How to do the Ecosim fitting

From 0 to the final plots

1. Create and load the time series

First of all, we need to create a .csv with all the time series that we have, including biomass, catch, fishing mortalities, fishing effort, environmental variables, … In this .csv the first row is the name of the functional group; the second row is the weight of the time-series (from 0 to 1) which is in some way how much we want the model to adjust to that time-series. The third row is the functional group number in the model, and the fourth row is the type of the time-series. Then each row contains the value of that time-series for each year.

	A	B	C	D	E	F	G	H	I	J	K
1	Title	Blue shark	Other billfish	Swordfish	Bigeye adult	Bigeye juveni	Yellowfin adı	Yellowfin juv	Skipjack adu	Skipjack juve	Albacore
2	Weight	1	1	1	1	1	1	1	1	1	1
3	Pool code	4	11	12	13	14	15	16	17	18	19
4	Type	1	1	1	1	1	1	1	1	1	1
5	2003	0.01451812	0.01428706	0.0103	0.0262	0.0127	0.0795	0.0306	0.0671	0.00225	0.00271217
6	2004	0.01124523	0.01336678	0.00812106	0.01981708	0.01508835	0.09084586	0.02550097	0.06700481	0.00247201	0.00196236
7	2005	0.00958049	0.01196806	0.00759754	0.02061648	0.01301654	0.0808583	0.02081115	0.06735616	0.0014638	0.00190999
8	2006	0.00925668	0.01251193	0.00831922	0.02073951	0.01341797	0.07034724	0.0163385	0.05706939	0.00101327	0.00268781
9	2007	0.00964423	0.01220125	0.00756275	0.01976581	0.01213759	0.05360449	0.01648917	0.03466657	0.00149766	0.00264244
10	2008	0.00754854	0.01215082	0.00786479	0.01957491	0.01099568	0.04262823	0.01997843	0.0320121	0.00198218	0.00240474
11	2009	0.00798548	0.01289727	0.00814996	0.01904099	0.0110808	0.04084625	0.02491932	0.03921893	0.00185254	0.00174824
12	2010	0.00889632	0.01295415	0.00655304	0.01643665	0.01177747	0.0484633	0.02487402	0.04643553	0.0014006	0.00192984
13	2011	0.00837645	0.01298621	0.00803047	0.0157893	0.00987961	0.05874719	0.02068122	0.04484092	0.0011757	0.00130835

Figure 1. Example of the .csv file needed to introduce the time-series to the Ecosim model.

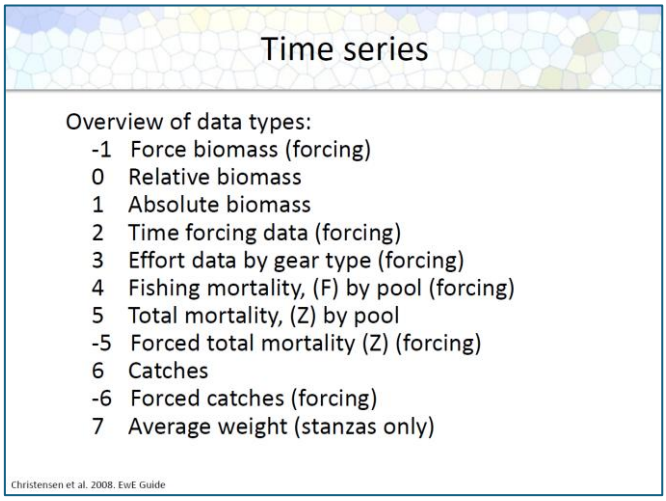

Figure 2. Reference of each poll code that needs to be used depending on the time-series data used (slide from Ecopath course – Marta Coll).

