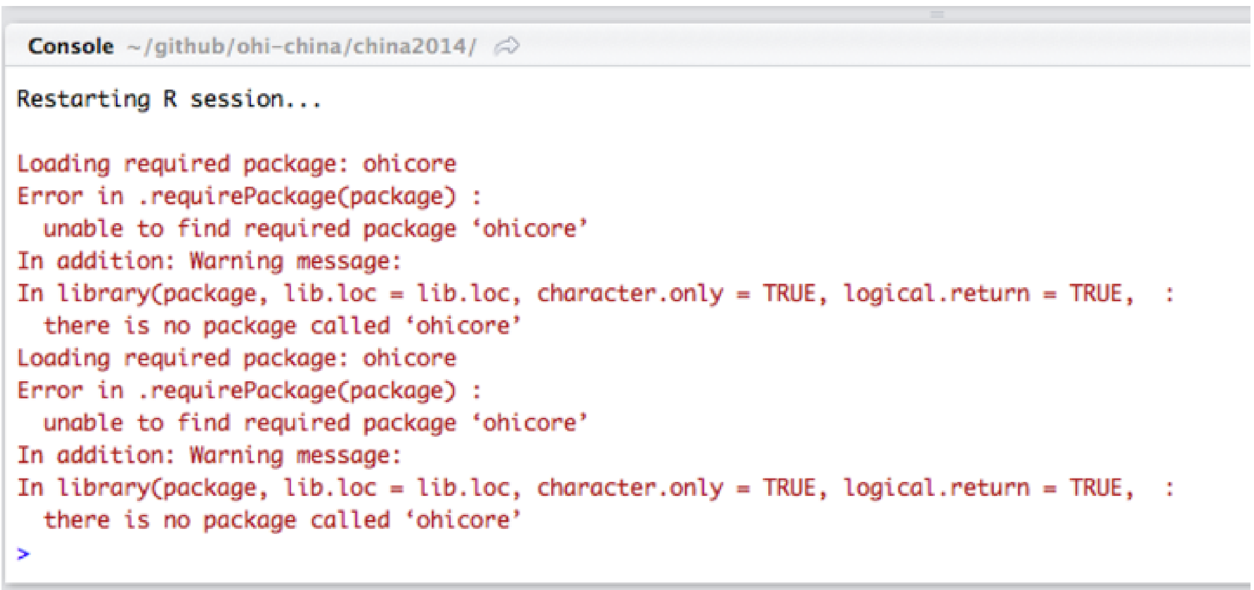
A: Commercial high and low bycatch are categorical values that were set based on fishing gear type. This began as a list of gear types used, producing a range of potential bycatch frequencies (from local reports when possible), which can be rescaled.

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 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:



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

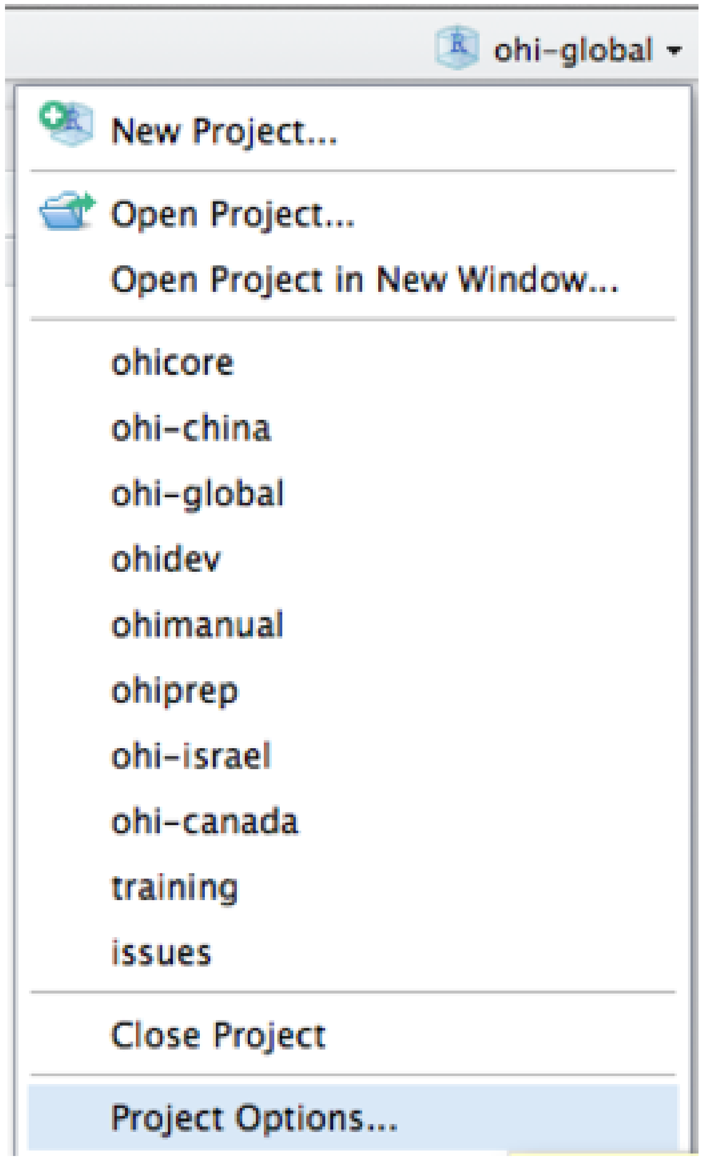
1. Go to Project Options, either in the pull-down menu or by double-clicking the .Rproj file:

