FHAST Run Instructions

How to run the Fish Habitat Assessment and Simulation Tool

Contents

1 Introduction **3**
2 Installation **3**
2.1 Pre Requirements 3
2.2 Installation Procedures 3
3 Graphical User Interface (GUI) **5**
3.1 Overview 5
3.2 General layout 6
3.3 General Concept 6
3.3.1 An Example 7
3.4 Input Files 8
3.5 The Plugins 9
3.5.1 FHAST Template Maker 10
3.5.2 FHAST Template and File Maker 10
3.5.3 FHAST File Loader 11
3.5.4 Add New Column 12
3.5.5 Run FHAST Simulation 12
4 Input Files **12**
4.1 Overview 12
4.2 Files 13
4.2.1 Cover File 13
4.2.1.1 Making/Editing The Cover File 14
4.2.2 Default Cover file Formatting 18
4.2.2.1 Land cover 18
4.2.3 Wildcard File 22
4.2.3.1 Making/Editing The Wildcard File 22
4.2.4 Canopy File 22
4.2.4.1 Making/Editing The Canopy File 23
4.2.5 Environmental Input File 23
4.2.5.1 Making/Editing The Environmental Input File 25
4.2.6 Fish Parameters Input File 25
4.2.6.1 Making/Editing The Fish Parameter Input File 26
4.2.7 Fish Population Input File 27
4.2.7.1 Making/Editing The Fish Population Input File 27
4.2.8 Predator Parameters Input File 27
4.2.8.1 Making/Editing The Predator Parameter Input File 28
4.2.9 Area of Interest Shapefile 28
4.2.9.1 Making/Editing The Area of Interest Input File 28
4.2.10 Grid Centerline and Top Point Shapefile 28
4.2.10.1 Making/Editing The Predator Parameter Input File 29

4.2.11 Habitat Input File 29
4.2.11.1 Making/Editing The Habitat Input File 30
4.2.12 Interactions Input File 30
4.2.12.1 Making/Editing The Interactions Input File 31
4.2.13 Tree Growth Parameter Input File 31
4.2.13.1 Making/Editing The Interactions Input File 32
4.2.14 Depth and Velocity Input Rasters 32
4.2.14.1 Making/Editing The Interactions Input File 32
5 Results 32
5.1 Overview 32
5.2 Tabular Data 32
5.3 GIS Data 35
5.4 Reports 36
6 New Run Setup 37
7 New System Setup 37
8 Complex Run Setup 38
9 Troubleshooting 38

1 Introduction

This Document outlines the installation and running of the Fish Habitat Assessment and Simulation Tool (FHAST). It covers installation, running FHAST with the graphical user interface (GUI), input file structure, editing the input files, and the structure of the output files and reports.

In this document:

file_names will be italicized
folder_names and **paths** will be bolded

2 Installation

2.1 Pre Requirements

FHAST is shipped with a self contained version of Java, NetLogo, R, and QGIS. It should not require any other software. Your computer must have sufficient hardware to run QGIS 3.

2.2 Installation Procedures

FHAST is distributed in a zip file. Once unzipped the user should see one folder: **FHAST**. The **FHAST** folder contains the FHAST program, a portable version or R with the necessary libraries, a version of NetLogo, and QGIS.

Move the entire FHAST folder to a desired location on your computer. The higher in the file structure it is, the less likely path errors caused by security restrictions will occur. Therefore, we recommend copying it to the root directory (this is the **C** directory by default on most Windows machines).

Copy the folder path where you decide to place the **FHAST** folder. If you used your root directory and that directory's label is **C** (we will assume this for the purposes of these instructions) then the path should look like **C:\FHAST**.

Next create a shortcut to a command prompt (Fig. 1). The easiest way to do this is to left click on the Windows start icon, type "cmd," right click on the "Command Prompt" app shortcut that appears, select "Open file location", right click on *Command Prompt*, and select "Create shortcut." These actions should create a new *Command Prompt* next to the old one. Move that new shortcut to wherever you want to launch FHAST from (for the purposes of this documentation we will use **C:\Users\user\Desktop**).

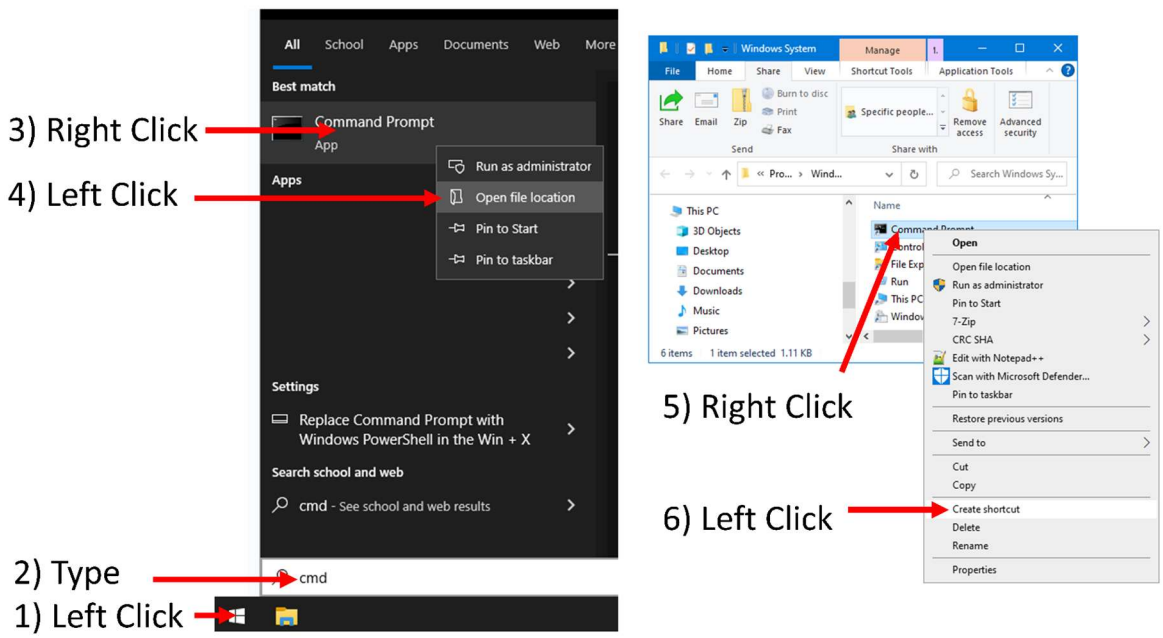

Figure 1. Steps to make a new command prompt shortcut. Follow steps 1 through 6.

Next, set the shortcut to run FHAST (Fig. 2). Right click on that new shortcut you just created and select properties. In the "Start in:" box, put the location of the **FHAST\bin** folder (**C:\FHAST\bin** in our example case). In the target box, add the following to the end of the command that already there:

/c qgis-ltr --customizationfile ..\customize.ini --profiles-path ..\profile

There needs to be a space in between the end of the previous command and this addition. This command is also written inside a text file inside the **FHAST** folder called *run_command.txt*.

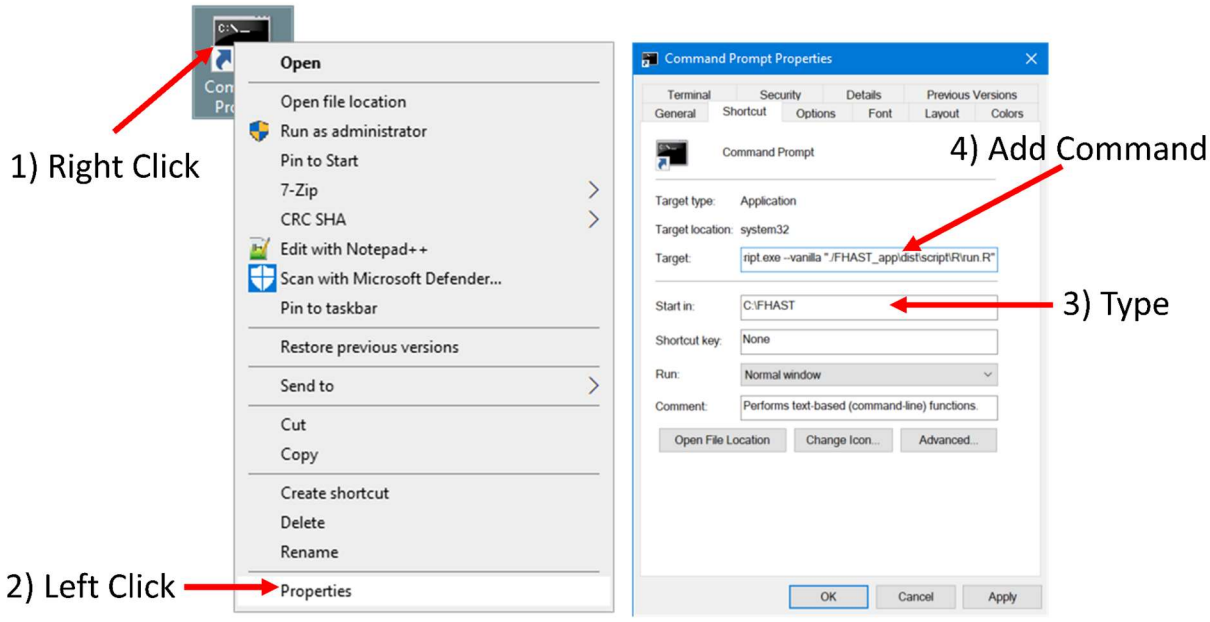

Figure 2. The steps to set up the shortcut to run FHAST. Follow steps 1 through 4.

OPTIONAL: Rename the shortcut “FHAST.” Right click on the FHAST shortcut and select “Rename.” Type “FHAST” as the new name.

OPTIONAL: Change the command prompt shortcut to a FHAST icon. Open the command prompt shortcut properties menu like in the previous step. Select “Change Icon.” select FHAST icon in the **FHAST** folder called *FHAST_icon.ico*.

OPTIONAL: Pin the FHAST shortcut to the start menu. Right click on the FHAST shortcut and select “Pin to start menu”.

