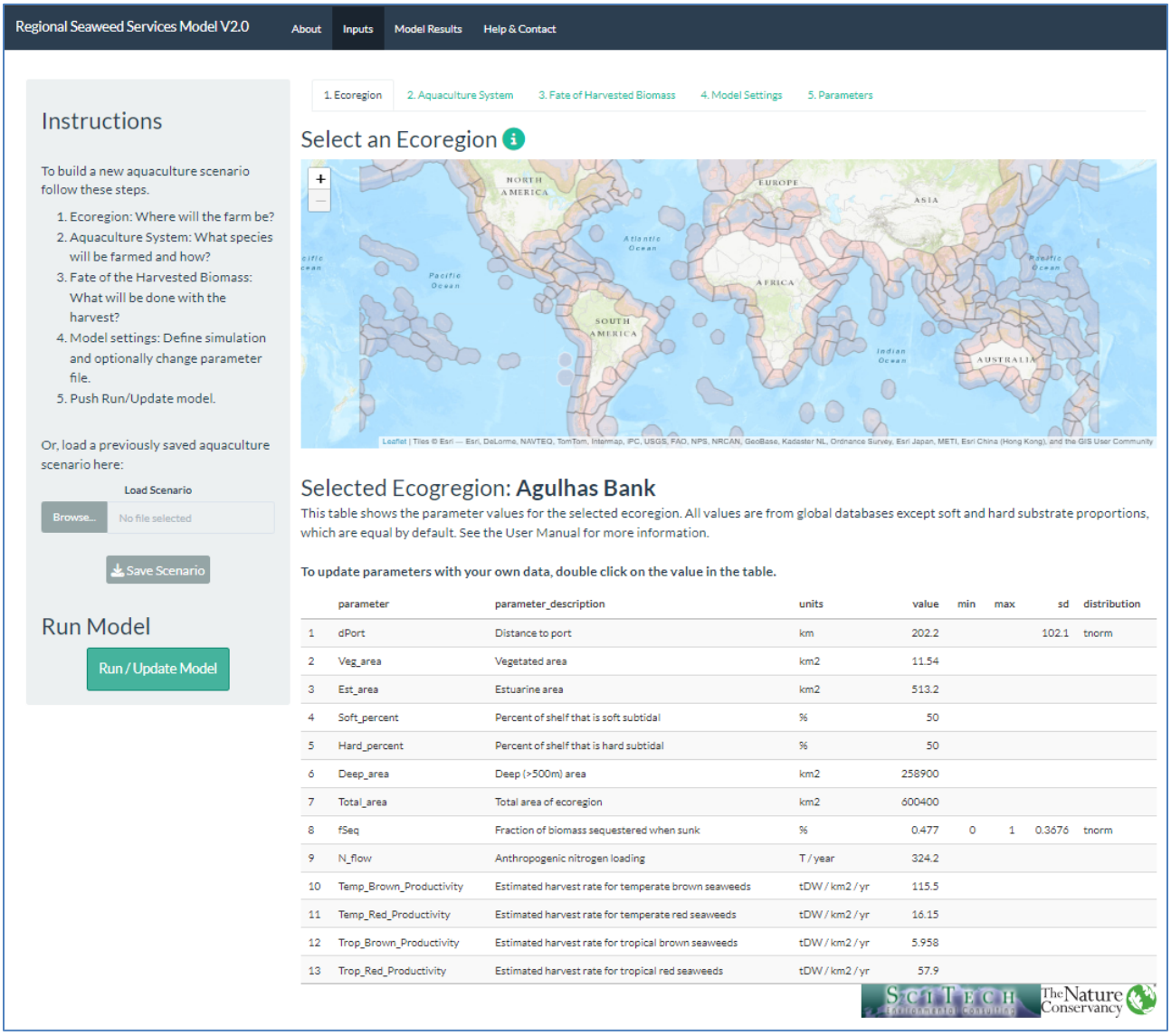
Regional Seaweed Services Model
User's Guide

Revised: 25 January, 2024



1 Getting started

Connect to the model at https://tnc-aquaculture-science.shinyapps.io/RegionalSeaweedServicesModel/.

Instructions are provided in the panel on the left. The steps are organized by the numbered tabs above the map. The top row on the display allows you to switch between screens showing information 'About' the model, the options available on the 'Inputs' and 'Model Results' screens, and 'Help and Contacts'.

