Ecopath with Ecosim

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EwE world wide

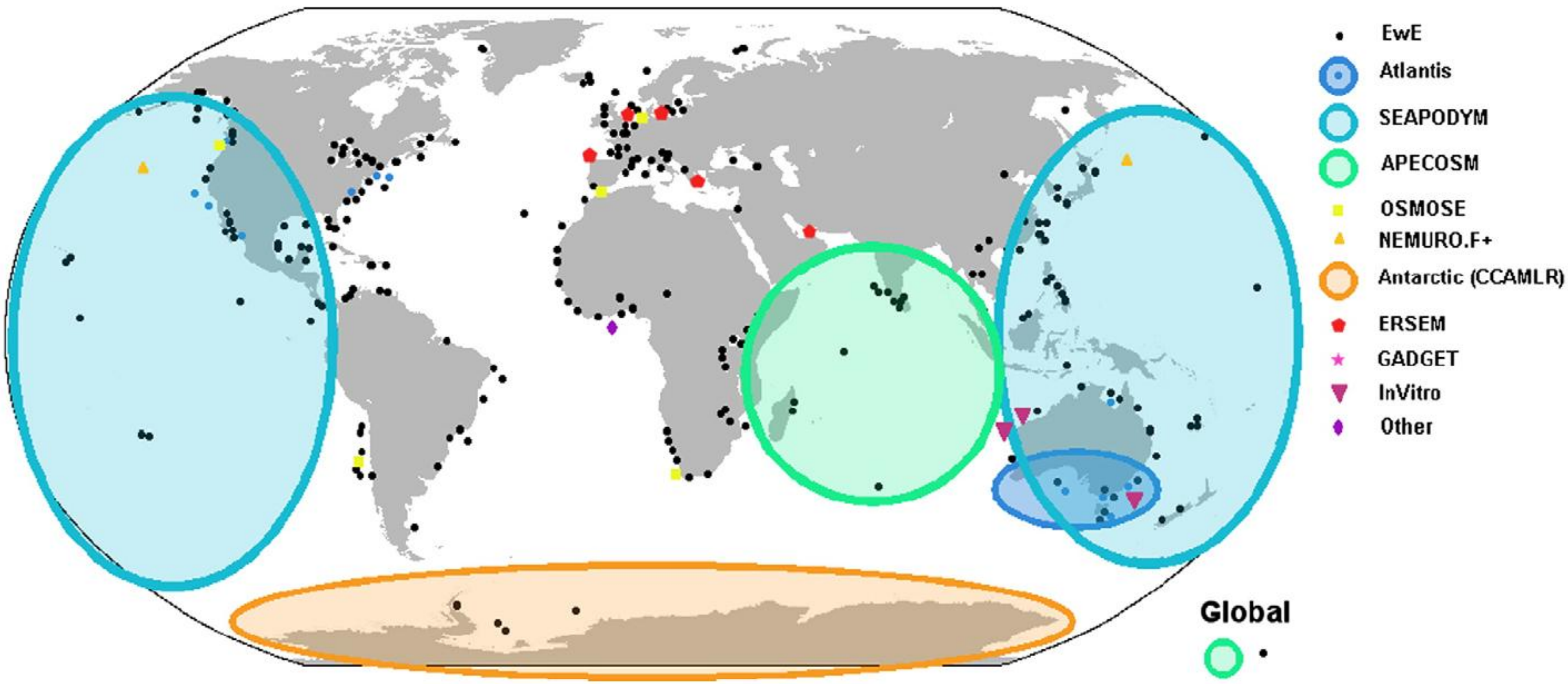
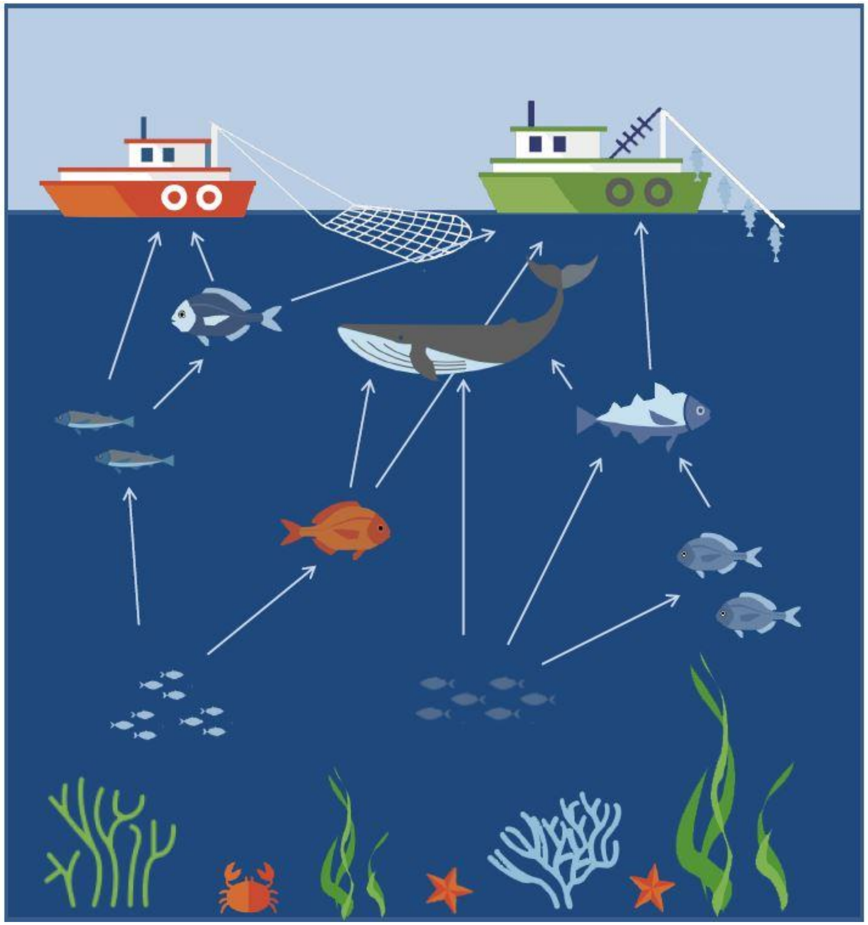