If you click on the FHAST shortcut the program should start.

3 Graphical User Interface (GUI)

3.1 Overview

The GUI is a minimal version of QGIS 3.16 with installed plugins which allow you to run FHAST. We will give a brief overview of the GUI interface but will mostly focus on the FHAST specific components. For a detailed description of the capabilities of QGIS please consult their user manuals.

3.2 General layout

The basic layout the the GUI main screen has 7 sections:

1) The map view will show open spatial layers and is where you can edit those layers.
2) The layers panel section will show loaded layers (both spatial and nonspatial).
3) The browser panel will show the file structure of your computer.
4) The add layer toolbar is one of the methods for loading layers.
5) The other toolbars are toolbars for moving the map view, accessing information about layers, visualizing rasters, and editing layers.
6) The FHAST plugin toolbar has the five FHAST specific plugins and one accessory editing plugin.
7) The menu bar where there is another option for accessing the FHAST plugins and other general menu options.

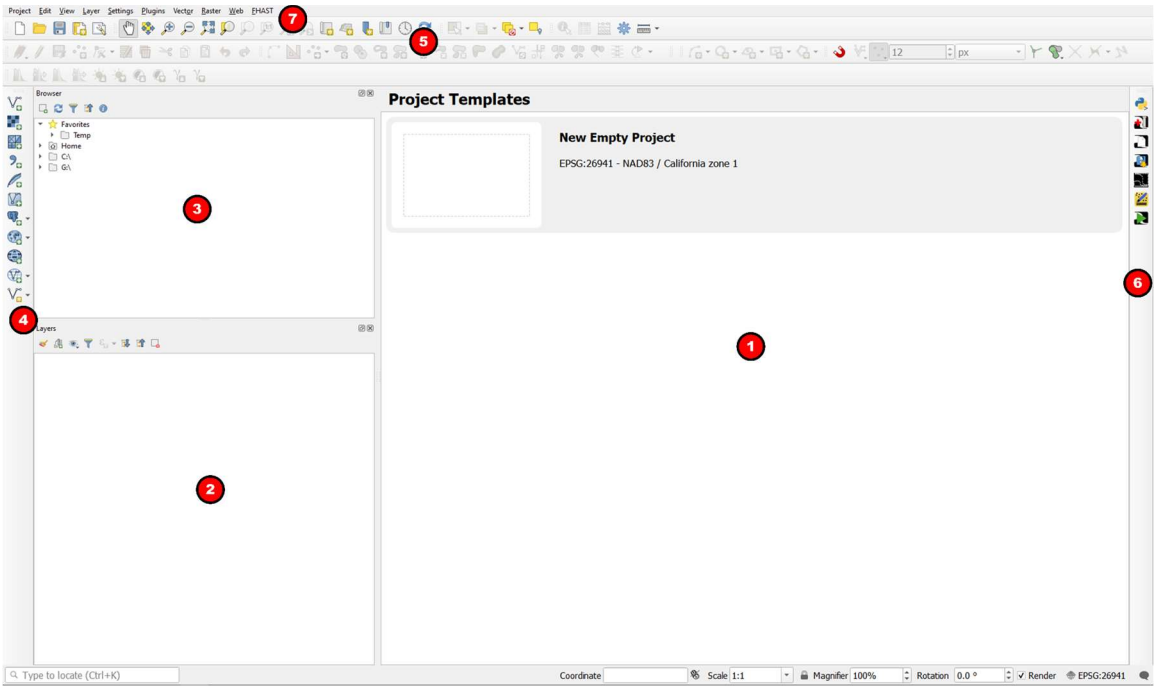

Figure 3. The basic layout of the QGIS based GUI. Descriptions of each numbered panel is in the text.

3.3 General Concept

The concept behind this interface is that QGIS projects are now FHAST projects. This means that if you load in all the necessary files into this interface you can save it as a QGIS project which will functionally be the same as saving a FHAST project. Keep in mind that QGIS projects do not contain the files in themselves but rather point to the files on your system. This means if you edit an input file in one FHAST project and that input file is used by another FHAST project, that second project will also be changed. You can load layers into QGIS in any of the standard ways with one exception. For CSV files, if you attempt to load them through the QGIS “Add

delimited text layer…” option they will not be editable. Thus you should load them by using one of the FHAST plugins or drag and drop them into the project for you computer file explorer.

3.3.1 An Example

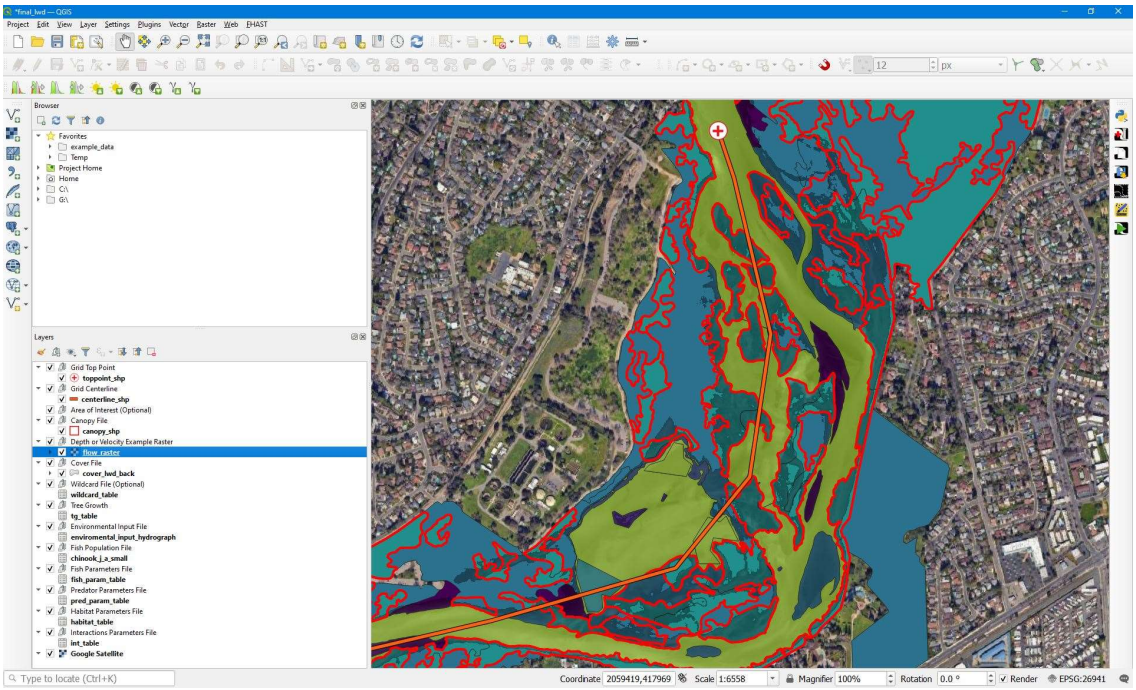

Figure 4. An example FHAST run loaded into the GUI.

FHAST will take all the input files loaded into the QGIS project and input them into the correct file structure for a FHAST run. It places each file in the FHAST file structure according to what group the file is loaded under in the layers panel. Thus before starting a FHAST simulation make sure all necessary files are loaded and are in the correct groups (Fig 5).

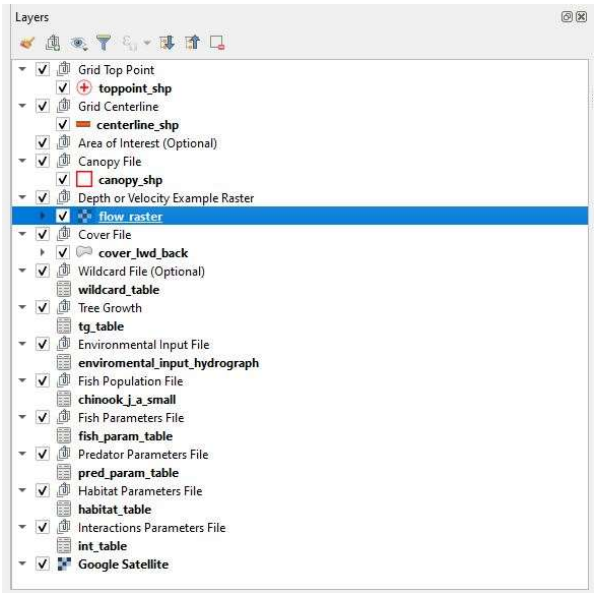

Figure 5. An example of the file structure for a FHAST run. Note each group (other than the optional AOI group) has one and only one file.

3.4 Input Files

The 13 required files include:

1. Notes FIle - a text file with user supplied notes about the run.
2. Depth and Velocity Raster Directory - raster folder which contains the depth and velocity rasters for various flows.
3. Daily Conditions - a daily conditions file that sets the daily flow, temperature, and turbidity.
4. Fish Population - a fish population file that gives the fish type, lifestage, and date of entry.
5. Fish Parameters - a fish parameters file that sets parameter values for the physiological and behavioral relationships for each fish species.
6. Grid Center Line - a grid centerline that marks the center of the grid.
7. Grid Top Point - a grid top point that marks what end of the grid centerline is upriver.
8. Interactions - an interactions file which has parameters that govern the interactions between the fish and the habitat.
9. Cover File - a cover shape file that has the fraction of wood, vegetation, fine sediment, gravel, cobble, and bedrock in each shape.
10. Canopy Cover File - a canopy file that has the height of each shape and an optional species designation.
11. Habitat Parameters - a habitat parameter file which has attributes of the habitat.
12. Predation Parameters - a predator CSV file which has the physiological and behavioral parameters for the predator species.
13. Tree Growth - a tree growth file which has the parameters for the tree growth equations by species as well as a default set of parameters.

The optional files include:

1. Optional Area of Interest - an area of interest (AOI) shapefile that marks the area over which habitat summary statistics should be calculated.
2. Optional Wildcard CSV - an optional wildcard file that lists the cover attributes to be used for any wildcard designated shape in the cover shape file.