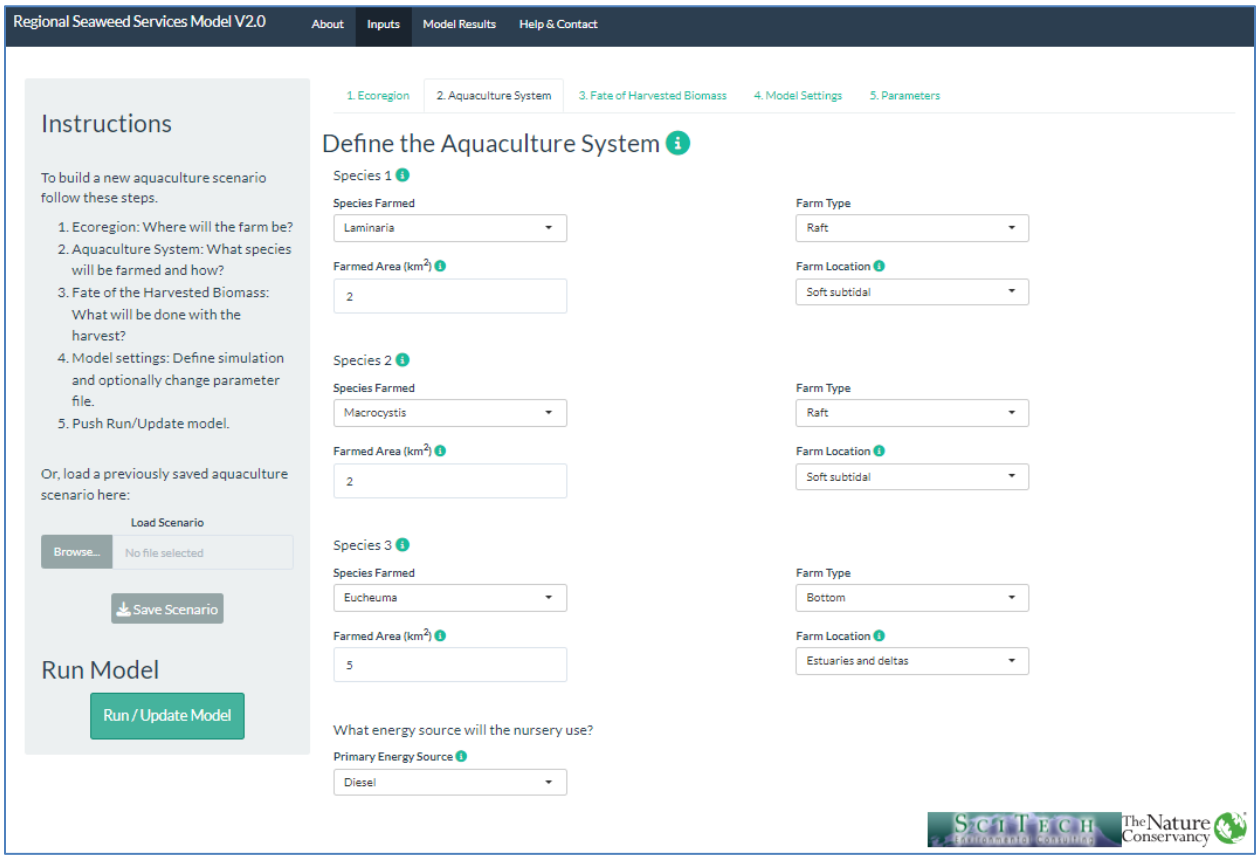
2 Model inputs

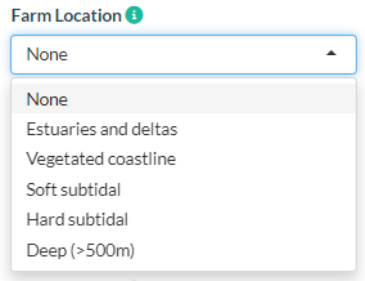
2.1 Ecoregion

Your first step is to select your area of interest from the marine ecoregions defined by Spalding et al. 2007). This is where you will place your seaweed farm(s). If your area of interest spans more than one ecoregion, you will need to run each ecoregion separately. The information held in the RSSM about the selected ecoregion appears in the table below the map and can be edited directly. We use these parameters to tailor the productivity and fate of the cultivated seaweed for the ecoregion. See the Technical Documentation for information on how these parameters are used.

2.2 Aquaculture System

The Aquaculture tab provides drop down lists from which you can select 1) the type(s) of seaweed(s) to be farmed, 2) the type of farming system to be used for the species, and 3) the Carbon Functional Unit (CFU) where the farm is located (Farm Location). See the Technical Documentation for a description of the CFUs. You must also specify the area farmed, and, at the bottom of the screen, the energy source to be used for any kelp nursery facilities. The model currently supports up to three farms to be defined.





We use the ecological setting of the farm to tailor the potential sequestration rates of detritus, typically referred to as particulate and dissolved organic carbon (POC, DOC).

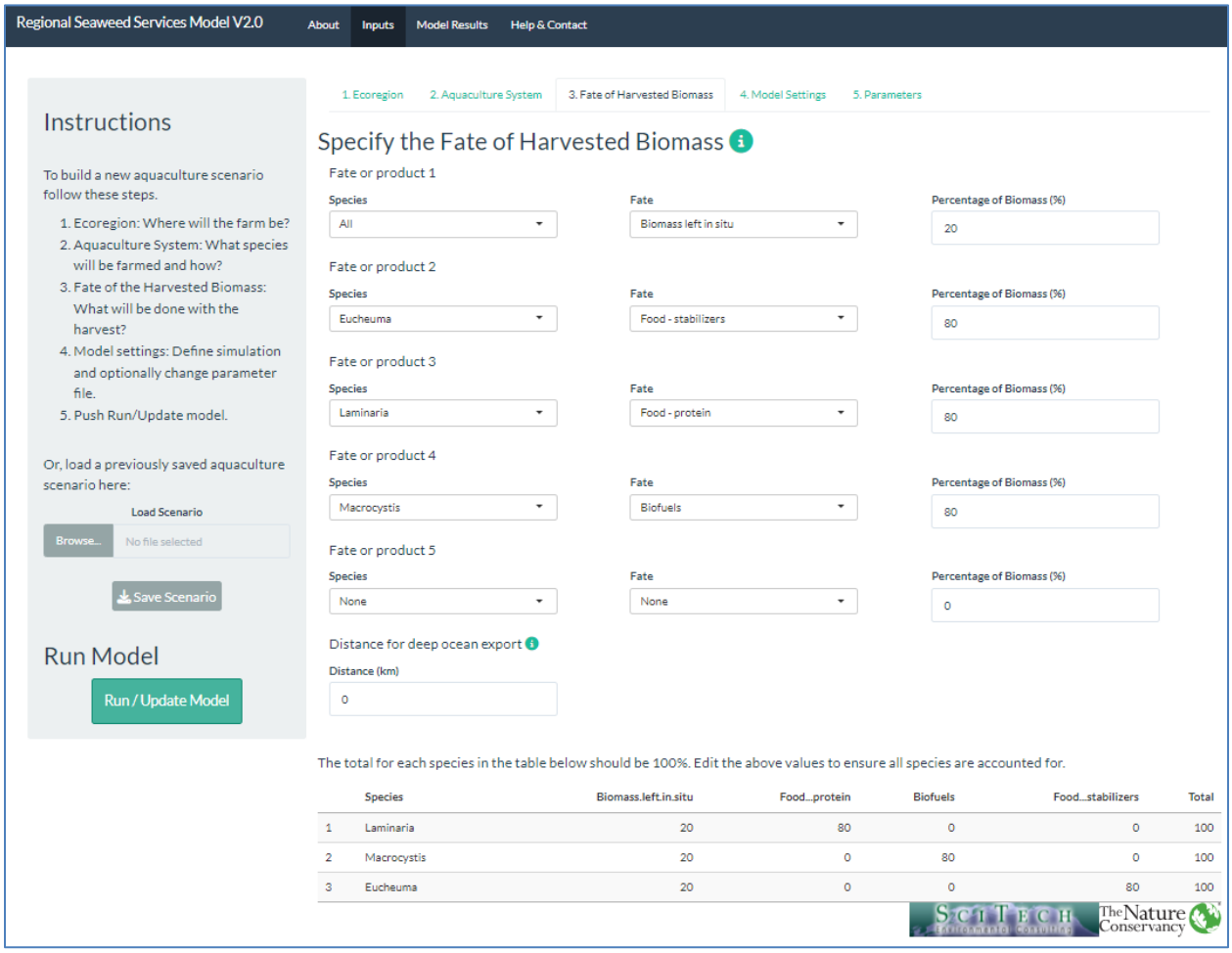
We assume soft bottom and vegetated settings are better at sequestering POC than other parts of the shelf because they are tend to be depositional environments. The proportion of hard and soft bottom is user-specified on the Ecoregions tab (see Technical Documentation).