Once we have the .csv document done, the best idea is to save it as the scenario that it represents, probably the Historical. After that we can import the time series to the Ecosim. Ecosim → Time series → Import and use the browser to find the .csv. Once all the time series are loaded, save the model. The next time that we open the model, when coing to the time series submenu, we will only need to press "Load" and select the file. After that we have to go to forcing function, Apply forcing functions (producer) and double-click on the white space of the second

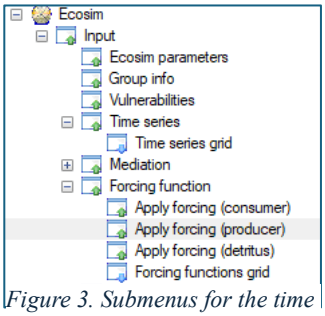

Figure 3. Submenus for the time series and the forcing function.

column, and assign the primary production time series to it. Once done, save again the model.

2. Model fitting

With the time series loaded we can move on to the fitting of the model, which basically the model try's to find the vulnerability values that give the best fit of the predictions to the observed values of the time series and gives us two statistical parameters of the performance, the sum of squares (SS) and the Akaike Information Criterion (AIC). The model with the best fit will be the one with the lowest values on both cases.

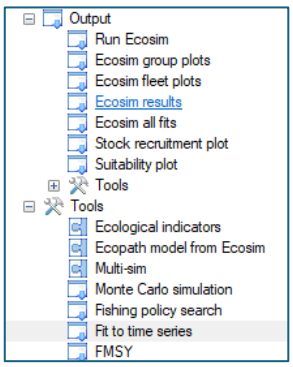

Figure 4. Submenus for the fitting.

To start, we need to go to Ecosim → Outputs → Run Ecosim and run the model. The predictions (lines) and the observed values (circles) should appear. Previously a pop-up window will appear, and we will have to give a name to the Ecosim model and the length in years that we want the model to run. After that we can go to Ecosim → Outputs → Tools → Fit to time series

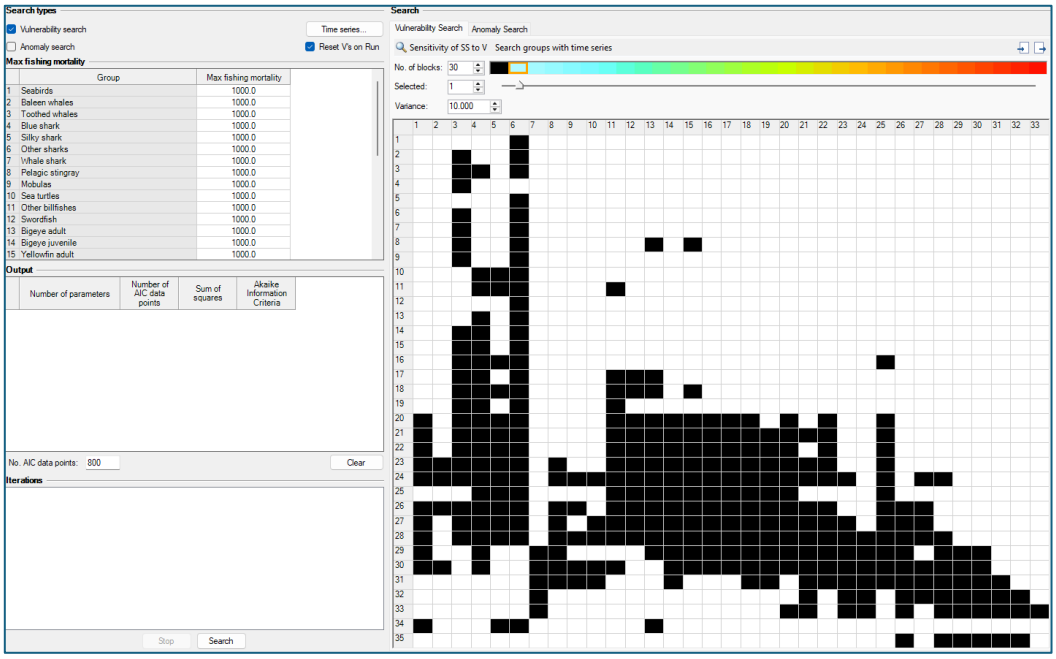

Figure 5. View of the fit to time series window.