The user can also supply a run name that is used in reports and in naming the output folder.

In adaptation to these files the user can add notes about the run to the “Abstract” section of the metadata. These notes will be copied over to the auto generated reports.

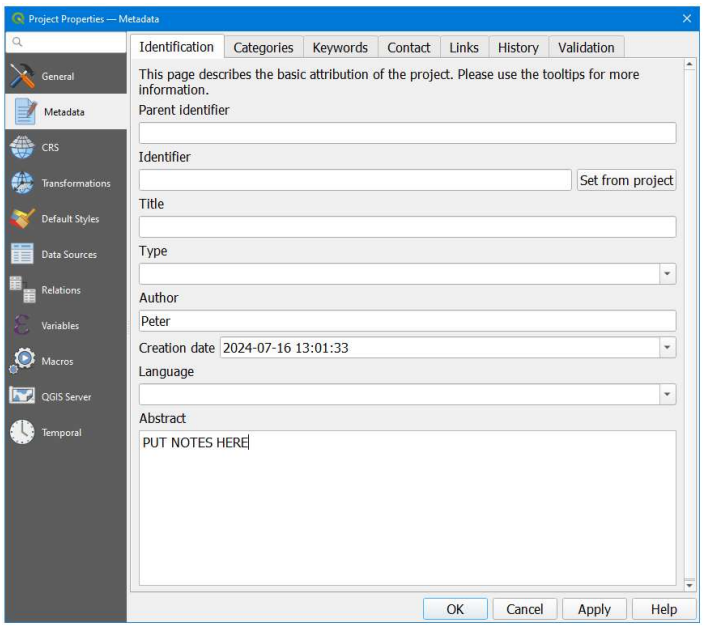

Figure 6. The location for placing notes for the FHAST run.

3.5 The Plugins

There are five FHAST specific Plugins (Fig. 7). They are:

1) Add New Column
2) FHAST Templet and File Maker
3) FHAST File Loader
4) FHAST Templet Maker
5) Run FHAST Simulation

Figure 7. The FHAST plugins as displayed on the side tool bar. Descriptions are in the text.

3.5.1 FHAST Template Maker

The FHAST Templet Maker is the most basic of the FHAST plugins. It simply makes the groups in your current FHAST project. You will need to load in the files by another method to construct the FHAST run.

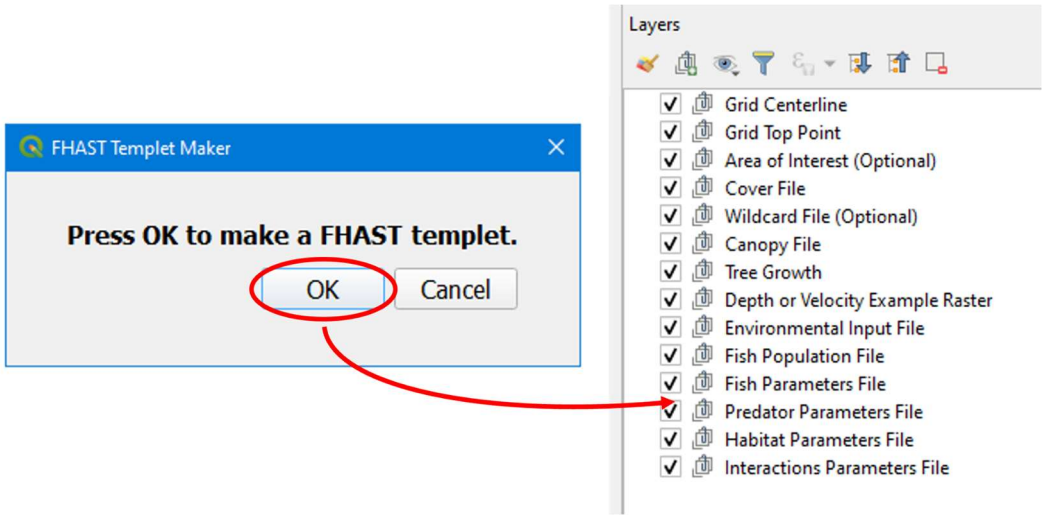

Figure 8. Once you select OK in the FHAST Templet Maker, it will populate the layers panel with the groups.

3.5.2 FHAST Template and File Maker

The FHAST Templet and File Maker performs a similar function as the FHAST Templet Maker except it also produces dummy files which are formatted correctly for each type of FHAST input file. Because it is saving files, you will need to select a folder to save them to, and, because some of them are spatial, you will need to select a CRS from the dropdown menu or click on the projection icon ( ) to see the full list.

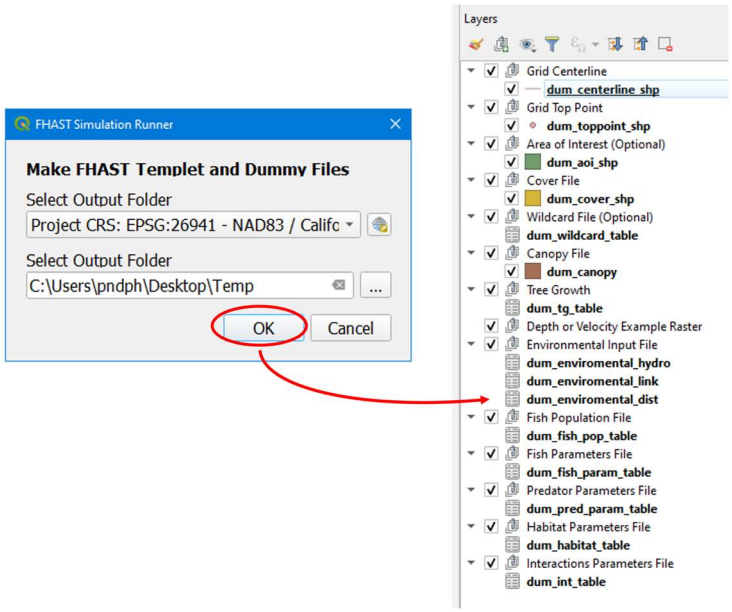

Figure 9. Once you select OK in the FHAST Templet and File Maker it will populate the layers panel with the groups and dummy input files.

3.5.3 FHAST File Loader

The FHAST File Loader can load one or multiple FHAST input files and place them in their assigned group (the user must set the assigned group).

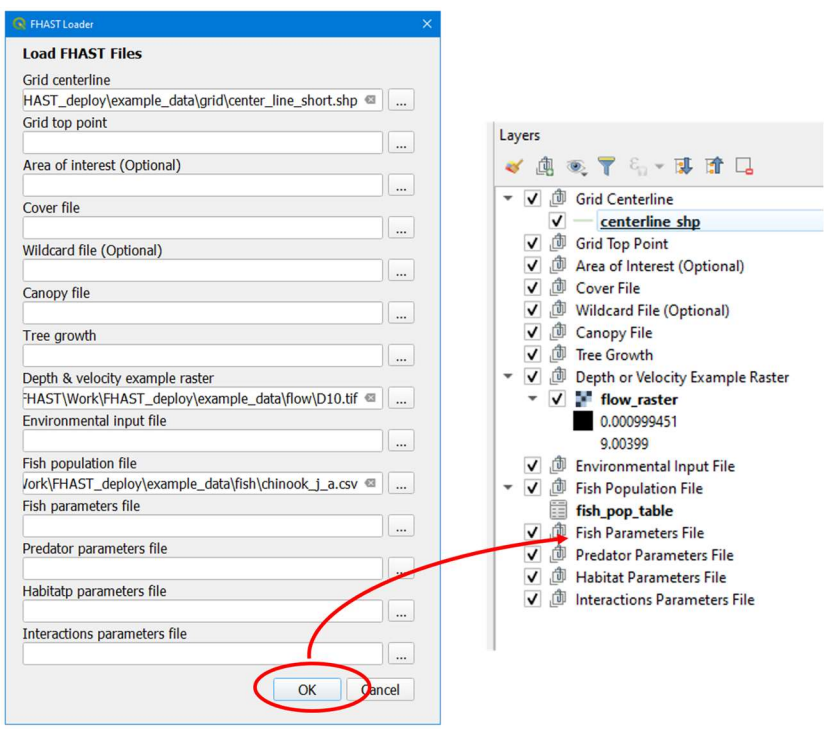

Figure 10. An example of loading three input files using the FHAST File Loader

3.5.4 Add New Column

Occasionally a user may want to add a row or column to a CSV file. Adding rows is done using the standard QGIS method (add feature icon in the attributes table ( )), however, to add a column the user needs to use a plugin. Select the desired CSV file you want to add a column to and give the new column a name. Of course the user may want to do CSV editing using external software, but this plugin gives them the option to do it natively

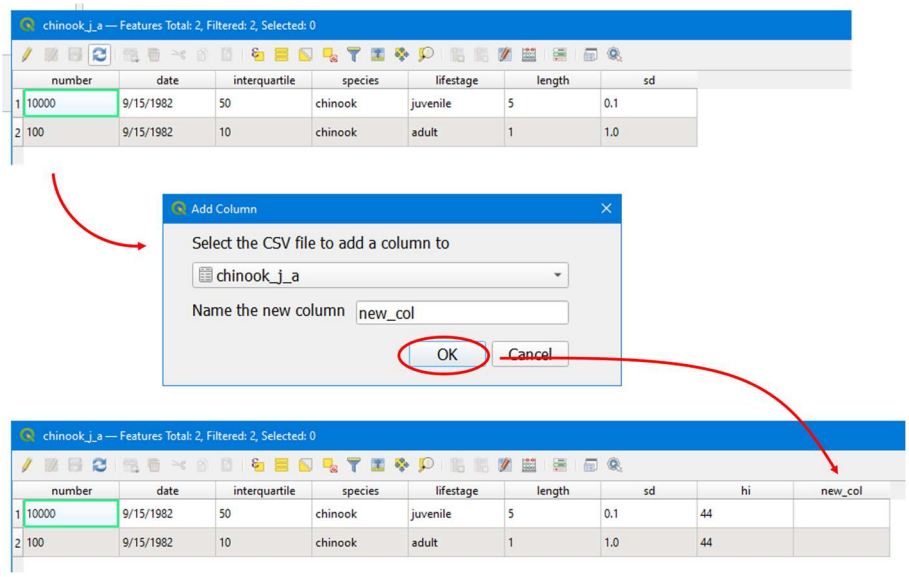

Figure 11. An example of adding a new column to a CSV.