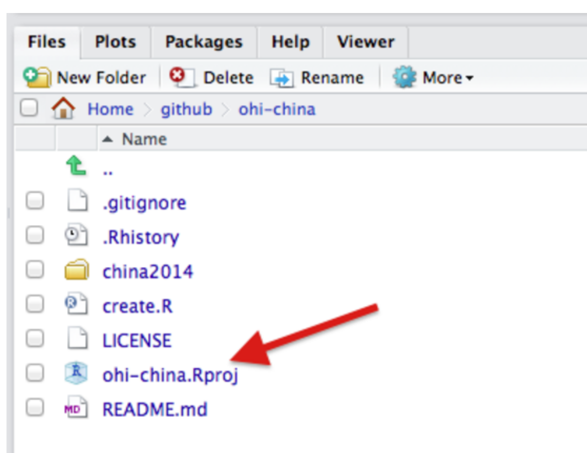
2. Change all options to **No:**

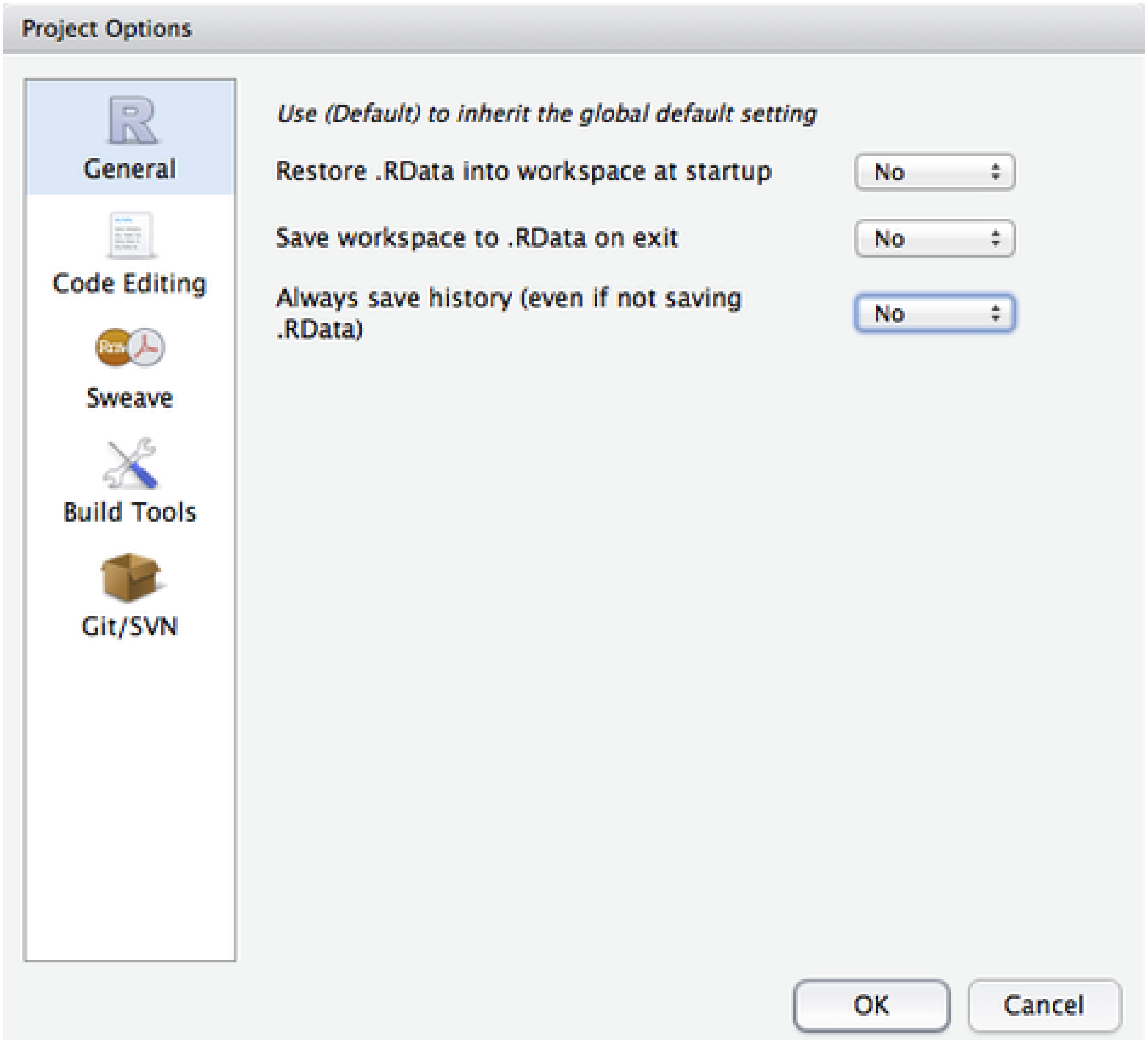
8.2 Calculating Pressures...