2.3 Fate of Harvested Biomass

Once the aquaculture system is specified, the next step is to describe how the harvested biomass will be used. This tab offers dropdown lists for the Species (selected from those specified on the Aquaculture System tab) and a diverse collection of fates. The percent of the harvested biomass assigned to that fate is also required. The model currently supports up to five fates to be defined.

The Distance for deep ocean export field is only required if Intentional Sinking is chosen as a fate.

A table below the selection options summarizes the biomass allocations to the selected fates to help ensure all the biomass is accounted for. Biomass fates are described in the Technical Documentation.



2.4 Model settings

This tab offers a summary of the scenario settings. This is useful if you have loaded a pre-defined scenario (see section 2.6 below).

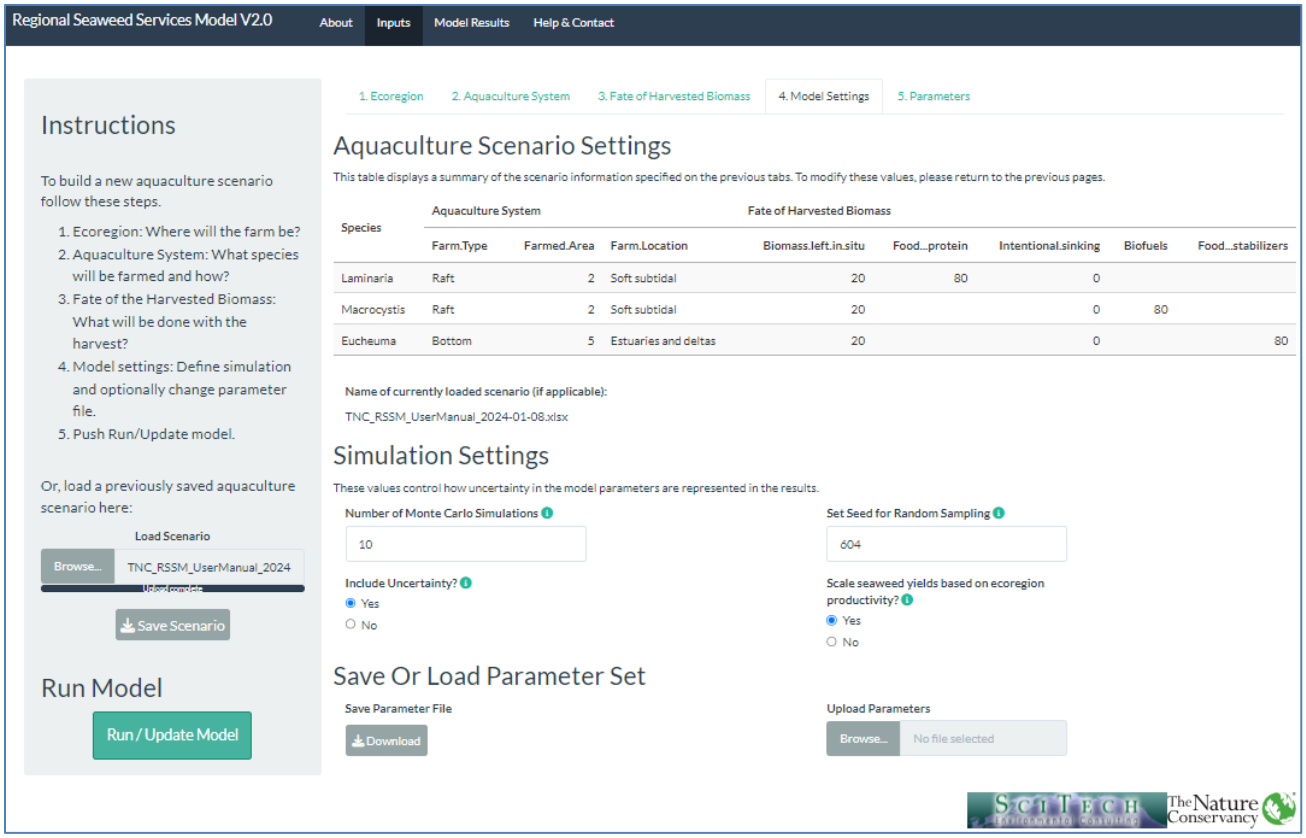
The tab also contains key settings for the model simulation: the 'Number of Monte Carlo Simulations' is a central to the model uncertainty analysis. The number specifies how many times the model will be run, with different set of pseudo-random parameters. The set of results defines the uncertainty for the scenario. IBM provides an accessible summary of Monte Carlo simulation here.