3.5.5 Run FHAST Simulation

The final plugin is the one which runs a FHAST simulation. Once you have loaded all the appropriate files and they are placed in the appropriate group you simply launch this plugin and select the location for the output folder. The outputs will be stored in a folder in the location named <the qgis project name>_outputs.

This plugin also has a check box which gives the option of previewing some information about the run.

As FHAST runs you can monitor it progress through the terminal window which should appear.

4 Input Files

4.1 Overview

In this section we will show the structure of the input files in more detail.

4.2 Files

4.2.1 Cover File

The cover shape file, which was briefly described above, can be altered either by editing the shapes or adjusting the values in the attributes table depending on their needs. The user may also set the class of a shape to “wildcard” and have FHAST automatically set the attributes values during each run (see the Wildcard File section below)

Figure 12. An example of what a cover file might look like.

class	veg	wood	fine	gravel	cobble	rock
water	NULL	NULL	NULL	NULL	NULL	NULL
t_veg	0.460714285714...	0.003571428571...	NULL	NULL	NULL	NULL
t_wood	0.125	0.410714285714...	NULL	NULL	NULL	NULL
t_wood	0.178571428571...	0.464285714285...	NULL	NULL	NULL	NULL
t_wood	0.125	0.5	NULL	NULL	NULL	NULL
urban	NULL	NULL	NULL	NULL	NULL	NULL
t_wood	0.196428571428...	0.464285714285...	NULL	NULL	NULL	NULL
t_veg	0.625	0.071428571428...	NULL	NULL	NULL	NULL
urban	NULL	NULL	NULL	NULL	NULL	NULL
water	NULL	NULL	NULL	NULL	NULL	NULL
t_veg	0.660714285714...	0.071428571428...	NULL	NULL	NULL	NULL
t_wood	0.285714285714...	0.428571428571...	NULL	NULL	NULL	NULL
t_veg	0	0	NULL	NULL	NULL	NULL
t_veg	0.482142857142...	0.017857142857...	NULL	NULL	NULL	NULL
t_veg	0.625	0.071428571428...	NULL	NULL	NULL	NULL
t_wood	0.107142857142...	0.589285714285...	NULL	NULL	NULL	NULL

Figure 13. An example of what the attributes table for a cover file might look like.

4.2.1.1 Making/Editing The Cover File

Editing or making a cover shapefile for FHAST is one of the more complicated setup procedures. As mentioned in the theory manual, FHAST uses spatial shape files to quantify the proportion of various forms of cover, sediment type, and overhanging canopy vegetation in a given area. Within the attribute table of each polygon, you can then specify the approximate proportion of each type of cover/sediment type, which should add up to about 1. For example, if 80% of a given polygon is vegetation, 5% is woody debris, and 15% is bare gravel, your attribute table for this polygon would contain a value of 0.8 for veg, 0.15 for gravel, and 0.05 for wood. These shape files can be edited with the FHAST GUI or other geo-spatial software such as ArcGIS or another version of QGIS. One can move vertices of existing features to change their shape, add new features by drawing new polygons over the map and manually entering proportions of cover types, or make new cover files starting from scratch.

When adding new features to a cover or canopy shape file, we recommend being as granular as possible with your polygons, ie. making several individual polygons around each type of cover, sediment type, etc., rather than adding one large polygon over a broad area that includes multiple different cover types and relying on the percentages in the attributes table to set each polygon's makeup. When using smaller polygons, one can include as much heterogeneity as possible and avoid averaging features over one large area. This level of detail is only necessary if the added polygons approach the size of the grid size of your FHAST model run. If the polygons are much smaller than the grid size, the content of each polygon will be averaged over its containing cell in the model's grid, and you will lose any heterogeneity more granular than the cell size. However, there may be edge effects as the polygons cross the boundary of cells, and so it is best practice to make the polygons as detailed as reasonable.

Example 1: imagine you wish to incorporate the island shape pictured below into your cover shape file by adding new cover polygons over it (Figure 14).

Figure 14. Example of a habitat with heterogenous distribution of cover types. The grid size in this particular example is 100m x 100m (orange line for scale).

You wish to include as much heterogeneity in vegetative cover and sediment type as possible, so you draw separate polygons to distinguish between patches of trees and the bare ground (Fig. 15).

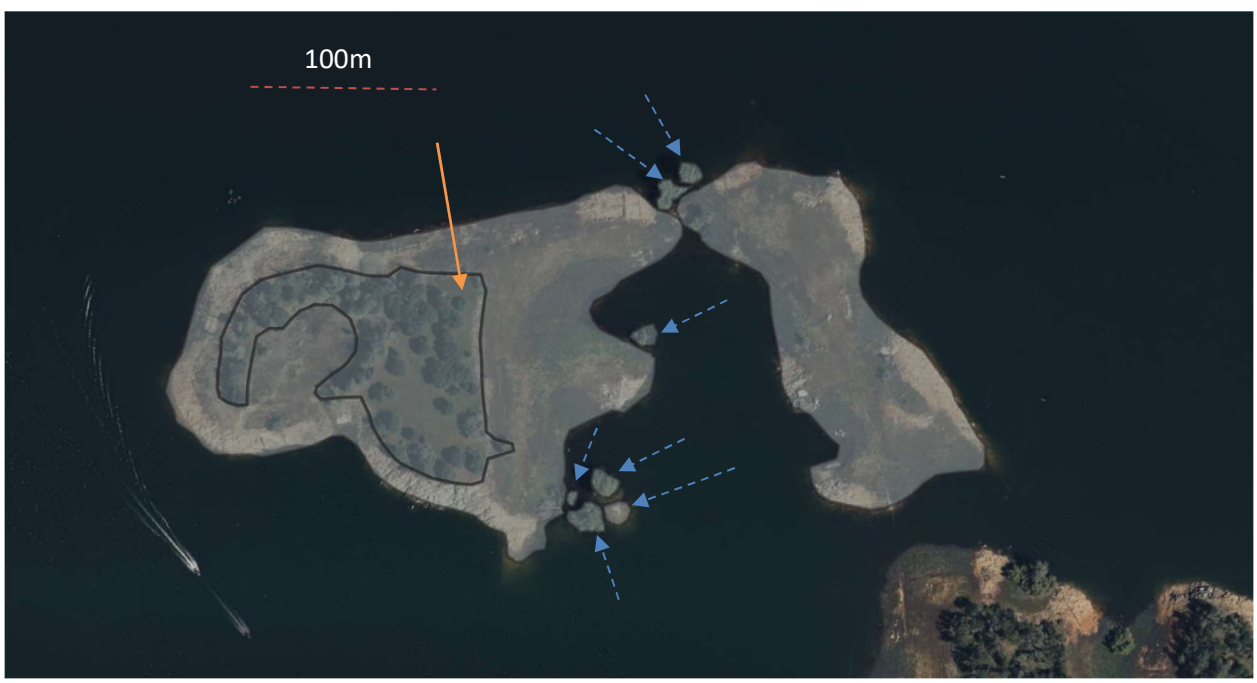

Figure 15. The habitat from Figure 1 overlaid with individual cover polygons (grey shading) that distinguish the internal patch of trees (green solid arrow) on the main island, as well as the smaller islands (blue dashed arrows) on the periphery. The grid size in this example is 100m x 100m (orange line for scale).

These polygons do a nice job of differentiating some obvious features, but you realize that the grid cell size in your desired FHAST Model input is very large (100 m x 100 m; typically much larger than would be used in FHAST but used here for demonstration purposes). The large internal polygon you've designated on the left side of this island (green arrow), is about 150 m on its longest side, but the small individual polygons placed around the island (blue arrows) are much smaller than 100m in width. Because the contents of each grid cell will be averaged-over anyway, there is no need to spend time meticulously drawing small, detailed polygons in an attempt to capture as much heterogeneity as possible.

A more appropriate set of polygons that approximates the size of your chosen grid size (while still accounting for as much heterogeneity as possible) is shown below in Fig. 16.

Figure 16. The same habitat as Figure 1 and 2, now overlaid with individual cover polygons that are more appropriate for the grid size of your model run (100m x 100m in this example). Polygons are small enough to capture important heterogeneity in cover type, but not so small to take inordinate amounts of time and effort only to be averaged over the larger area of each grid cell.

In this case, you have incorporated as much heterogeneity as possible given your grid size, without having to spend an inordinate amount of time manually drawing around individual trees. You can then use the attributes table to represent the heterogeneity within each polygon.

Example 2: here we apply the same principles as Example 1, but on a smaller scale (grid size of 20 m x 20 m). Imagine you want to incorporate these small islands of vegetation with cover polygons (Fig. 17).

Figure 17. A smaller scale example with a grid size of 20 m by 20 m where we wish to include cover polygons over the tree islands in the water (orange dashed line for scale)

This example is a little more complicated. There are some very small points of vegetation- much smaller than 20 m- that are spread out across the water. As such, we may wish to draw polygons around blocks of them that approach this size, rather than attempting to draw polygons over individual trees (Fig. 18).