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

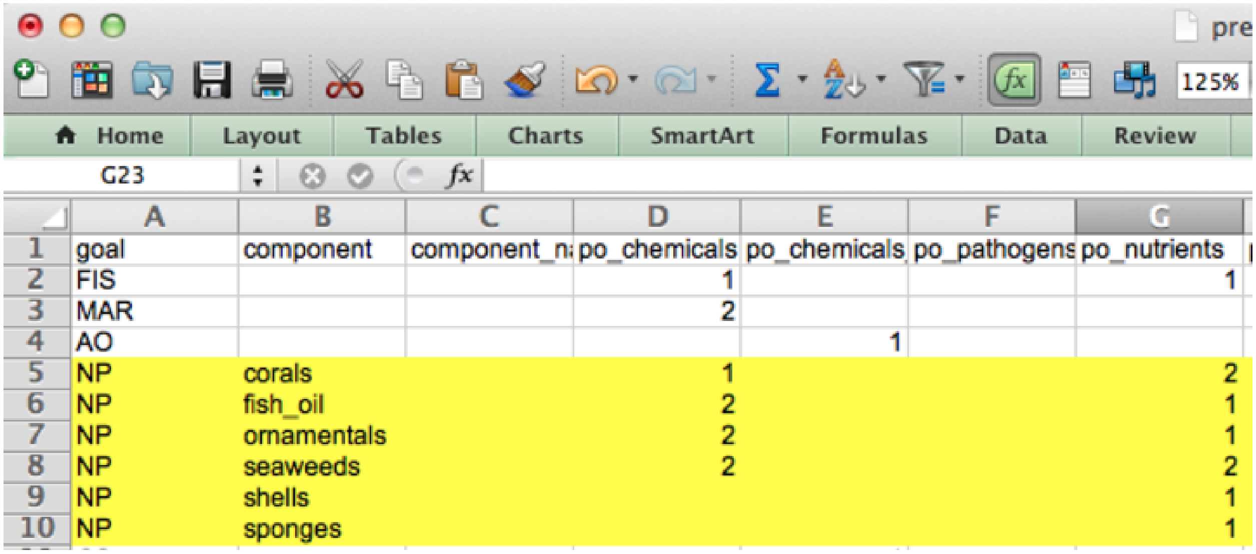
Example:


ohi-global
New Project...
Open Project...
Open Project in New Window...
ohicore
ohi-china
ohi-global
ohidev
ohimanual
ohiprep
ohi-israel
ohi-canada
training
issues
Close Project
Project Options...