The maximum number of vulnerabilities that we can estimate if:

$$Max\ Vs\ to\ estimate = (n^{o}of\ biomass\ time\ series + n^{o}\ of\ catch\ time\ series)-1$$

Before to start we need to create a spreadsheet named "Fitting"to write down the results. As shown in *Figure 6*.

First column is a series of numbers, the second one is the name of the scenario, third one is the K, the next one is the number of vulnerabilities that the model is estimating, # spline is 0 as we have a time series of primary production anomaly in the model, and in the SS column and in the AIC column we will write down respectively the results of each fitting try.

	Name	K	# Vs	# spline	SS	AIC
1	Fishing, PP	0	0	0		
2	Fishing, PP and 1v	1	1	0		
3	Fishing, PP and 2v	2	2	0		
4	Fishing, PP and 3v	3	3	0		
5	Fishing, PP and 4v	4	4	0		
6	Fishing, PP and 5v	5	5	0		
7	Fishing, PP and 6v	6	6	0		
8	Fishing, PP and 7v	7	7	0		
9	Fishing, PP and 8v	8	8	0		
10	Fishing, PP and 9v	9	9	0		
11	Fishing, PP and 10v	10	10	0		
12	Fishing, PP and 11v	11	11	0		
13	Fishing, PP and 12v	12	12	0		
14	Fishing, PP and 13v	13	13	0		
15	Fishing, PP and 14v	14	14	0		
16	Fishing, PP and 15v	15	15	0		
17	Fishing, PP and 16v	16	16	0	609.0571	-185.4651
18	Fishing, PP and 17v	17	17	0	597.1332	-199.1947
19	Fishing, PP and 18v	18	18	0	594.2903	-200.9193
20	Fishing, PP and 19v	19	19	0	594.4565	-198.5970
21	Fishing, PP and 20v	20	20	0	592.1725	-199.5727
22	Fishing, PP and 21v	21	21	0	587.7334	-203.4829
23	Fishing, PP and 22v	22	22	0	590.3066	-197.8732

Figure 6. Example of the spreadsheet needed to write down the results of the fitting.

Once we know the maximum number of vulnerabilities that we can estimate we make click on sensitivity of SS to V. In the pop-up window we will select "By predator", set the number of categories to the max Vs number and click on search. Once finished the columns will appear in colours, click Ok. The columns of the main window of the "fit to time series" will change to different colours; make sure that "Vulnerability search" and "Reset Vs on the run" are selected and click Search. After a couple of minutes, the search will be finished and in the window of the middle a SS and an AIC value will appear, copy and paste them in the corresponding cells of the spreadsheet. Then, open the vulnerabilities window, the values will no longer be 2, each FG will have a different number. Reset all the vulnerabilities to 2 and repeat the process of the "Fit to time series" but reducing the number of categories by one and run again the process until getting the SS and AIC. Repeat this process until you see a clear trend of SS and AIC growing.

Once done this, check the three lowest values of AIC in the spreadsheet and mark them as the best fitting matrix of vulnerabilities. Then, in a new sheet of the same Fitting spreadsheet do two tables as in *Figure 7*.

Vuln	**18**	**20**	**21**
SS	**594.29**	**592.17**	**587.73**
AIC test	**-200.92**	**-199.57**	**-203.48**
Swordfish	1.522	1.449	1.434
Bigeye Adult	0.501	0.51	0.506
Bigeye Juvenile	2.174	1.918	2.067
Yellowfin Adult	1.01	1.112	1.217
Yellowfin Juvenile	1.936	1.92	1.945
Skipjack Adult	1.207	1.236	1.243
Skipjack Juvenile	3.661	3.734	3.754
Albacore	2.74	2.89	3.005
Total	14.751	14.769	15.171

Vuln	**18**	**20**	**21**
SS	**594.29**	**592.17**	**587.73**
AIC test	**-200.92**	**-199.57**	**-203.48**
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Yellowfin Adult	1.01	1.112	1.217
Yellowfin Juvenile	1.936	1.92	1.945
Skipjack Adult	1.207	1.236	1.243
Skipjack Juvenile	3.661	3.734	3.754
Total	10.489	10.43	10.732

Figure 7. Example of the tables needed to select the best fitting matrix of vulnerabilities.