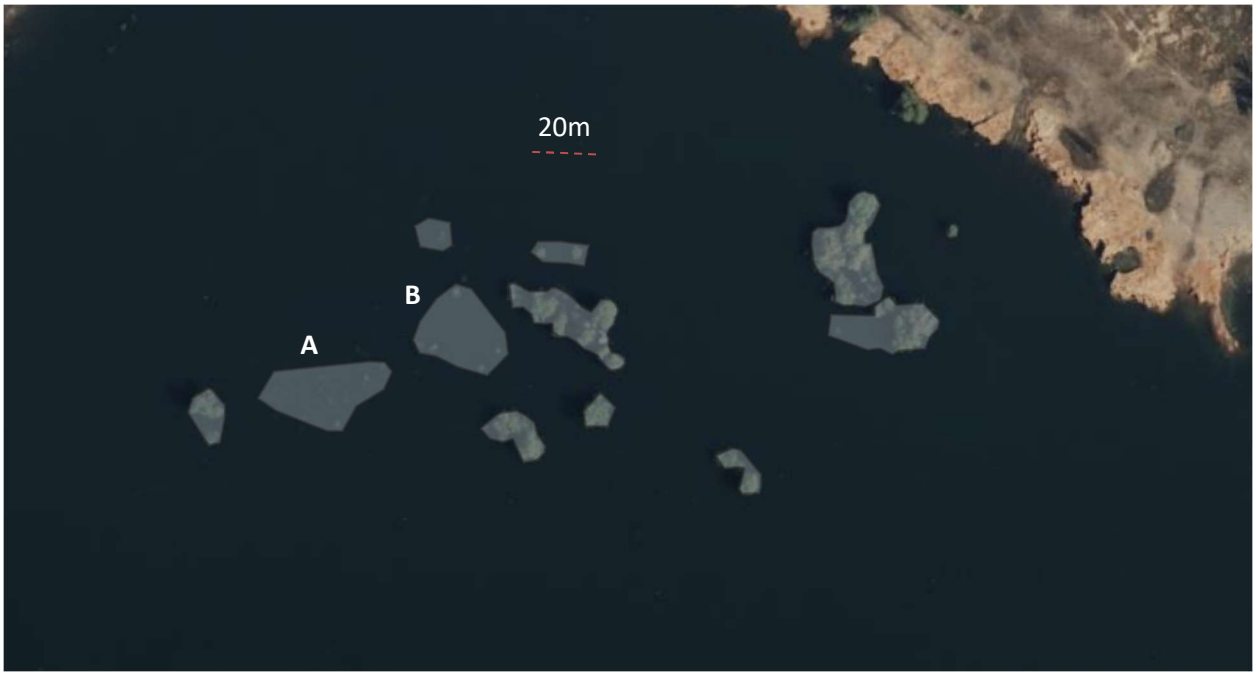

Figure 18. Cover polygons drawn over the habitat from Figure 4. Polygons A and B are examples of polygons that are mostly water but include some small points of vegetation.

Note that some of these polygons in Fig. 18 are primarily water with small proportions of vegetative cover (Fig. 18, polygons A and B). In these cases, you will have to deal with this in the polygon's attribute table by assigning approximate proportions of water and vegetation (0.95 value for water and a 0.05 value for t_veg, for example). The alternative in this case would be drawing individual polygons around these small points. Overall, the goal is to capture as much heterogeneity as possible, while being efficient in drawing these polygons by working on a scale appropriate for the resolution of our model grid.

4.2.2 Default Cover file Formatting

4.2.2.1 Land cover

The base land cover file included with FHAST covers the initial region of interest for the model. Is derived from the data set "Vegetation - Central Valley Flood Protection Planning Area Update - 2016 [ds2890]" (metadata and download available here). The base file is a shapefile containing 38 columns, which we condensed into 8. We used the column "CV_Group" (39 labels) as the basis for creating a new label, "class," to generically describe each polygon (6 labels: t_wood, t_veg, water, urban, gravel, and rock; Fig. 19). References to mines and quarries in CV_Group were dropped from the cover file.

CV_Group	class
RWF: Riparian Evergreen and Deciduous Woodland	t_wood
VPG: California Vernal Pool and Grassland Matrix	t_veg
URB: Urban	urban
WAT: Water	water
BGS: Bare – Gravel/Sand	gravel
CRO: Cliffs and Rock Outcrop	rock

Figure 19. Examples of CV_Group labels from the base cover file and their assigned class labels in the FHAST cover file. t_wood, terrestrial wood cover; t_veg, terrestrial vegetation cover.

The base file contains information regarding the total percent vegetation cover in each polygon. We converted values > 100% or reported as NA to 0. The maximum cover value for any polygon was 56%. However, according to the metadata, a polygon with a cover value of 40% would appear nearly completely covered. Therefore, we rescaled all cover values by dividing them by the maximum cover value (i.e. 56%). All cover values were then converted from percent to proportion, so total cover ranges from 0 to 1. FHAST's cover file has two columns related to vegetation cover: "wood" and "veg." Wood is the base file column "PER_TREE" converted as described above, while veg is the difference between the converted base file column "PER_TOTAL" and the FHAST wood column. All polygons with the "urban" or "water" class are assigned cover values of NA (Fig. 20).

class	veg	wood
t_veg	0.32	0.11
t_wood	0.21	0.59
urban	NA	NA
water	NA	NA

Figure 20. Examples of vegetation and wood cover values for various polygon classes from the FHAST cover file.

FHAST's cover file has four substrate attributes: "fine," "gravel," "cobble," and "rock." However, the base file contains little information about substrate. Some polygons are labeled with the class "gravel" or "rock". For gravel polygons, the "fine" and "gravel" attributes are set to 0.5 each, with other substrate values set to NA. For rock polygons, the "rock" attribute is set to 1 and all others to NA (Figure 21). These polygons are relatively rare in the FHAST cover file (gravel: 2.2% of polygons; rock: 0.01% of polygons). All other polygons have their substrate attributes set to NA. See section 4.2.2.3 for more information on how substrate attributes are assigned for other polygons.

class	fine	gravel	cobble	rock
rock	NA	NA	NA	1
gravel	0.5	0.5	NA	NA
t_veg	NA	NA	NA	NA

Figure 21. An example of the default substrate values for various polygon classes in FHAST's cover file.

Finally, the base cover file contains tree height data in the column "HT_CODE." These values indicate the mean height of vegetation in the polygon and are reported as ranges. For FHAST's cover file, we used the mean values of these ranges to represent the vegetation height (Fig. 22; note: the value "< 1m" was converted to 0.5 in FHAST; i.e., the average of 0 and 1). The "height" column is only used in the canopy cover file (see section 4.2.4), which includes polygons with a height > 3 m.

HT_CODE	height
"< 1m"	0.5
"1 – 5m"	3
"5 – 20m"	12.5
"20 – 50m"	35

Figure 22. Vegetation height values from the base cover file (HT_CODE) vs. height values from FHAST's canopy cover file.

4.2.2.3 Benthic Substrate

To create a rough approximation of benthic substrate class as a background layer over the mainstream Sacramento River, we analyzed data from Singer 2015, who performed bottom-grab samples along the Sacramento River. We extracted values of *d50* (median grain size, mm) vs. river kilometers upstream. We designated d50 values below 3 mm as "sand". For those above 3 mm, we designated them as "gravel". We then fit these data as a binomial that predicts the probability that the *d50* is gravel-sized or larger as a function of distance from the river mouth (km, Figure 23). Model predictions were mapped to cells along the Sacramento River. Note that this model is not necessarily predicting the *fraction* of gravel or sand in each cell within this background benthic substrate. In these benthic substrate background cells, values for "gravel" are best interpreted as "the probability that the median grain size in this cell is gravel-size or larger" and values for "sand" are best interpreted as "the probability that the median grain size in this cell is sand-sized or finer."

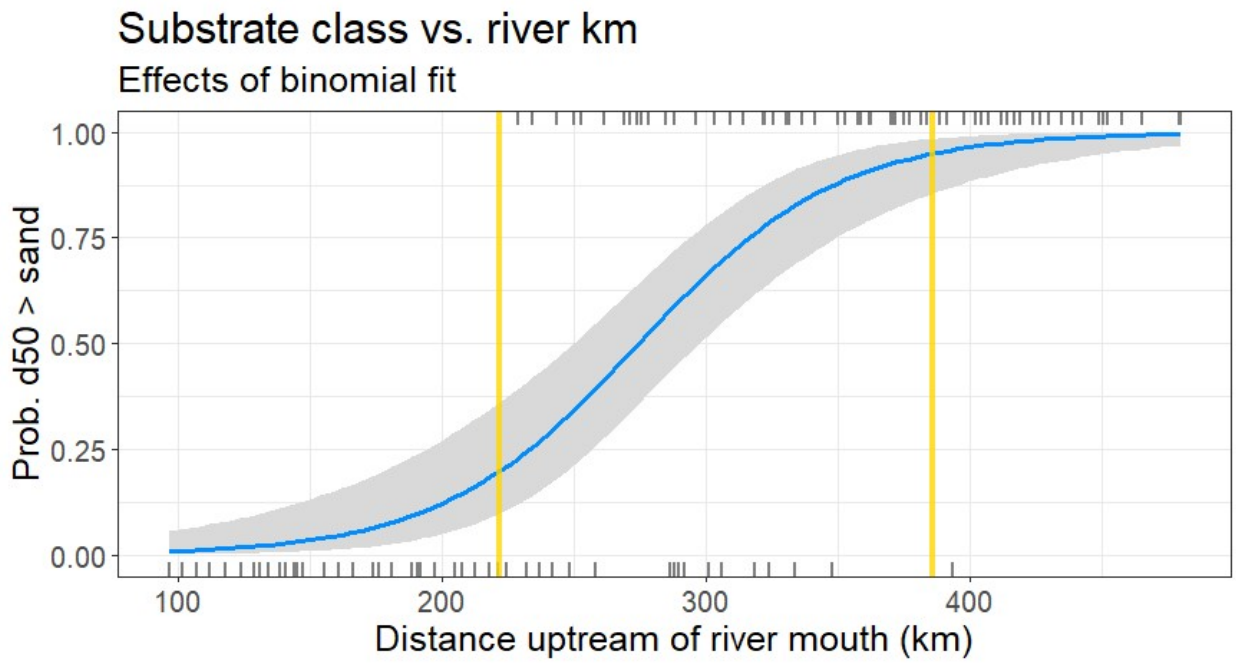

Figure 23: Binomial fit showing probability that median grain size (d50) is larger than sand vs. distance of sampling site in terms of kilometers upstream of the river mouth. The gold lines represent the boundaries of the Gravel Transition Zone, the region where the shift from predominantly fine to coarse sediments is steepest in the Sacramento River (Singer et al. 2015).

