

Habitat Volume Model (HabVol)

User's Guide

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HabVol Developers

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Habitat Volume Model (HabVol) description

The Habitat Volume Model (HabVol) calculates a geometric volume of suitable habitat for a specific organism and life stage (e.g., adult striped bass, juvenile soft clam) as it changes over time. It can be run using fixed criteria or bioenergetics calculations. When run with fixed criteria, physiological tolerances of the organisms are used to calculate the volume of suitable habitat in terms of salinity, temperature and dissolved oxygen, as well as their intersection. When run in bioenergetics mode, the volume of habitat is calculated that corresponds to a user-defined threshold in potential growth.

HabVol is an open-source offline model written in Fortran and is based on an algorithm that calculates the volume of habitat given one or more constraints (Smith et al. 2009). HabVol uses output from a coupled 3D hydrodynamic model, the Regional Ocean Modeling System (ROMS), and a dissolved oxygen model implemented within ROMS (Li 2012) to calculate the volume of suitable habitat in each model grid cell. The HabVol model grid cells are the same as the ROMS model grid cells. For each grid cell, linear interpolation in the vertical direction is used to find the depth of the constraints (e.g., minimum DO required for survival) (Fig. 1a). Then the most constraining factors in each grid cell are used to define the volume of suitable habitat in the cell (Fig. 1b). This volume is divided into four triangular “prisms” (Fig. 1c) and the habitat volume in the grid cell is then calculated as the sum of the volume of each prism. The volume in all model grid cells is summed (Fig. 1d) to derive the domain-wide total habitat volume in each time step (e.g., Fig. 2). For more information on the application of HabVol, please see Schlenger et al. (2013) and Schlenger (2012). Please cite Schlenger et al. (2013) when referring to HabVol.

If you have questions regarding HabVol, please e-mail both Adam Schlanger (aschleng@umces.edu) and Elizabeth North (enorth@umces.edu).

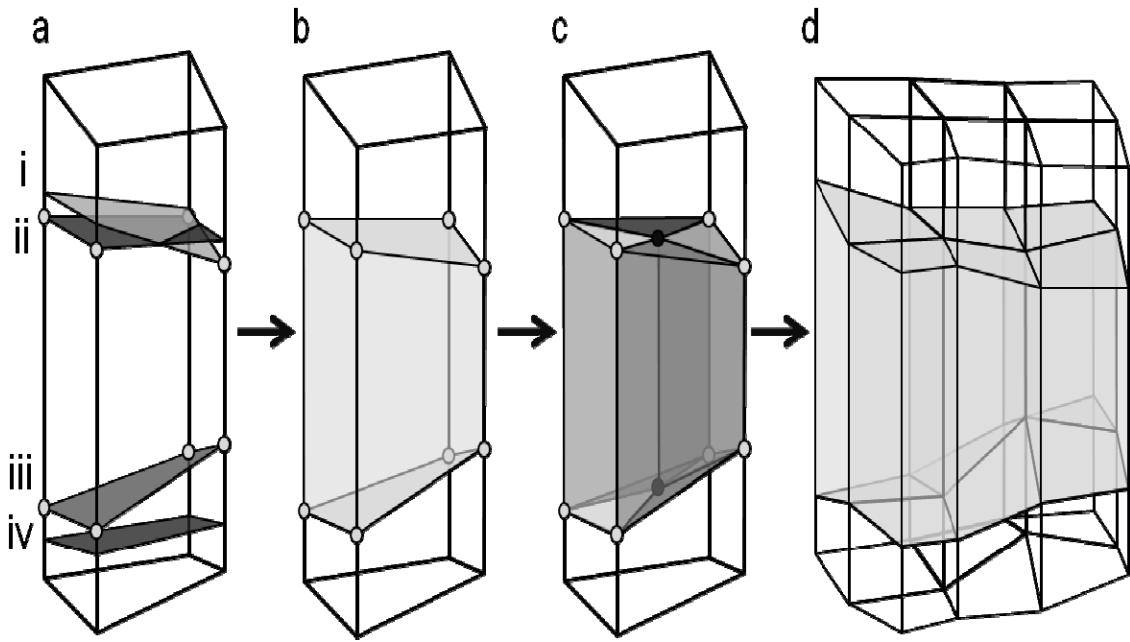


Fig. 1. Diagram of habitat volume calculation. (a) Upper bound for salinity (i), lower bound for dissolved oxygen (iii), and upper (ii) and lower (iv) bounds for temperature are found based on linear interpolation. (b) The most limiting tolerance constraints (gray circles) define the habitat volume in the grid cell. (c) Volume is calculated by dividing the volume into four “prisms” and summing their volumes. (d) This process is repeated for all grid cells in the model, and the volumes are summed to find the Bay-wide habitat volume. From Schlenger et al. (2013).