The 'Seed for Random Sampling' specifies the starting point for the random number generator used by the Monte Carlo process. Using the same seed for repeated runs of the same scenario will generate identical results, while a different seed will produce a different, but convergent result (See Technical Documentation for more information).

The settings tab also includes the option for turning off the Monte Carlo uncertainty analysis. This is useful for examining the model state with the mean values of the parameters.

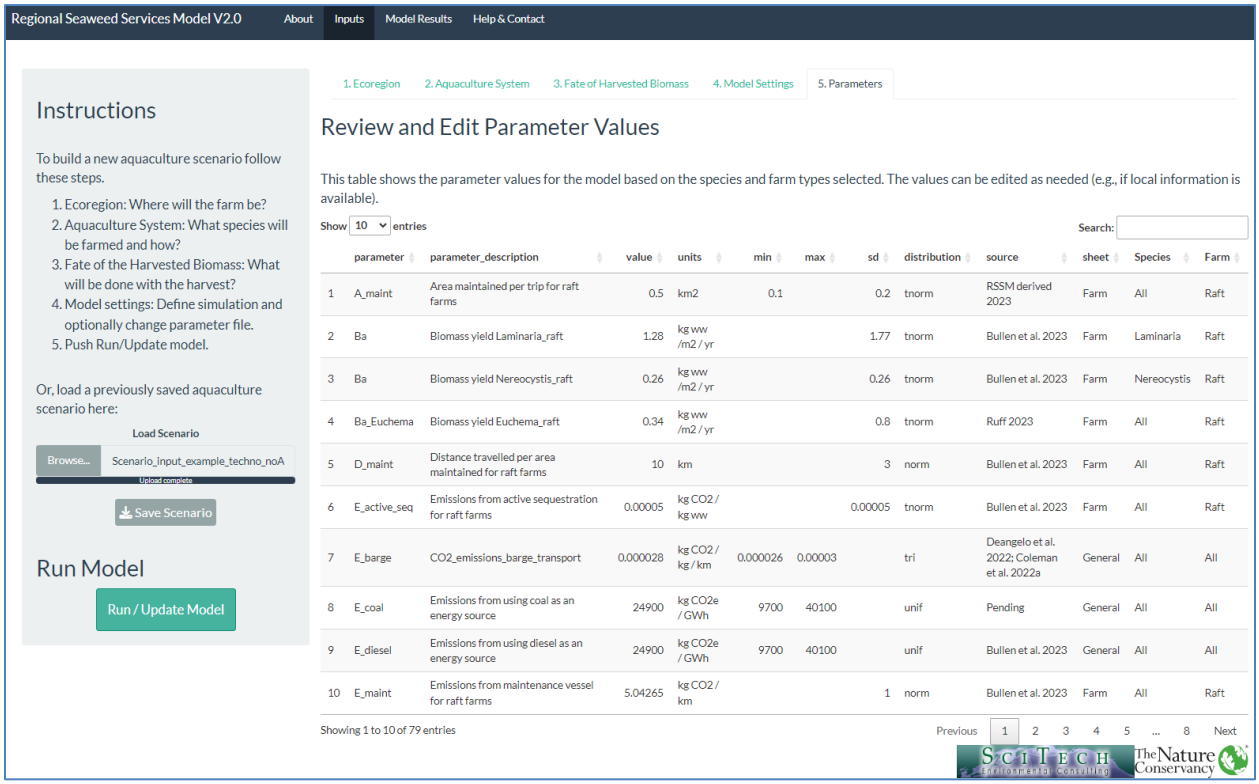
We also provide the option to turn off the Ecoregion scaling of the seaweed production values. Please turn this off if you have location-specific productivity values for the location and species of interest.

This tab also allows you to save or re-load a set of customized parameters (see the following 2 sections).



2.5 Parameters

This tab allows you to view and edit any parameter value in the model. Using the search option allows you to limit the list. If you have a set of parameters you would like to save for your area of interest, you can edit them here, and then export them to a MS Excel spreadsheet (.XLSX) on the model settings tab.



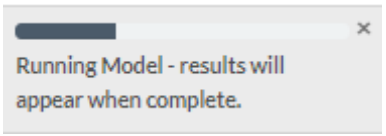
2.6 Loading and saving scenarios and parameters

We anticipate the model will be used mainly in an exploratory fashion, to examine how parameter changes will influence productivity, emissions, and benefits. We have therefore provided options to save and re-load the farming scenario (i.e., Aquaculture System and Fate of Harvested Biomass). Thus, once you have created a farming scenario that represents your study area, you can use the 'Save Scenario' button on the Instructions panel to save the scenario to a MS Excel file (.XLSX). This can then be loaded at a future time without the need to build the scenario from scratch.

The model parameters can also be saved and loaded (from the Model Settings tab described above). Parameters can be edited within the RSSM, or using Excel to modify a saved parameter set. However, caution is warranted as any changes to the format or structure of the file may cause re-loading to fail. We therefore strongly recommend using backups when editing the parameter file directly.

3 Model results

After pressing 'Run/Update Model' on the Instructions panel, a progress bar will appear on the bottom right of the screen. Depending on how many Monte Carlo simulations you selected on the Model Settings tab, the run will take from a few seconds (for 10 runs) to a few minutes (for 1000 runs), depending on the speed of your computer.