In this tables we will include the number of vulnerabilities on the top, the value of SS and the value of AIC. Then we will include the most important FG of the model, or the functional groups for which we have more interest to be good fitted. Then we will run again each the "fit to time

series" routine but only for the three numbers of vulnerabilities selected. For the first one, once finished and we have clicked on Run Ecosim, first we will go to the vulnerabilities matrix, copy the matrix and paste it in a new sheet of the Fitting spreadsheet. Then we will go to the Run Ecosim plot and select the first FG that we have included in the table of *Figure 7*, and on the top of the column of all the functional groups names will appear the value of the SS for that FG (*Figure 8*); write that value in the table of *Figure 7*. Do the same with the rest of the FG until the first column of the table is completed. The total is the sum of all values. Repeat the same process for the other two vulnerabilities and select the model that gives the lowest Total value.

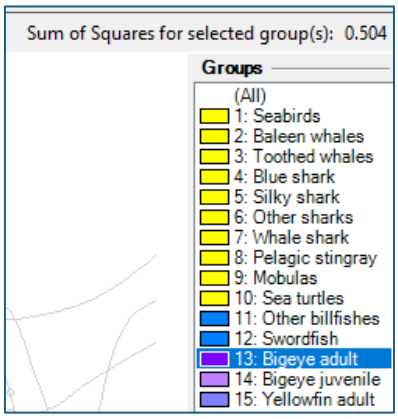


Figure 8. Example of the sum of sqaures value for the Bigeye adult functional group.

Once we have found the best vulnerability matrix, we run again the "fit to time series" with that value and save the model. Further improvements on the vulnerabilities can be done manually.

3. Obtain the model results

Once we have the model with a good fitting we can move on to obtain the results.

First, we will go to the top menu and click on Tools → Ecological indicators and we will select all the indicators of the white column, and Run with Ecopath, Run with Ecosim, Run with Monte Carlo, and automatically save CSV files (*Figure 9*).