A) YOY

B) Yearling

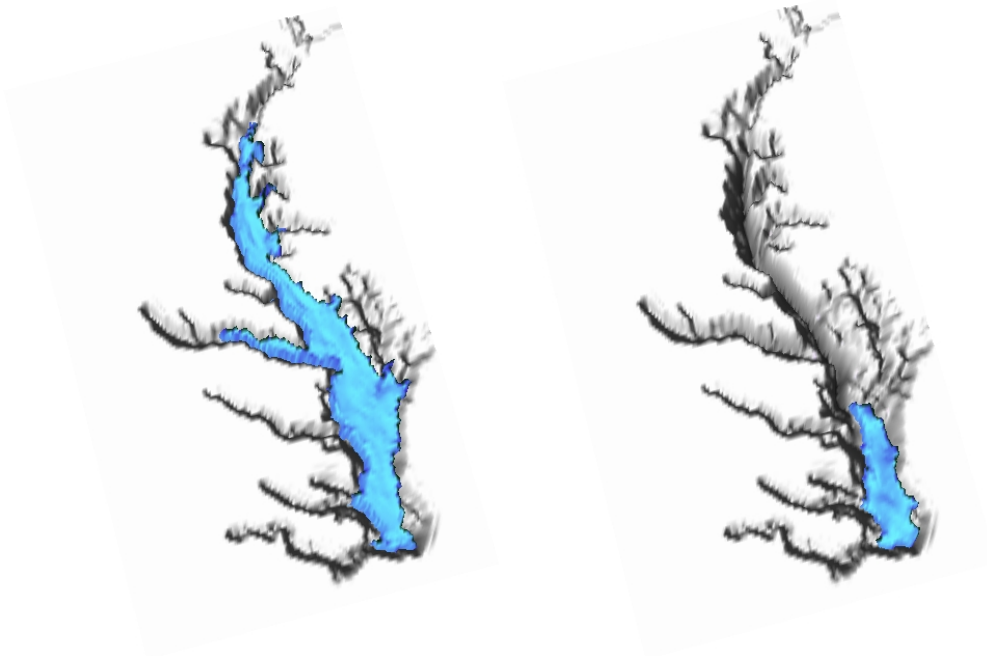


Fig. 2. 3D habitat volume model output. Example of optimal habitat volume (blue) for young-of-the-year (YOY) (A) and yearling (B) Atlantic sturgeon on July 6, 1996. Optimal habitat requirements for YOY are as follows: temperature (16-24 °C), salinity (3.5-18.5), and dissolved oxygen (≥ 5.0 mg l⁻¹). Optimal habitat requirements for yearlings are as follows: temperature (16-24 °C), salinity (18.5-25.5), and dissolved oxygen (≥ 5.0 mg l⁻¹). From Schlenger et al. (2013).

Test Case Description

The test case model available at the HabVol website (http://northweb.hpl.umces.edu/open_source_code/HabitatVolumeModel.htm) is set up to calculate the combined habitat volume for adult bluefish based on salinity, temperature, and dissolved oxygen over a 15 day period from 6/25/04 to 7/8/04. Salinity, temperature, and dissolved oxygen ranges are based on the following criteria:

	Temperature (C)	Salinity (ppt)	DO (mg/L)	References
	Required	Required	Required	
Adult	8-35	5-36	≥ 5.1	Lund (1971), Olla et al. (1975), Middaugh et al. (1981), Buckel et al. (1995), Shepard and Packer (2006), Grothues and Able (2007)

The habitat predicted by the fixed criteria habitat volume model is categorized as *required* habitat. Required habitat is defined as the domain (volume) of environmental conditions outside of which mortality would occur.

Instructions for running HabVol

The following is a step by step guide to running one instance of the HabVol on a Linux machine. These instructions are specific to the test case that is provided on the HabVol website (http://northweb.hpl.umces.edu/open_source_code/HabitatVolumeModel.htm).