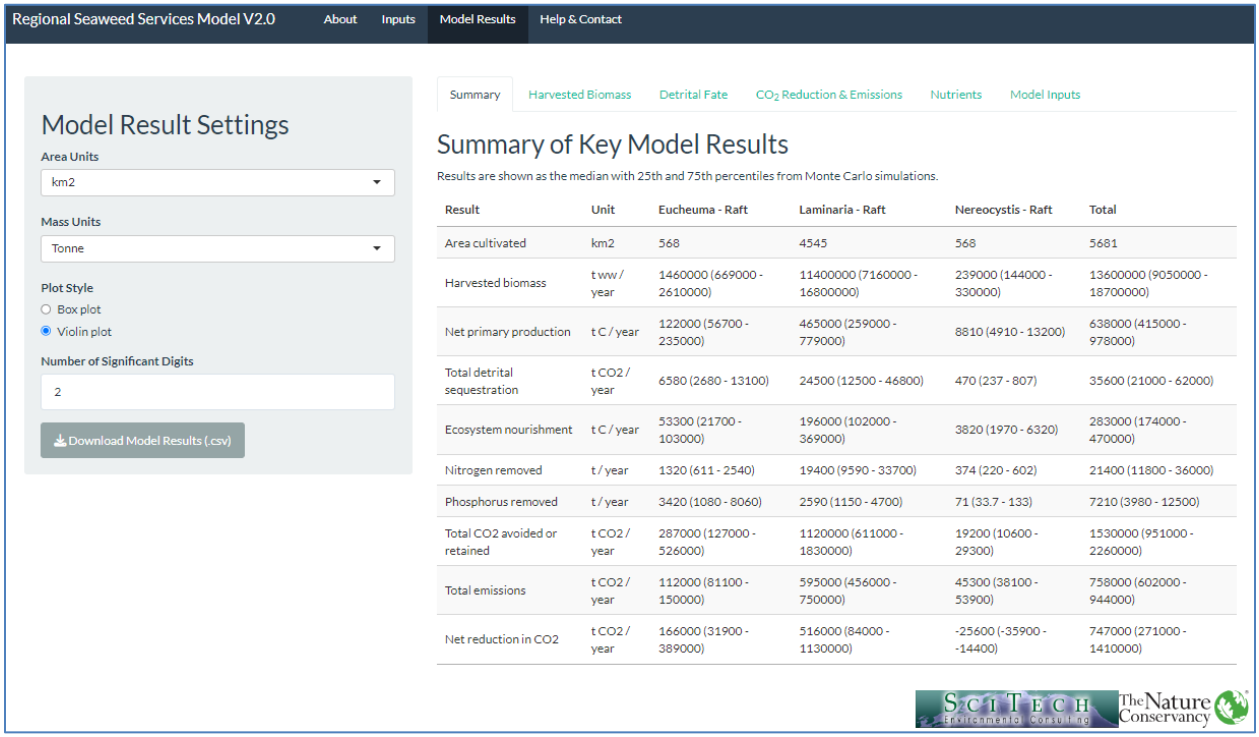


Once the run is complete, the model will switch to the Summary tab of the Model Results screen.

3.1 Summary

As the first tab of the results screen, the Summary of Key Model Results provides numerical values (as the median, along with the 25th and 75th percentiles from the Monte Carlo simulation.

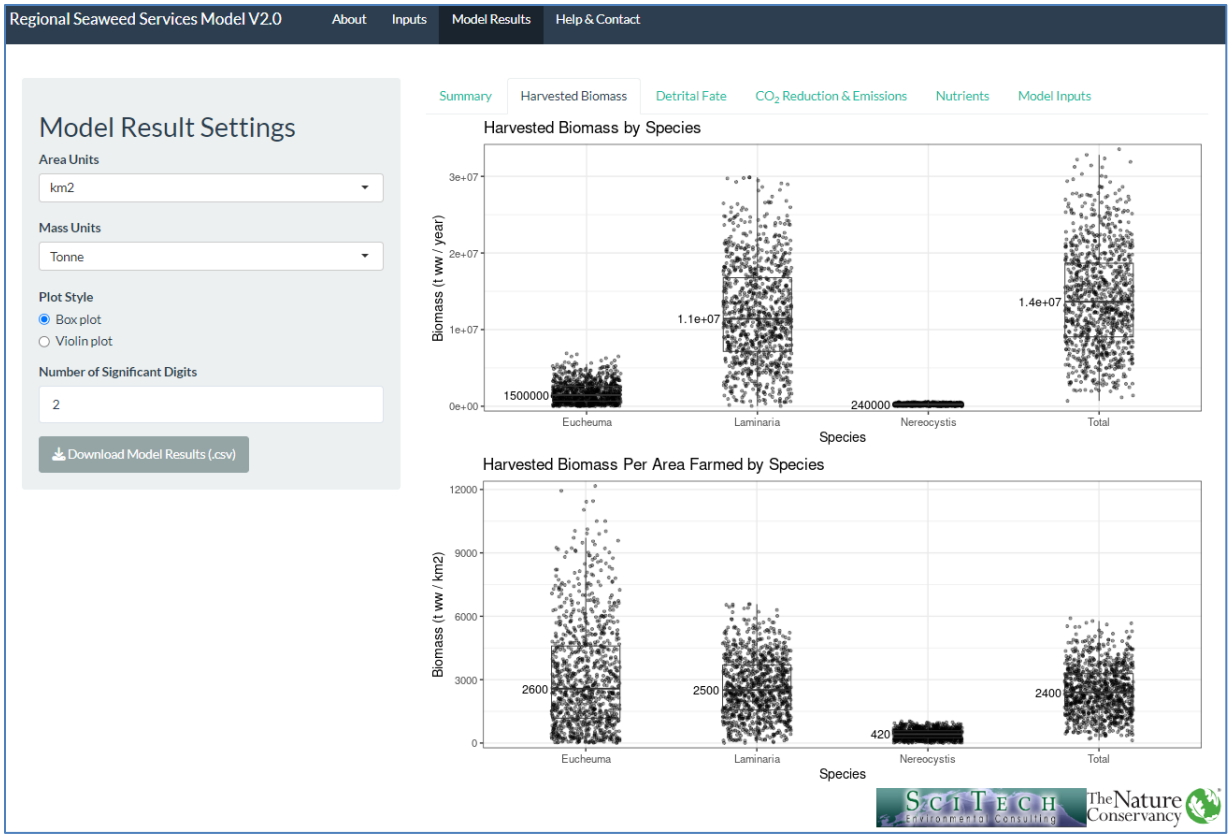
For ease of interpretation the Model Results Settings panel on the left allows you to change the units to the most appropriate for any result you are interested in, as well as adjusting the number of significant digits displayed on tables or figures. You can also choose between box plots and violin plots, illustrated in the following section.