Important: this contrasts with the methodology used in cover shape files drawn by the user, wherein values for each substrate type (“gravel”, “sand”, “fine”, “cobble”, etc.) *do* reflect the estimated proportions of each substrate type. There is not yet a broad-scale dataset of sediment type proportions across the Sacramento River, and so this background layer is primarily intended to generally delineate areas theoretically suitable for spawning “e.g. gravel” vs. finer sediment types. As such, we recommend supplementing this background substrate data with targeted sediment sampling in specific reaches if fine-scale data is unavailable.

References:

Singer, Michael Bliss. "Impact scales of fluvial response to management along the Sacramento River, California, USA: transience versus persistence." *Geomorphic approaches to integrated floodplain management of lowland fluvial systems in North America and Europe* (2015): 53-85.

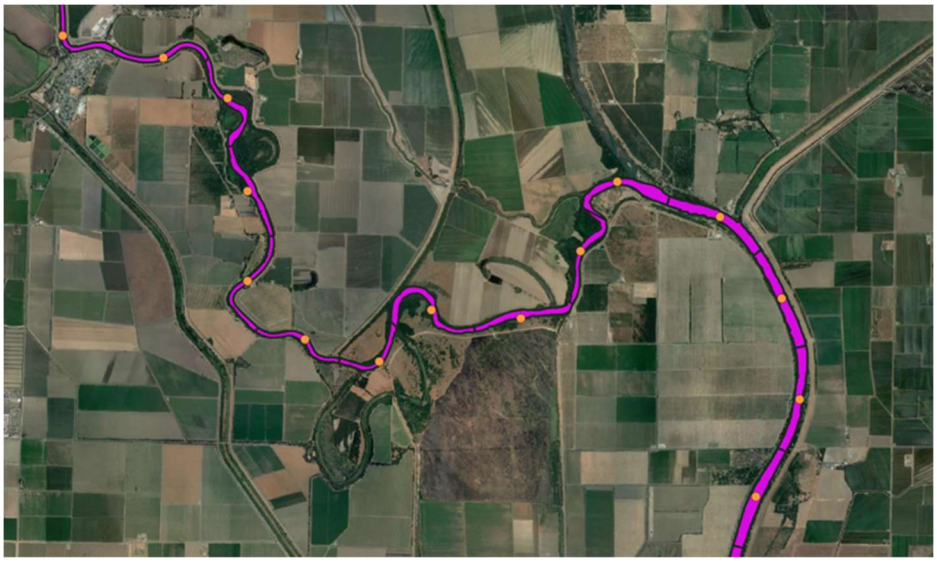

Figure 24. Background benthic substrate layer (pink cells). Bottom samples taken by Singer et al. (2015) shown as orange dots within cells.

4.2.3 Wildcard File

The wildcard file is an optional file designed to allow the user to rapidly change values in the cover shape file without using GIS editing procedures. If any element of a shape file has a class value set to “wildcard,” FHAST will use this file to set some of all of the other attributes of those elements. Any element listed in the wildcard file will be changed and elements not listed will remain as they are in the shave cover shape file. These values are only changed in the FHAST run; the cover shape file itself is not edited.

wood	rock	veg
0.6	0.2	0.1

Figure 25. An example of a wildcard file. This file will change the values of wood, rock, and veg attributes of any element of the cover shapefile with the class “wildcard.” The other values (e.g. fine) in those elements will remain unchanged.

4.2.3.1 Making/Editing The Wildcard File

The wildcard file can be edited in the GUI or with the user's preferred CSV editor. Simply add the desired columns you want to include and provide a fractional value to use.

4.2.4 Canopy File

The canopy file is used for calculating shade shape files in FHAST. The attributes file has only 1 required column: “height.” The user can also include an optional “species” column, which is used in the tree growth portion of FHAST. To edit this file the user can either edit the layout of the shapes or adjust the values in the attributes table depending on their needs.

Figure 26. An example of what a cover file might look like.

4.2.4.1 Making/Editing The Canopy File

This follows a similar method to the cover shapefile. Please see section 4.2.1.1 for instructions.

4.2.5 Environmental Input File

There are three types of Environmental Input File: the hydrograph, link, and distribution type. The hydrograph file is simply a text file with a designation of hydrograph for type, a file name, and a start and end date (Fig. 27). The hydrograph data is a CSV file with a date for each day of the run, a flow value in cubic meters per second, a temperature value in Celcius, and a turbidity value in NTUs (Fig. 28). In these input files (as is true for most text input files for FHAST) there are specific names for parameters which are followed by a “=” and then a value.

```
type = hydrograph
file = "daily_data.csv"
start date = 4/29/2020
end date = 6/20/2020
```

Figure 27. An example of what a Hydrograph Input File might look like.

date	flow_cms	temp_c	turb_ntu
4/14/2020	182.38	10.30	0.11
4/15/2020	193.43	9.40	2.16
4/16/2020	199.66	9.40	2.05
4/17/2020	206.46	10.10	2.94
4/18/2020	212.69	10.20	1.28
4/19/2020	226.00	10.80	3.21
4/20/2020	237.61	10.80	3.35
4/21/2020	248.09	10.90	1.54
4/22/2020	261.97	10.90	1.97

Figure 28. An example of what a hydrograph data file might look like.

The distribution environmental input types have the same five attributes for temperature and turbidity while flow has all those same ones plus a minimum flow value. The attributes include the distribution (normal or log-normal with mean and standard deviation) from which to draw the daily value, an autocorrelation which gives the fractional value of the previous days flow which makes up the current days flow (if this value were 1 each day would have the same flow and if it were 0 each days flow would be fully determined by a random draw from the distribution), and the daily change in the mean value of the distribution. This final attribute allows the user to have the values increase or decrease around a linear function. The file also has a designation that the type is distribution and a start and end date.

```
type=distribution
flow distribution=normal
flow mean=400
flow SD=100
flow autocorrelation=0.9
flow change=1
flow min=0.1
temperature distribution=normal
temperature mean=15
temperature SD=2
temperature autocorrelation=0.9
temperature change=0
turbidity distribution=normal
turbidity mean=1
turbidity SD=1
turbidity autocorrelation=0.9
turbidity change=0
start date=08/01/1982
end date=01/31/1983
```

Figure 29. An example of what a distribution Environmental Input File might look like.

The link environmental input type includes the same six attributes for flow as the distribution file, but with different parameters for turbidity and temperature. The file also has a designation that the type is link and a start and end date. The temperature and turbidity are given an intercept and slope which relate them to the flow, a correlation coefficient which determines what fraction of that days values is calculated based on the linear relationship and what fraction comes from a random draw from a normal distribution about that point, and a standard deviation which dictates the spread of the random part around the linear relationship.

```
type = link
flow distribution = normal
flow mean = 400
flow SD = 200
flow autocorrelation = 0.9
flow change = 4
flow min = 100
temperature SD = 1
temperature correlation = 1
temperature slope = -0.005
temperature intercept = 20
turbidity SD = 0.2
turbidity correlation = 1
turbidity slope = 0.001
turbidity intercept = 5
start date = 10/03/1982
end date = 10/01/1983
```

Figure 30. An example of what a link Environmental Input File might look like.

4.2.5.1 Making/Editing The Environmental Input File

The user can edit these files using their preferred text and CSV editors or with the GUI. Using the GUI to see the graphs in the outputs tab is a good way to investigate how changing the numeric parameters affects how the time series looks. If the user wishes to have a nonmonotonic input (e.g. a pulse flow), they will need to use the hydrograph input style file.

4.2.6 Fish Parameters Input File

The Fish Parameter Input File has the most parameters of any file in FHAST. The parameters are stored in a CSV file with species names as column headers and the list of parameters in the far left column. You can provide more species than are used in the model. FHAST considers the species provided in the Fish Population Input Files to be to ones the user is interested in. FHAST ignores any column of parameters for a fish species not included in the fish population file.

species	chinook	green_sturgeon	steelhead
cmax_a	0.63	0.16	0.63
cmax_b	-0.3	-0.21	-0.3
cmax_c	19.5	19.1	17.4
cmax_d	9.8	12	5.3
territory_a	0.0015	1	0.0015
territory_b	2.5	1	2.5
benthic_fish	0	1	0
react_dist_a	0	1	0
react_dist_b	0.05	1	0.05
turbid_threshold	2.5	1	0.5
turbid_min	0.13	1	0.1
turbid_exp	-0.07	1	-0.01
energy_density	4778	4393	5338
ucrit_a	27.1	36.7	27.1
ucrit_b	3.33	0.55	3.33
ucrit_c	18.2	19.4	18.2
ucrit_d	11.3	9.53	11.3
move_dist_a	7.86	7.86	7.86
move_dist_b	0.85	0.85	0.85
mort_high_temp_T1	26.2	29.3	25.9
mort_high_temp_T9	24.3	29.2	21.5
mort_condition_K1	0.37	0.73	0.37
mort_condition_K9	0.67	0.76	0.67
capture_V1	1.49	0	1.49
capture_V9	0.37	1	0.37
length_mass_a	0.013	0.009	0.019
length_mass_b	2.9	2.9	2.9
met_int	3.2	-2.74	2.43
met_lm	0.88	1.57	0.8
met_lt	0	2.56	0.79
met_v	0	3.34	0
met_lm_lt	0	-0.256	0
met_t	0.097	0	0
met_lm_t	-0.009	0	0
met_sqv	2.27	0	1.69
smolt_P1	11.3	0	10.5
smolt_P9	13.2	1	14.1
outmigrate_V1	0.1	0.1	0.1
outmigrate_V9	0.75	0.75	0.75
eg_juvenile_length	5	10	5
eg_adult_length	60	160	60
smolt_max_L1	8	21	16
smolt_max_L9	10	34	17
adult_feeding	0	1	0
small_cover_length	6	6	6
migration_max_dist	24000	49000	24000
adult_migration_min_flow	4000	50	4000
feeding_speed	1	0.2	1

Figure 31. An example of a Fish Parameter Input File with three species of fish.