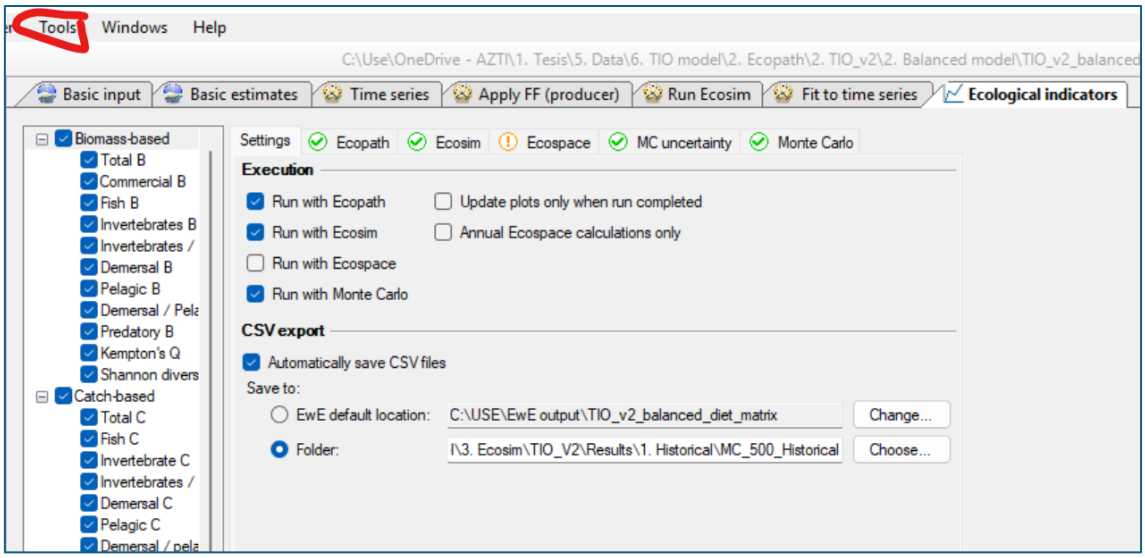


Figure 9. Boxes that need to be checked before proceeding to obtain the results.

Then, before proceeding to run the Ecosim and the uncertainty we need to create a few folders.

In the folder where we have saved the Fitting spreadsheet, we will create a folder named "Results"

Inside this Results folder we will save a .csv document called "fg_names…" with one clomn named fg_number and another one named fg_name, containing all the numbers and the names of the functional groups respectively (*Figure 10*).

Then, inside this folder we will create 4 folders as in *Figure 11*.

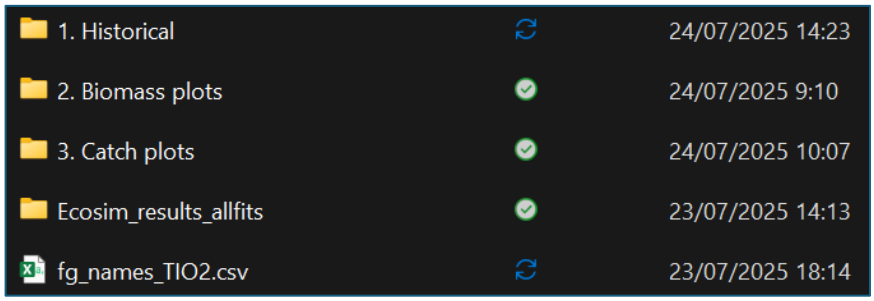
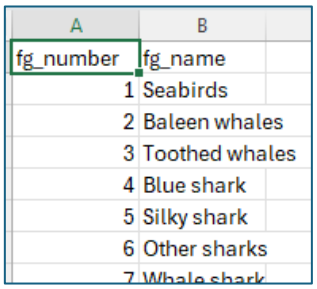


Figure 11. The 4 folders that need to be created.



fg_number	fg_name
1	Seabirds
2	Baleen whales
3	Toothed whales
4	Blue shark
5	Silky shark
6	Other sharks
7	Whale shark

Figure 10. Example of the document

The inside the first folder, we will have to create 5 new folders with the following names.

The number, in this case, 250, depends on the number of Monte Carlo simulations that we do. We will have to set the folder Indicators_Historical, as the folder on the "Save to:" of Figure 9.

Once we have done this we can go to Ecosim → Outputs → Tools → Monte Carlo simulation

In there we have to select the number of simulation trials. In "Save output as:" make sure it's Separated files per trial. Click on Timeseries… and make sure they are charged. And then select the same boxes and maintain the values of *Figure 12*.