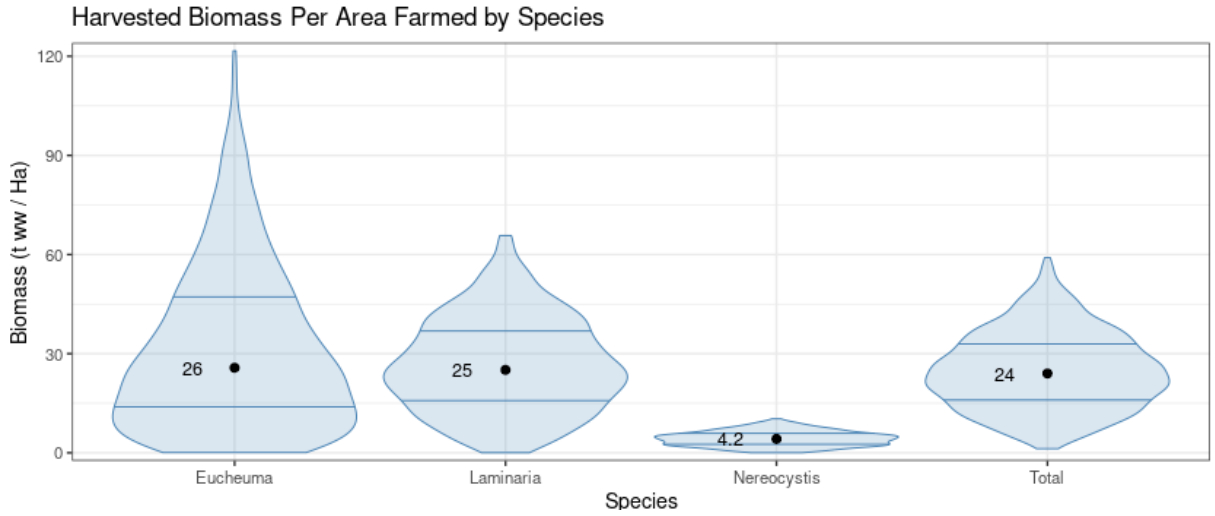
Result	Unit	Eucheuma - Raft	Laminaria - Raft	Nereocystis - Raft	Total
Area cultivated	km2	568	4545	568	5681
Harvested biomass	t ww / year	1460000 (669000 - 2610000)	11400000 (7160000 - 16800000)	239000 (144000 - 330000)	13600000 (9050000 - 18700000)
Net primary production	t C / year	122000 (56700 - 235000)	465000 (259000 - 779000)	8810 (4910 - 13200)	638000 (415000 - 978000)
Total detrital sequestration	t CO2 / year	6580 (2680 - 13100)	24500 (12500 - 46800)	470 (237 - 807)	35600 (21000 - 62000)
Ecosystem nourishment	t C / year	53300 (21700 - 103000)	196000 (102000 - 369000)	3820 (1970 - 6320)	283000 (174000 - 470000)
Nitrogen removed	t / year	1320 (611 - 2540)	19400 (9590 - 33700)	374 (220 - 602)	21400 (11800 - 36000)
Phosphorus removed	t / year	3420 (1080 - 8060)	2590 (1150 - 4700)	71 (33.7 - 133)	7210 (3980 - 12500)
Total CO2 avoided or retained	t CO2 / year	287000 (127000 - 526000)	1120000 (611000 - 1830000)	19200 (10600 - 29300)	1530000 (951000 - 2260000)
Total emissions	t CO2 / year	112000 (81100 - 150000)	595000 (456000 - 750000)	45300 (38100 - 53900)	758000 (602000 - 944000)
Net reduction in CO2	t CO2 / year	166000 (31900 - 389000)	516000 (84000 - 1130000)	-25600 (-35900 - -14400)	747000 (271000 - 1410000)

3.2 Harvested Biomass

This results tab shows the net farm production as harvested biomass by species, and illustrates how the graphs display the distribution of the Monte Carlo results. In this case, we are showing the results from 1000 simulations.