4.2.6.1 Making/Editing The Fish Parameter Input File

The theory model outlines how all the parameters were fit to data. To adjust or create a new set of fish parameter inputs a user will need to use their preferred fitting software to fit the functions to data for the fish species of interest. Consult the Theory Manual for the function and theories used to fit each parameter.

4.2.7 Fish Population Input File

The Fish Population Input File tells FHAST the number and distribution of fish which should enter the model. Currently this includes juveniles who will attempt to rear on the model reach and adults who will migrate up river through the reach. The file lists the number of fish, the mean date of arrival, and interquartile range (in days) to describe the spread of arrival times, the species, the lifestage, and the mean and standard deviation of length (the length parameters are ignored for adults)

number	date	interquartile	species	lifestage	length	sd
100000	9/15/1982	50	chinook	juvenile	5	0.1
100	9/15/1982	10	green_sturgeon	adult	1	1

Figure 32. An example of a potential Fish Population Input File.

4.2.7.1 Making/Editing The Fish Population Input File

Simply add new fish by rows as necessary. It is recommended that the user use an external program or use the “Preview” check box option to examine the distribution of fish before you start a full FHAST run. Fish populations entirely outside the time range of the daily environmental inputs will prevent FHAST from running.

4.2.8 Predator Parameters Input File

The predator parameters are stored in a CSV file with species names as column headers and the list of parameters in the far left column (the same as the Fish Parameter Input File).

species	pikeminnow	bass
gape_a	4.64E+00	4.64E+00
gape_b	2.48E-06	2.48E-06
pred_glm_int	-1.09E+00	-1.08E+00
pred_glm_shade	-5.09E-01	9.50E-01
pred_glm_veg	6.94E-02	-1.57E+00
pred_glm_wood	8.46E-01	-4.25E-01
pred_glm_depth	2.09E-01	1.61E-01
pred_glm_velocity	-4.63E-02	-5.95E-01
pred_glm_substrate	4.63E-01	9.30E-01
pred_length_mean	4.76E+00	4.79E+00
pred_length_sd	4.64E-01	5.32E-01
area_pred_10	3.42E+00	3.42E+00
area_pred_90	2.48E+01	2.48E+01

Figure 33. An example of a Predator Parameter Input File with two species of fish.

4.2.8.1 Making/Editing The Predator Parameter Input File

The theory model outlines how all the parameters were fit to data. To adjust or create a new set of predator parameter inputs a user will need to use their preferred fitting software to fit the functions to data for the predator species of interest. Consult the Theory Manual for the function and theories used to fit each parameter.

4.2.9 Area of Interest Shapefile

The area of interest is a shape file used when calculating habitat summary statistics.

Figure 34. An example area of intrease shape (black polygon). FHAST will run the model using all the grid cells (shown in white), however, FHAST produces habitat statistics using only the grid cells inside the AOI (shown in red).

4.2.9.1 Making/Editing The Area of Interest Input File

The user should use the GUI or their preferred GIS software to make AOIs as necessary.

4.2.10 Grid Centerline and Top Point Shapefile

The grid centerline and top point trace the centerline of the simulation domain and indicate the upriver end of the model.

Figure 35. An example of a grid centerline (red line) and a grid top point (blue x).

4.2.10.1 Making/Editing The Predator Parameter Input File

The user should use their preferred GIS software to make centerlines and grids as necessary. The top point should be within the resolution distance (form the habitat file) of the top end point of the grid center line. The center line should pass through the center of the wetted area of interest. If the river section has side channels or flooded areas next to it the best center line may not follow the main channel of the river (see Fig. 35 for example).

4.2.11 Habitat Input File

The habitat file lists parameters related to the habitat in the simulation. The parameters include

1. benthic food density (g/m^2)
2. benthic food energy density (J/g)
3. benthic food habitat - habitat types that have benthic food available.
4. cover habitat - habitat types that provide cover from predation.
5. small cover types - habitat types that provide cover from predation for small fish, which are defined in the fish parameter file by the small_cover_length parameter.
6. drift food density (g/m^3)
7. drift food energy density (J/g)
8. velocity and depth cutoffs - defines cutoffs for depth and velocity in habitat areas that may be of interest to the user, and are not use in the model in any way other than reporting spatial statistics about area below and above these cutoffs.
9. the grid resolution (m) - seta the length and width of the grid cells.
10. the grid buffer or distance (m) - distance from the river centerline the grid should cover.
11. the predators per area ($individuals/m^3$)
12. vegetation growth years - the number of years that canopy file vegetation have been growing by the starting time of the model run.

```
benthic food density = 0.87
benthic food energy density = 2284
benthic food habitat = fine, gravel, cobble
cover habitat = veg, wood
small cover habitat = veg, wood, cobble
drift food density = 0.0001
drift food energy density = 2891.38
velocity cutoff=0.61
depth cutoff=0.5
resolution=20
buffer=600
predators per area = 0.003
vegetation growth years = 0
```

Figure 36. An example Habitat Input file.

4.2.11.1 Making/Editing The Habitat Input File

Most of these parameters will depend on data gathered from the section of the river where the simulation takes place. The resolution is up to the user to set. Finer resolution is often better but can quickly slow down computation. Larger grids can smear out heterogeneity of the simulation domain and change results. It is advisable to run simulations at a few grid resolutions to see if the grid size selection has an unacceptably large effect or results above a certain size.

4.2.12 Interactions Input File

The habitat file lists parameters related to the habitat in the simulation.

The interactions table provides inputs for parameters that govern how the habitat interacts with the fish. The theory manual provides detailed descriptions of these parameters and they are only briefly described here.

1. Cover Velocity Fraction - the fraction of the velocity experienced by a fish in cover.
2. Percent Cover - parameters (Intercept, Root, Slope, 3-2 Root) relate the percent cover in a cell to the distance to hiding cover.
3. Temperature Predator Area Baseline - sets the base level area for the temperature relationship and predator area in a cell.
4. Temperature Predator Area Effect - sets value to multiple the temperature effect function result by to add to the predator area in a cell.
5. D84 Size - used in the law of the wall calculation.
6. Benthic Velocity Height - also are each used in the law of the wall calculation.
7. Turbidity Cover - parameters (10 and 90) specify how fish survival success to predation is modified by distance to cover.
8. Distance To Cover- parameters (10 and 90) specify how fish survival success to predation is modified by turbidity.

```
cover velocity fraction = 0.488
percent cover intercept = 0.477
percent cover root = -0.576
percent cover slope = -0.183
percent cover 3-2 root = 0.282
temperature predator area baseline = 0.5
temperature predator area effect = 0.01
d84 size = 0.05
benthic velocity height = 0.01
superindividual ratio = 20
turbidity cover 10 = -116
turbidity cover 90 = 169
distance to cover 10 = 1.57
distance to cover 90 = 0
```

Figure 37. An example Interaction Input file.

4.2.12.1 Making/Editing The Interactions Input File

The Theory Model outlines how all the parameters were fit to data. To adjust or create a new set of interaction parameter inputs a user will need to use their preferred fitting software to fit the functions to data for the interaction of interest. Consult the Theory Manual for the function and theories used to fit each parameter.

4.2.13 Tree Growth Parameter Input File

The tree growth file lists the parameters for both tree vertical as well as crown growth. The equations used for these calculations are described in the theory manual.

species	Acer negundo	Alnus rhombifolia	Fraxinus latifolia	Pla			default
common	Boxelder maple	White alder	Oregon ash	We		illow	default
type	tree	tree	tree	tre			tree average
d_max	80	90	80	1		10	130
h_max	1829	2286	2133	22		305	2387.5
g	116.7	133.3	100	5:		230	97.4
usfs_data_analogue	Boxelder maple	River birch	Oregon ash	We			NA
usfs_region	MidWst	Piedmt	PacfNW	Inlt	...		NA
eq_name	loglogw3	lin	cub	qua			quad
a	-0.11047	2.45947	0.18904	:			1.362856667
b	1.80298	0.20529	0.37563	0.			0.337603333
c	0.00065	NA	-0.00399				-0.00149
d	NA	NA	0.00002	NA			NA

Figure 38. An example Tree Input FIle.

4.2.13.1 Making/Editing The Interactions Input File

The user can add a new species of tree to the file by adding in a column and selecting appropriate parameter values for the necessary parameters. Only the parameters that take numeric values and the “eq_name” are used in FHAST.

4.2.14 Depth and Velocity Input Rasters

FHAST requires a series of depth and velocity rasters at known flows in a single folder. They should follow the naming scheme of a letter (D for a depth file and V for a velocity file) and a numeric value of the flow (in cms) the file represents.

Figure 39. An example of the file structure in the flow folder.

4.2.14.1 Making/Editing The Interactions Input File

The user should use their preferred hydraulic model to make 2D depth averaged rasters for FHAST. The flows should span all flow values you intend to use in the model. As FHAST uses linear interpolation between provided flow values the gaps should not be so large as to make the interpolated rasters unrealistic.

5 Results

5.1 Overview

FHAST outputs three reports which contain summary data in the form of tables, graphs, and maps. It also saves a large number of data files which the user can access for further analysis.

5.2 Tabular Data

The following tabular data outputs are saved to the output folder.

abm_cell_info_output: Every timestep, information from every cell containing at least one fish is recorded and a CSV is produced at the end of each simulation. Cell information includes the cell’s x and y coordinates, velocity, depth, survival probability, probability of predation, the total net energy of the cell, the number of fish in the cell, and the average mass, length and condition of the fish in the cell.

abm_detailed_pop_output: At the end of every timestep, information about the fish population in the system is recorded, including the total number of juveniles in the system ("juveniles" or nonmigrants), number of juveniles with positive daily growth ("rearers").

abm_events_output: Every timestep, information from every fish in the simulation is recorded, along with environmental conditions that the fish experiences, including the velocity, depth, and probability of surviving predation within the cell the fish selected at the end of the timestep. The "events" column records whether the fish is alive or dies (and the cause of death), and whether it migrates during a timestep. If a fish migrates during a specific time step, it will have three events recorded during that timestep. These events include "migrated", and either "alive_migrant", "migrant exited river", or a cause of death if the migrant died before reaching the end of the river. See Table 1 for all possible events that can be recorded and their description.