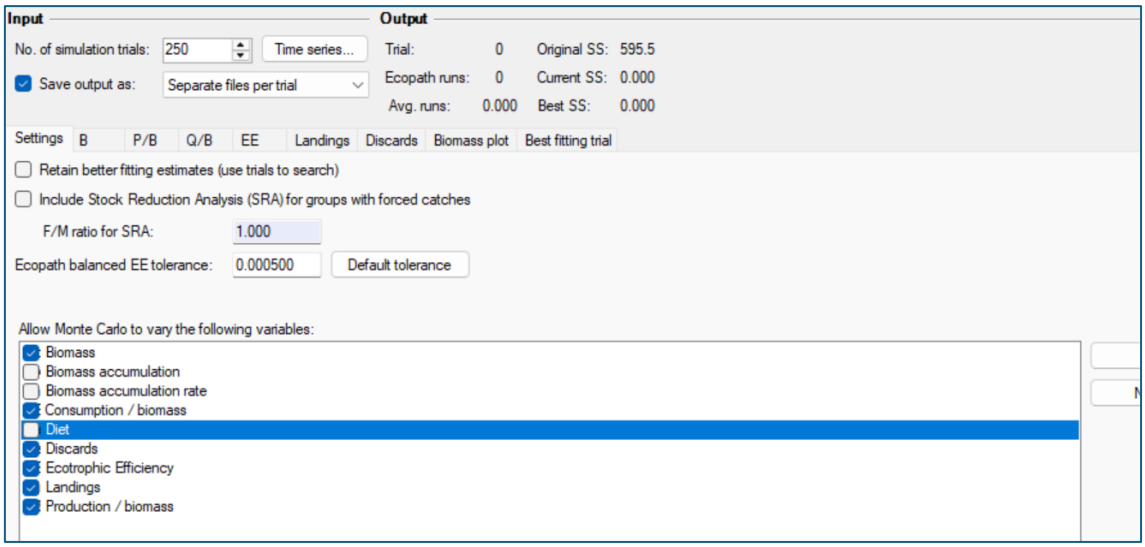
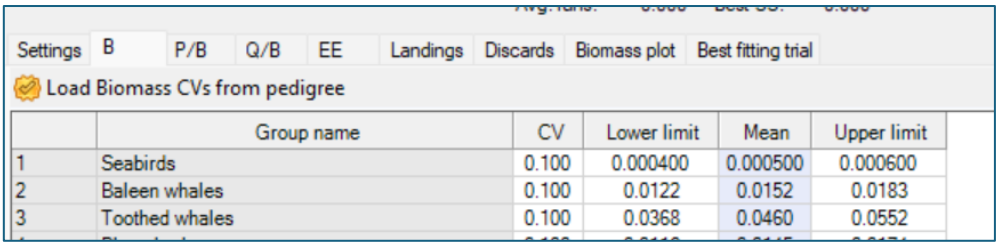


Figure 12. Things to set before running the Monte Carlo.

Then we need to set the CV and we have two options, set them manually or if we have previously introduced values of the pedigree, we can charge them just by clicking on the 2Load Biomass CVs from pedigree" icon (*Figure 13*).



	Group name	CV	Lower limit	Mean	Upper limit
1	Seabirds	0.100	0.000400	0.000500	0.000600
2	Baleen whales	0.100	0.0122	0.0152	0.0183
3	Toothed whales	0.100	0.0368	0.0460	0.0552

Figure 13. Icon to load the CVs from the pedigree.

We have to do the same for the B, P/B, Q/B, EE, Landings and Discards. Once we have this done, we can hit "Run trials". This can take a few hours or even a day depending on the number of simulations and the CVs.

Once the Monte Carlo is finished, we have to go to the folder that appears in the "EwE default destination" in *Figure 9*. There we will find a folder which will contain a mc_input folder and as many folders as Monte Carlo trials we have set. We have to copy this entire folder and paste it in our "MC_250_Historical" folder. Then we will have to check our Indicators_Historical folder where we should find four files (*Figure 14*).

Figure 14. Four files generated by the Ecological Indicators submenu after running the Monte Carlo.