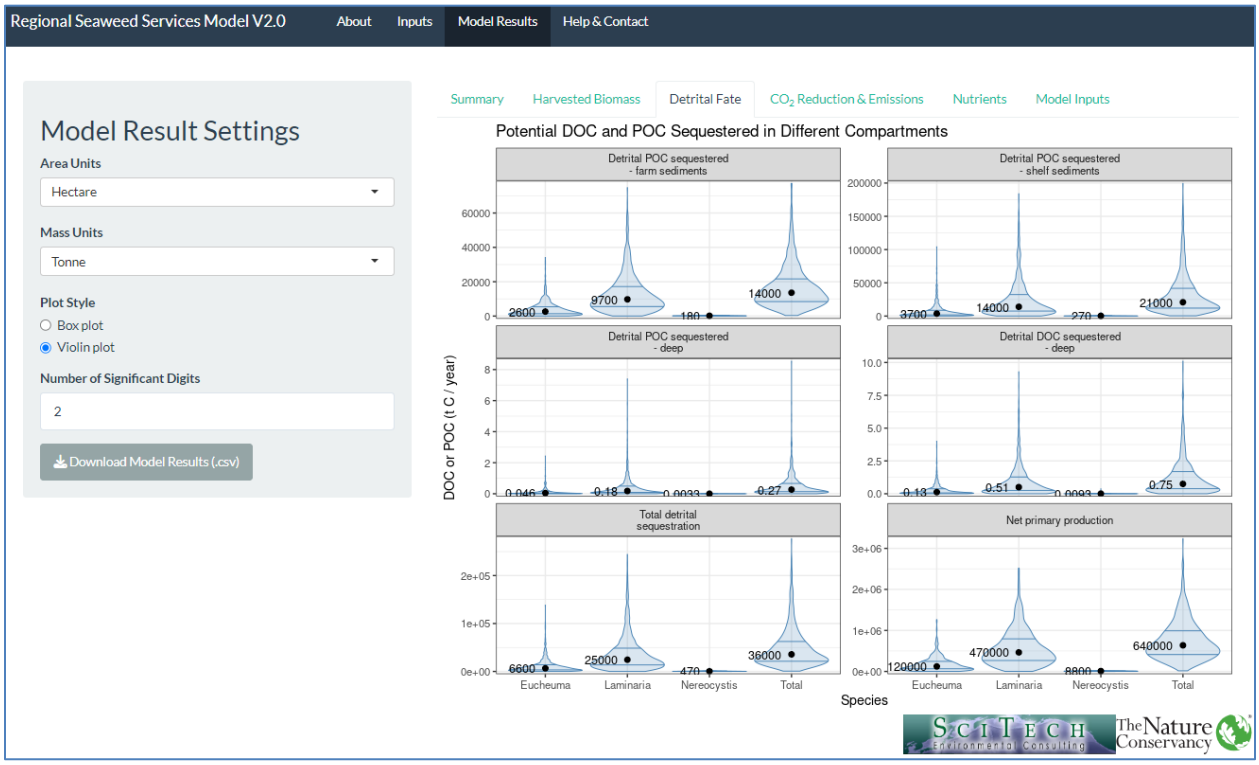
The figure below shows the same information as the bottom panel in the above figure, illustrating the ability to change units, and to display the data as a violin plot. In this case, we changed the units to display tonnes / Ha, a common unit for areal biomass estimates. The violin plots more clearly show the distribution of the uncertainly as estimated by the Monte Carlo simulation.



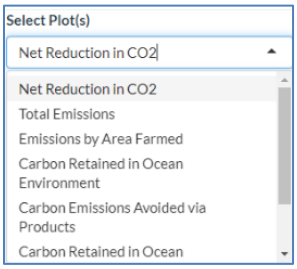
3.3 Detrital fate

This Results tab shows the predicted sequestration in the different potential compartments. For POC, these include under-farm sediments, other on shelf sediments (conditioned on the farm location), and natural transport to the deep ocean. We assume that DOC, by its nature and ecological role, does not sequester unless it is transported below a sequestration threshold, which we set at 500 m.

See the Technical Documentation for a description of these pathways and the supporting equations.



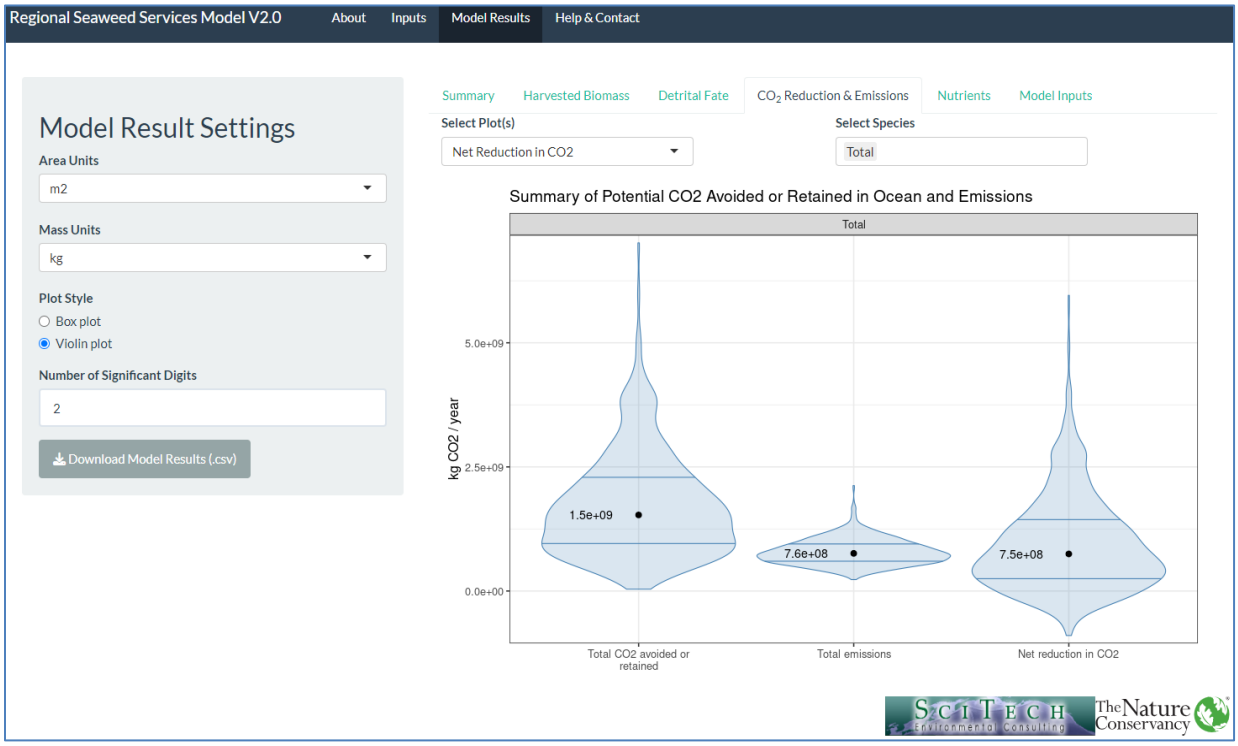
CO_2 Reduction & Emissions



This tab provides plots to view potential CO_2 reductions and emissions from seaweed production and the manufacture of replacement products.