1. Create directories for HabVol code and ROMS model output.

Create a folder containing current versions of the necessary model code files. These files include:

- Constraints_Module.f90
- CPB_GRID_wUV.nc
- HabitatVolumeBoundary.csv
- HabitatVolumeModel.f90
- HabitatVolumeModel.h
- Hydro_Data_Module.f90
- Hydrodynamic_Module.f90
- Input.inc
- ly04_0351.nc
- Parameter_Module.f90
- point_in_polygon_module.f90
- Vol_compile.sh
- Volume_Module.f90

2. Modify Input.inc file.

Within the desired model run folders, the input.inc file must be changed so that it contains the correct path directories for the hydrodynamic grid (e.g., CPB_GRID_wUV.nc) and output history (e.g., ly04_0351.nc) files. Also, make sure that (LEN=##) is set (i.e., change ## to a specific number) so that the number is equal to or larger than the number of characters in the entire path plus the name of the file.

The Input.inc file is also where model options must be changed to the appropriate settings for each specific model run. This includes the model method used, the desired types of output, and the use of specific boundary conditions such as a depth cutoff (meters) or geographical limit. A complete list of model variables are provided within the input.inc file along with a short description of each. Once the desired changes have been made, save the file and exit.

For this example, the model is run using fixed criteria so make sure that the 'Bio_on' option is set to '.FALSE.'

The starting date of the hydrodynamic file needs to be specified and can be identified using a simple procedure. See Appendix A for one method to calculate start dates.

3. Modify HabitatVolumeBoundary.csv

This file can be used to control the HabVol model domain if the user wants to specify a smaller domain than the ROMS model domain. The file in this example has 8 pairs of latitude and longitude values used to constrain the spatial extent of the HabVol model. In order to use this information in the model, the input.inc file was modified so that 'lconst = .TRUE.' and the number of coordinate pairs was specified.

4. Modify constraints file

The constraints file is where tolerance information pertaining to specific species is adjusted for each model run. For this particular example, there are only six variables that need to be changed, related to fixed criteria. These variables define the physiological tolerance limits to temperature, salinity, and dissolved oxygen.

maxsalt = Maximum salinity tolerance
minsalt = Minimum salinity tolerance
maxtemp = Maximum temperature tolerance (°C)
mintemp = Minimum temperature tolerance (°C)
maxdo = Maximum dissolved oxygen tolerance (mmol m⁻³)
mindo = Minimum dissolved oxygen tolerance (mmol m⁻³)

There is a minimum and maximum value listed for each parameter. Set the maximum DO threshold to an unrealistically high value so that there is effectively no upper limit. These tolerance limits can also contain multivariate equations, such as temperature-salinity dependencies.

The constraints file is also where the bioenergetics equations can be modified. A description of the bioenergetics volume model calculation can be found in Appendix C.

5. Running the model

This section provides instructions for running the habitat model on a Linux server using the SSH command window.

- A) Change the SSH directory path to the desired model run folder.
- B) Type the command 'ls', which lists the files that are located in a specific folder. Use this command to make sure that all the necessary files are present.

C) Type the command './Vol_compile.sh'. This command compiles all of the required files so that the program runs properly.

D) Type the command './Volume.exe'. This command starts the model run. This example should take less than one minute to complete.

Example of properly running model:

```
aschlegl@phoenix:~/Hmodel/Habvol/All/ ./vol_compile.sh
Compiling f_modules.
Parameter
Point-in-Polygon
Hydro Data
Constraints
Hydrodynamic
Volume

Compiling Habitat Volume Model

Compilation Complete
aschlegl@phoenix:~/Hmodel/Habvol/All/ ./volume.exe
read-in grid information
create elements
/share/home/aschlegl/Hmodel/Habvol/All/ly04_0351.nc
existing matrix, time step= 2
existing matrix, time step= 3
existing matrix, time step= 4
existing matrix, time step= 5
existing matrix, time step= 6
existing matrix, time step= 7
existing matrix, time step= 8
existing matrix, time step= 9
existing matrix, time step= 10
existing matrix, time step= 11
existing matrix, time step= 12
existing matrix, time step= 13
existing matrix, time step= 14
existing matrix, time step= 15
existing matrix, time step= 16
existing matrix, time step= 17
existing matrix, time step= 18
existing matrix, time step= 19
existing matrix, time step= 20
```

E) The model will calculate volumes for the 15 days worth of hydrodynamic data. If the model continues to run past this point, you will see the error 'Problem NF90_open'. This can be avoided by setting the 'days' variable in the input.inc to 15 or by pressing 'control C'

This process can be automated to work on multiple model runs. In order to accomplish this, a script must be written and run in the SSH command window. The

script can be written as a text file in notepad and then saved as .sh file. See Appendix B for instructions on creating the script.