After that we can go back to the Ecopath software, and go to Ecosim → Outputs → Run Ecosim (before making sure that the time series are loaded). Once the Ecosim has run, we go to the menu below "Ecosim group plots" (*Figure 15*) and click on "Save results to .csv"

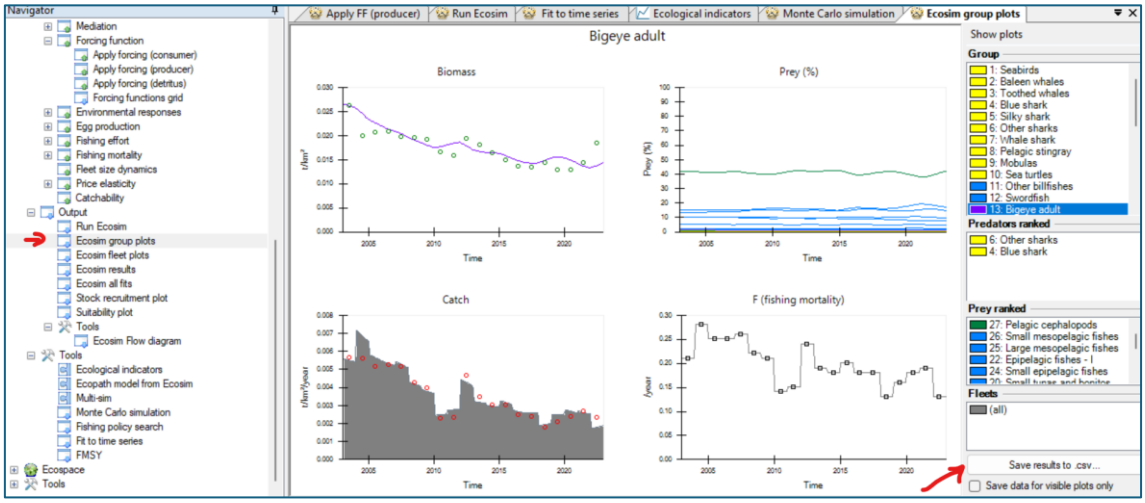


Figure 15. Ecosim group plots window.

Once we click on Save results to .csv a pop-up window will appear. We must search and select the folder named "Predicted" that is found inside the 1. Historical folder. At this point we have managed to have all the results needed at the moment. Now we can move on to process this data to produce the plots.

4. Process the data

First, we need to create a folder with the name "csv" inside the "Outputs_250_historical", and inside this "csv" folder we need to create two new folders named: Biomass and Catch.

Once we have this done we can open the script "Ecosim_Monte_Carlo_files_tretment_ECOTUN.R" that can be found here: https://github.com/roger045/Ecosim_Fitting/tree/main

This script saves in the corresponding Biomass and Catch folders of the csv folder a .csv file for each functional group, which contain the columns shown in *Figure 16*. Apart it produces a basic plot for each FG and saves it in the same folder.

	years	mean	p05	p95	predicted	observed
2	2003	0.01450951	0.01359251	0.01540983	0.01451811	0.01451811
3	2004	0.01376246	0.0129401	0.0145851	0.01375826	0.01124523
4	2005	0.01195117	0.01118066	0.01281569	0.01193519	0.00958049
5	2006	0.01026063	0.00952147	0.01113428	0.01023575	0.00925668
6	2007	0.00925158	0.00845094	0.01023465	0.00921888	0.00964423
7	2008	0.00841801	0.0075573	0.00942555	0.0083786	0.00754854
8	2009	0.00759536	0.00668525	0.00865992	0.00755075	0.00798548
9	2010	0.00705567	0.00605932	0.00818203	0.00700567	0.00889632
10	2011	0.00684492	0.00572381	0.00811828	0.00678879	0.00837645
11	2012	0.00634868	0.00519444	0.00763457	0.0062893	0.00687314
12	2013	0.0056671	0.00453625	0.00694918	0.00560588	0.00663936
13	2014	0.00555855	0.00435317	0.00696912	0.00548973	0.00565775
14	2015	0.0058505	0.00448559	0.00746589	0.00576835	0.00689337

Figure 16. Example of the file resulting for each FG after running the script.

We can also do the same for the indicators, with an script that opens the data saved in the folder "Indicators_Historical" and produces the .csv files like in Figure 16 for each indicator apart from a simple plot. We have to manually create a .csv file with the names of the indicators and their units. Both, the script "Indicators_files_and_simple_plots.R" and the .csv with the names "biodiv_ind_Monte Carlo_names.csv" can be found here: https://github.com/roger045/Ecosim_Fitting/tree/main. The resulting .csv files will be saved in the folder "Outputs_Indicators_Historical".