The plots are selected from the Select Plot(s) drop down list (at right).

These include Net Reduction in CO_2 shows the total CO_2 avoided or retained in the ocean, total CO_2 emissions, and the difference (image below).

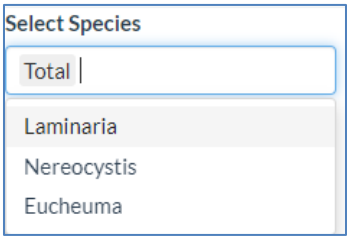


Other plots include:

- Total Emissions: shows a breakdown of the production and replacement product emissions;
- Carbon retained in the Ocean Environment: shows the total seaweed biomass potentially sequestered.
- Carbon emissions avoided via replacement products

Plots of emissions, carbon retained, and emissions avoided are also available scaled to the farm area.

Each of these plots can show totals, or the results for any individual species, as well as combinations of species and total by using the Select Species dropdown.



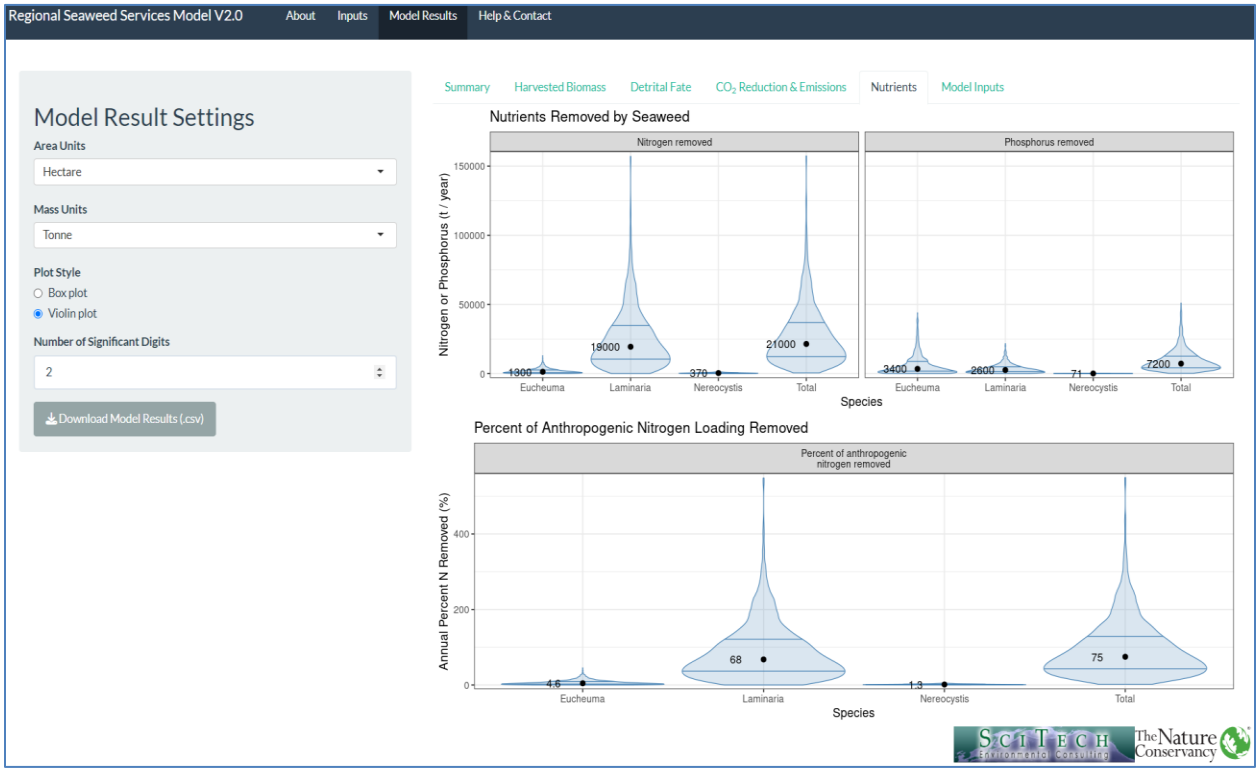
To add multiple plots, just click on the ones desired from the 'Select Species' dropdown. To remove a plot, simply highlight the species to remove and press 'Delete' on your keyboard.

See the Technical Documentation for a description of these pathways and the supporting equations.

3.4 Nutrients

These results represent the first global assessment of the regional utility of seaweed farms at mitigating excess nutrients from coastal waters. While these estimates could be overestimates in ecoregions where farms would be situated further from highly developed regions, the could also underestimate the effectiveness in regions where seaweed farms are located in areas of high terrestrial nitrogen input. In either case, the relative effectiveness across ecoregions and different farm types remains accurate.

These results present the total nutrient mitigation, and the proportion removed by each species farmed. We report the estimates as both mass of nutrients (nitrogen and phosphorus) removed, and the annual percent of anthropogenic loadings removed.



See the Technical Documentation for a description of the underlying equations and parameters.

3.5 Model inputs

This tab allows you to explore the value of every parameter in the current model run. Simply select the parameter from the dropdown list and the parameter value will appear. The number of parameters on the drop-down list will increase with model complexity, as additional parameters are required.

Parameters include both constants and distributions. Constants are shown as the value with units, distributions generated as part of the Monte Carlo analysis are shown as distributions.

The appearance of these distributions will become increasingly smooth as the number of Monte Carlo simulations are increased (on the Inputs, Model Settings tab). Several thousand simulations are required to create a smooth distribution. The image below shows one distribution from 1000 simulations.