Files
Plots
Packages
Help
Viewer
New Folder
Delete
Rename
More
Home
github
ohi-china
Name
..
.gitignore
.Rhistory
china2014
create.R
LICENSE
ohi-china.Rproj
README.md




```
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
```

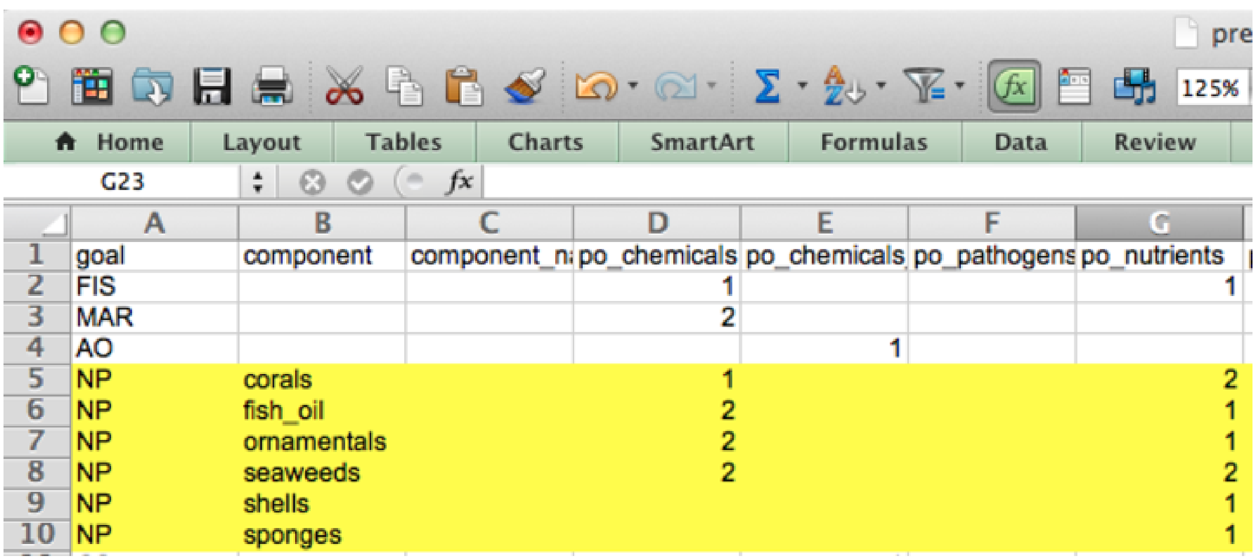


	A	B	C	D	E	F	G
1	goal	component	component_n	po_chemicals	po_chemicals	po_pathogens	po_nutrients
2	FIS			1			1
3	MAR			2			
4	AO				1		
5	NP	corals		1			2
6	NP	fish_oil		2			1
7	NP	ornamentals		2			1
8	NP	seaweeds		2			2
9	NP	shells					1
10	NP	sponges					1

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

8.2.2 'Error in matrix. . . '

Example: >

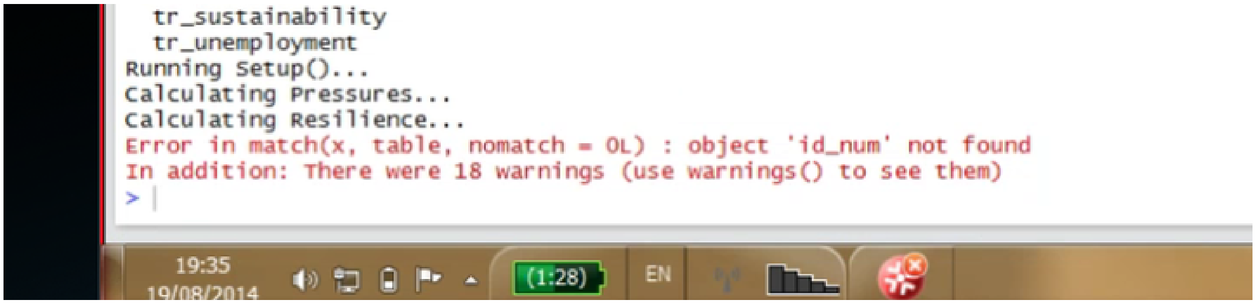


	A	B	C	D	E	F	G
1	goal	component	component_n	po_chemicals	po_chemicals	po_pathogens	po_nutrients
2	FIS			1			1
3	MAR			2			
4	AO				1		
5	NP	corals		1			2
6	NP	fish_oil		2			1
7	NP	ornamentals		2			1
8	NP	seaweeds		2			2
9	NP	shells					1
10	NP	sponges					1

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

8.3 Calculating Resilience . . .

8.3.1 '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`.