Once we have all this files we can proceed to plot it.

5. Plot the data

To produce the biomass plots we need to open the scrip "1. plots_pred_obs_biomass.R" that can be found in here: https://github.com/roger045/Ecosim_Fitting/tree/main

This script uses the scripts previously created for each FG to produce a plot of the predicted biomass (line), observed values of biomass (dots) and the 5th and 95th percentiles of uncertainty around the prediction obtained from the Monte Carlo routine (*Figure 17*). In also ads a p-value and a rho prom a Spearms correlation test.

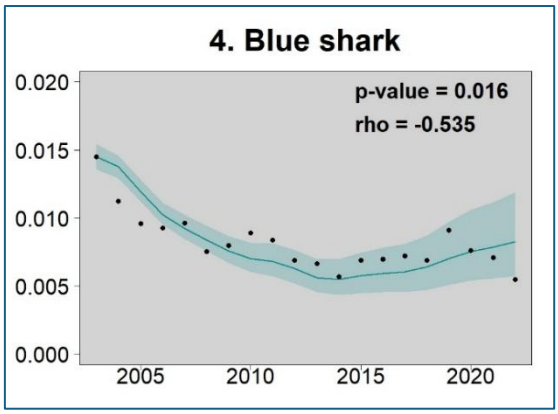


Figure 17. Example of a plot produced with the mentioned script.

To produce the same plots but for the catch instead of biomass we need to open the scrip "2. plots_pred_obs_catch.R" that can be found in here: https://github.com/roger045/Ecosim_Fitting/tree/main

This script produces the same figures as for the biomass but using the catch files (*Figure 18*).

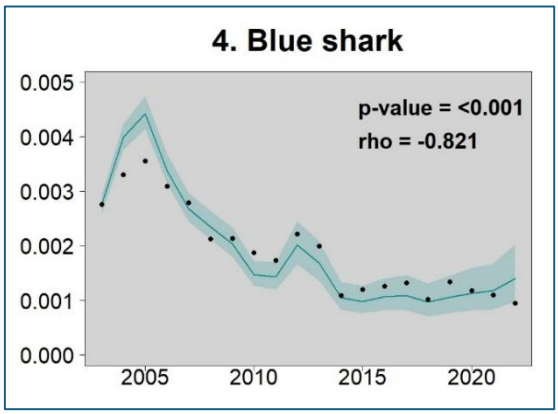


Figure 18. Example of a plot produced with the mentioned script.

Both, biomass and catch figures need to be saved manually to the folders that named "2. Biomass plots" and "3. Catch plots" that we created before inside the "Results" folder (*Figure 11*).

To produce the same plots but for the indicators we need to open the scrip "3. plots_pred_indicators.R" that can be found in here: https://github.com/roger045/Ecosim_Fitting/tree/main

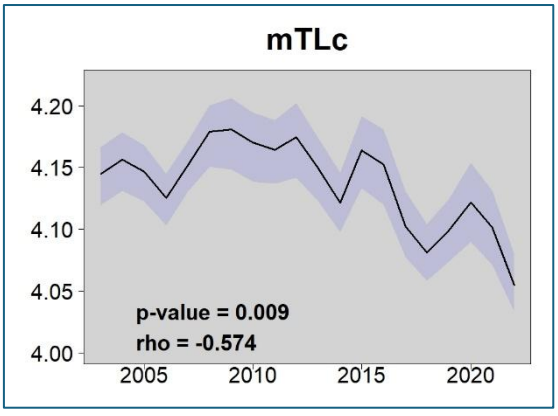


Figure 19. Example of the final plot of an indicator, mTLc, when using the script 3. plots_pred_indicators.R