During any timestep, a fish can turn into a "drifter". Fish can become drifters when no cells within their search radius confer positive net energy. The "drifter_history" column records whether the fish turned into a drifter during the timestep, why, and whether the fish remained a drifter at the end of the timestep, or found a destination. See Table 2 for all possible entries for "drifter_history" that can be recorded and their description. Note that there is also a "is_drifter" column with either "true" or "false" entries, but this column does not record drifters who became drifters at the beginning of the timestep but ended up finding a cell with positive net energy at the end of the timestep (when "is_drifter" status is turned "off" and set to "false").

Table 1: Events and their description

Event	Description
migrated	Fish that initiated migration that timestep
alive_migrant	Migrant fish that is alive at the end of the timestep
drifter_alive	Drifter fish that is alive at the end of the timestep
alive	Non-migrant, non-drifter fish that is alive at the end of the timestep
Died of stranding	Fish who died of stranding
Died of poor condition	Fish who died of poor condition
Died of high temperature	Fish who died of high temperature
Died of predation	Fish who died of predation
Migrant exited river	Migrant that reached the end of the reach, is removed from the system

Table 2: Possible entries for the “drifter_history” column and their description

Drifter_history	Description
Was not drifting, found dest	Fish who was not a drifter last timestep, found cells within search radius with positive net energy
Was drifting, found dest	Fish who was a drifter last timestep, found cells within search radius with positive net energy
Drifting, no dests available	Fish who just turned into a drifter that timestep (or may have been a drifter last timestep), but does not have any cells within its radius with positive net energy (only starving fish). Stays a drifter at the end of the timestep
No valid destinations or cells with pos net energy, drifted out of river	Fish who are currently a drifter that timestep, have an exit status of 1, did reach the end of the river
No valid destinations or cells with pos net energy, tried to exit river but did not reach end	Fish who are currently a drifter that timestep, have an exit status of 1, but did not reach the end of the river because there were either no valid destination cells or no cells with positive net energy within search radius

adult_migration_energy_data: This is a table of the energy used by each species to migrate up the river section each day.

adult_migration_path_<species>: This is the paths used by adults of each species to migrate up the river section.

<species>-<lifestage>_daily: Each combination of species and life stage will produce a CSV which has daily average values for the habitat and the fish. These data are not based on the ABM portion of FHAST but rather using the example length given in the Fish Parameter Input File for each species and they are calculated over the entire habitat each day and then averaged. New outputs in the CSV are the mortality risk from predators (pred_mort_risk), the fish metabolic rate (fish_met_j_per_day), the energy intake from feeding (energy_intake), and the net energy budget of the fish (net_energy).

<species>-<lifestage>_map: Each combination of species and life stage will produce a CSV which has location average values for the habitat and the fish. These data are not based on the ABM portion of FHAST but rather using the example length given in the Fish Parameter Input File for each species and they are calculated each day and then averaged for each cell. New outputs in the CSV are the mortality risk from predators (pred_mort_risk), the fish metabolic rate (fish_met_j_per_day), the energy intake form feeding (energy_intake), and the net energy budget of the fish (net_energy)

daily_conditions_processed: The daily environmental inputs. This file also has calculated photoperiod in adaptation to flow, temperature, and turbidity.

daily_fish_processed: The number of each fish species and life stage entering the model each day.

habitat_daily_data: A summary of the habitat data by day

habitat_map_data: The average values of habitat characteristics for each cell over the entire run time.

5.3 GIS Data

FHAST generates the following shapefiles:

shape_shade<month>: Shape field of the shade each month.

sampeled_shape: The grid after it was used to sample the cover file.

Column names are auto generated abbreviations from R data frames. They are:
veg: The fraction of vegetation cover in this cell.
bn_fd_f: The fractional area of the cell that produces benthic food.
covr_fr: The fractional area of the cell that has cover for fish.
smll_c_: The fractional area of the cell that has cover for small fish.
aoi: If the cell is in the AOI.
ID: Cell ID
distanc: Distance cell is down river.
area: Area of the cell.
lft_r_r: A negative or positive # denoting if the cell is left or right of the center line.
lat_dst: The distance the cell is laterally from the centerline.
wood: The fraction of wood cover in this cell.
fine: The fraction of fine sediment covering the cell.
gravel: The fraction of gravel covering the cell.
cobble: The fraction of cobble covering the cell.
rock: The fraction of rock covering the cell.
shade_#: The fraction of shade covering this cell for # month.

river_grid: A shapefile of the model grid.

preview_river_grid_outline: The extent of the river grid domain.

habitat_map: The average values of habitat characteristics for each cell over the entire run time.

Column names are auto generated abbreviations from R data frames. They are:
lat_dst: The distance the cell is laterally from the centerline.
distanc: Distance cell is down river.
depth: Average depth of the cell over the run.
velocty: Average velocity of the cell over the run.
wettd_r: The average wetted area of the cell.
temp: The average temperature of the cell.

turb: The average turbidity of the cell.
photprd: The average photoperiod of the cell.
shade: The average shade covering the cell.
veg: The fraction of vegetation cover in this cell.
area: Area of the cell.
wood: The fraction of wood cover in this cell.
fine: The fraction of fine sediment covering the cell.
gravel: The fraction of gravel covering the cell.
cobble: The fraction of cobble covering the cell.
rock: The fraction of rock covering the cell.
covr_fr: The fractional area of the cell that has cover for fish.
aoi: If the cell is in the AOI.
rch_prd: THe number of predators in the reach.
wetted: Fraction of days the cell is wetted.
hb_rtng: Habitat rating used for predator distribution.
blw_d_c: If the cell average depth is below the user supplied cutoff.
blw_v_c: If the cell average velocity is below the user supplied cutoff.
Blw_grp: The group the cell is in according to the cutoff
00 = Below none
01 = Below depth cutoff
10 = Below velocity cutoff
11 = Below both cutoffs

fish_map_<species>-<lifestage>: The average values of habitat characteristics for each cell concerning each species and lifestage over the entire run time.
Column names are auto generated abbreviations from R data frames. If not defined above, they are:
prd_mr_: the mortality rish in the cell from predation.
bnthc_f: flag if the fish is benthic.
fsh____: The fish metabolic rate
enrgy_n: The fish fish energy intake.
nt_nrgy: The fish net energy.

adult_migration_path_<species>: The paths and frequency of use for adult migration for each species.

5.4 Reports

There are three reports generated by FHAST

report_adult_migration: An html report covering summary results from adult migration simulations.

report_juvenile_rearing: An html report covering summary results from the juvenile ABM rearing model.

report_genral: An html report covering summary habitat statistics both for the environment and each specific combination of species and lifestage.

6 New Run Setup

When making a new FHAST simulation the following suggestions will be helpful. First, use as much of the file structure from a previous run as possible. Even on very disparate simulations, much of the file structure will be the same and reusing old files as templates will save time and minimize errors. It is also possible that data in non GIS files may be full or partially reusable. For example, if you are working on a different river but on the same species, most of the fish parameter input file can be reused, while if you are working just upriver from a previous run, most of the non GIS file could likely be reused (but should of course be reviewed beforehand).

Thus when setting up new runs in reasonable proximity to older runs much of the work will be in creating the four new GIS files (the grid line and tip point files, the depth and velocity raster files, the cover files, and the canopy files). How to make each of these is outlined in their respective sections above.

The final consideration when setting up a new run is: “what are you simulating?”. These considerations will largely inform what your fish population input file and the environmental input file contain. For example, if simulating the effect of a pulse flow on established rearing fish you will want to have a sufficient pulse of fish entering the system and have sufficient time to establish rearing positions before simulating a flow pulse. If you are simulating the effects of habitat alternations of a system then likely you will be conducting two nearly identical runs except changing one or both of the cover file or the set of depth and velocity input rasters.

7 New System Setup

The structure of FHAST is designed to be mechanistic and general, therefore it is possible that it could be used on different systems and with different species than the ones it was developed on. When moving to a different system, obviously all GIS files will need to be remade but likely the habitat, interactions, and predator files will need to be reparameterized (i.e. have new parameter values entered) or heavily modified.

The largest hurdle will be if the user wishes to use a new species of fish. When considering this the initial question to ask is does the structure of FHAST accommodate this species. FHAST should be able to accommodate most species provided they are anadromous and engage in either drift or search feeding. However if a main driver of the species ecology is not in the structure of FHAST, then that species should not be modeled with FHAST. Examples of drivers that might be significant on certain systems that are not included in FHAST would be significant terrestrial or avian predation on the fish, very small rivers with large daily fluctuation in temperatures, systems where very low temperature affect survival, and likely several others.

8 Complex Run Setup

While each FHAST run is for a single habitat at a point in time, more complex FHAST projects could be implemented with a series of runs with each individual run representing a snap shot in the evolution of a habitat. To achieve this the user would either have to make a series of cover or depth and velocity files that represent the change in the habitat over time.

For example, if a user wanted to simulate how bank erosion over five decades might affect salmon rearing, they would likely need a new set of depth and velocity rasters for each of the five decades (thus a new digital elevation model for each decade). These depth and velocity rasters would represent how erosion of the bank changed the depth and velocity profiles of the river from one decade to another. They would likely also need a new cover file for each decade as the bank erosion would likely change the cover class in the area where the bank was being eroded.

9 Troubleshooting

Under development

Verify you have matching depth and velocity raster files for each river

The input_file.txt file should use consistent folders throughout for accessing input files

Verify Java is installed on computer

Aoi is inside grid

Install ‘cli’ and ‘here’

Verify you have matching depth and velocity raster files for each river

The input_file.txt file should use consistent folders throughout for accessing input files

Verify Java is installed on computer

Create a FAQ / trouble-shooting notes section / appendix