6. Output files

Two summary output files are given in this example, STD_Volumes.csv and StTp_Volumes.csv. STD stands for salinity (S), temperature (T), and dissolved oxygen (D) while StTp stands for salinity (St) and temperature (Tp). These files contain the total volume of each parameter and intersection of parameters for each time step of the HabVol model.

Within the STD_Volumes.csv output file are columns pertaining to the following variables:

- Time = Model Day (days)
- vol = Total volume in model domain (m^3)
- st vol = Total volume within salinity constraints (m^3)
- tp vol = Total volume within temperature constraints (m^3)
- do vol = Total volume within dissolved oxygen constraints (m^3)
- std vol = Total volume meeting the combined salinity, temperature, and dissolved oxygen constraints (m^3)

Within the StTp_Volumes.csv output file are columns pertaining to the following variables:

- Time = Model Day (days)
- vol = Total volume in model domain (m^3)
- st vol = Total volume within salinity constraints (m^3)
- tp vol = Total volume within temperature constraints (m^3)
- do vol = Total volume within dissolved oxygen constraints (m^3)
- s&t vol = Total volume meeting both the salinity and temperature constraints (m^3)

In addition to summary output files for habitat volume, are also output files that are written each time step and provide snapshots of information for each time step. There are two types of these ‘timestep-specific’ output files in HabVol: **total volume** (e.g., similar to above examples) and **habitat surfaces** (e.g., Fig. 2). These output files can be created by changing the appropriate variable in the input.inc files and have a numeric suffix that identifies the timestep. The habitat surface files provide vertical water column habitat information for each grid cell location in the model domain.

The habitat surface output files have the following columns:

- Column 1 – Longitude
- Column 2 – Latitude
- Column 3 – Habitat mask category (-1 = land, 0 = no habitat, 1 = target habitat)

- Column 4 – Bottom depth (m)
- Column 5 – Water surface depth (m)
- Column 6 – Ideal habitat bottom depth (m)
- Column 7 – Ideal habitat surface depth (m)

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Appendix A: Identifying the start date of ROMS output (history) files

Identifying the start date for a ROMS hydrodynamic file can be done in SSH and MATLAB using the following steps.

A) In the SSH command window, type the following command. Make sure to replace 'filename' with the target hydrodynamic file

```
ncks -s "%f\n" -H -C -v ocean_time <filename>
```

B) This will provide a string of numbers. Copy those numbers and paste them into the following command using MATLAB

```
datestr(<numbers here>/86400+datenum([1995 01 01 00 00 00]))
```

example: `datestr(9.410400000000e+007/86400+datenum([1995 01 01 00 00 00]))`

This will calculate a specific date. Use this to identify the hydrodynamic files containing the initial target date for the model run.

Appendix B: Writing a script to run multiple HabVol programs

Scripts should have the following format with separate commands to compile and run the model.

The ‘□’ symbols represent the return command, which could not be inserted into a word document. The ‘rm cat*.csv’ and ‘rm volume*.csv’ delete unnecessary files. However, do not include these commands if you need all of the files for post analysis. It tends to be more efficient to write separate script files, one for compiling the necessary folder and one for running. For example:

```
cd year/DO-Yearling-G-10-98/□./Vol_compile.sh□
```

```
cd 2002/YOY-G-2m-02/□./Volume.exe 2>&1 | tee -a output.txt□rm cat*.csv□rm  
volume*.csv
```

Appendix C: Running HabVol in bioenergetics mode

The habitat volume model can also be run for Atlantic sturgeon using the bioenergetics equations derived from Niklitschek and Secor (2009a,b). The model will similarly incorporate striped bass bioenergetics, but this addition is still under development. In order to run the habitat volume model to calculate volumes of water meeting specific growth criteria defined by bioenergetics, make sure that the 'Bio_on' option in the input.txt file is set to '.TRUE.'

Bioenergetics model parameters and equations are defined in the Constraints_Module.f90. The Atlantic sturgeon bioenergetics equations use a difference unit for dissolved oxygen than the hydrodynamic data so there is a section of code that converts DO to the correct units. Within the bioenergetics model, variables such as fish weight and consumption can be adjusted. Target growth ranges, which are used to define specific habitat categories used by the habitat volume model, are located at the very end of the bioenergetics section. Each category has a minimum and maximum value and the number of categories can be adjusted to the required number. Bioenergetics output files are directly related to these growth categories. For example, setting the model up for two categories will result in two sets of output files with the prefixes 'Cat1_' and 'Cat2_' for the total volume summaries as well as 'Category1_' or 'Category2_' for the individual timestep calculations.