Fig. 3. Map of end-to-end models implemented to date (many more have been proposed or are in early development).

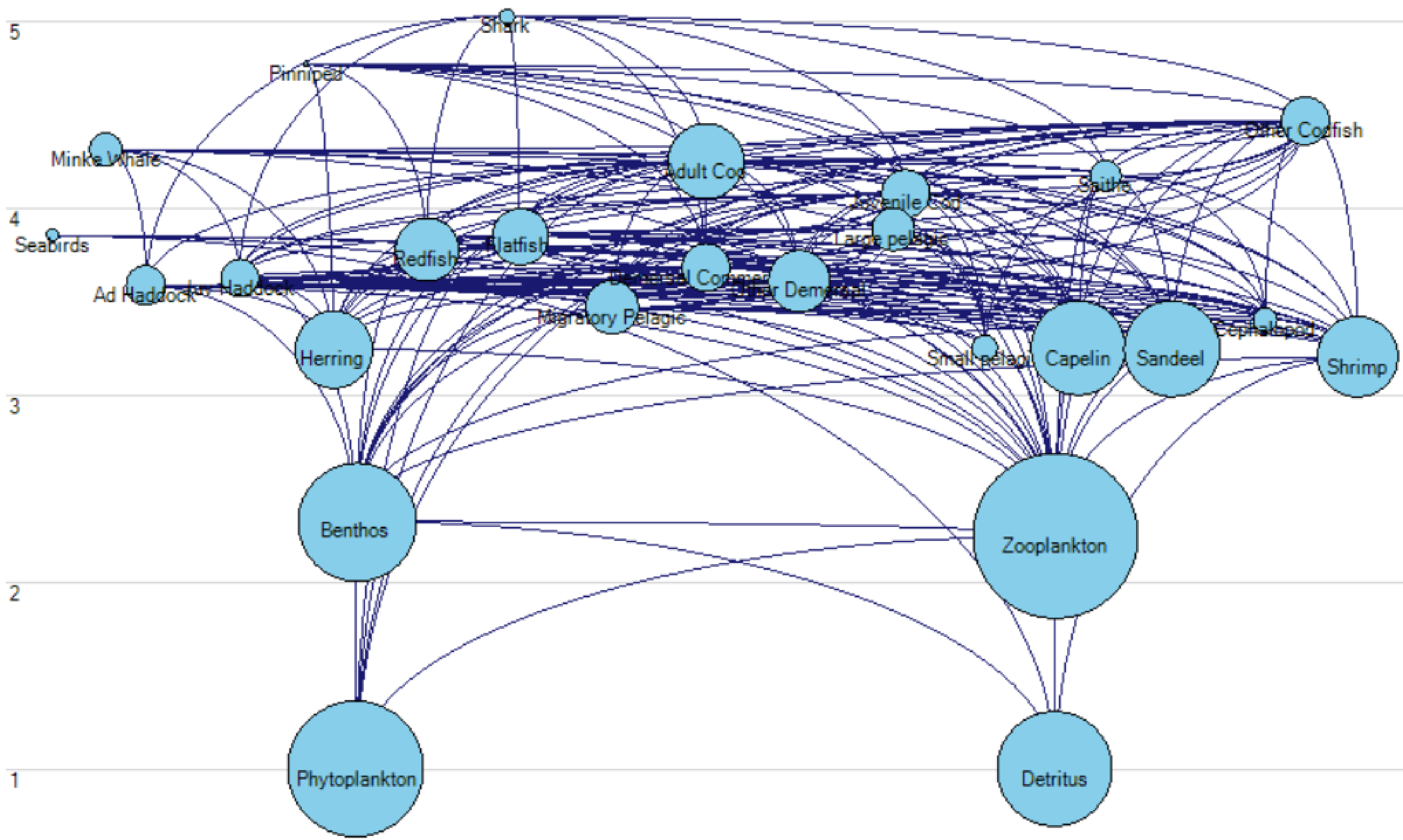
Fulton et al. (2010)

Ecopath with Ecosim (EwE)

- Ecopath: a static, mass-balanced snapshot of the system.
- Ecosim: a time dynamic simulation module.
- Ecospace: spatial component



Ecopath – food web



The Ecopath Equations

- **Production =**
  - \+ **Catch**
  - \+ **Predation**
  - \+ **Net migration**
  - \+ **Accumulation**
  - \+ **Other mortality**

The Ecopath part

- **The Ecopath equations**

$$P_i = Y_i + M2 + E_i + BA_i + MO_i$$

$$M2_i = \sum_{j=1}^{n} Q_j * DC_{ij} \qquad M0_i = P_i(1 - EE_i)$$

The Ecopath part

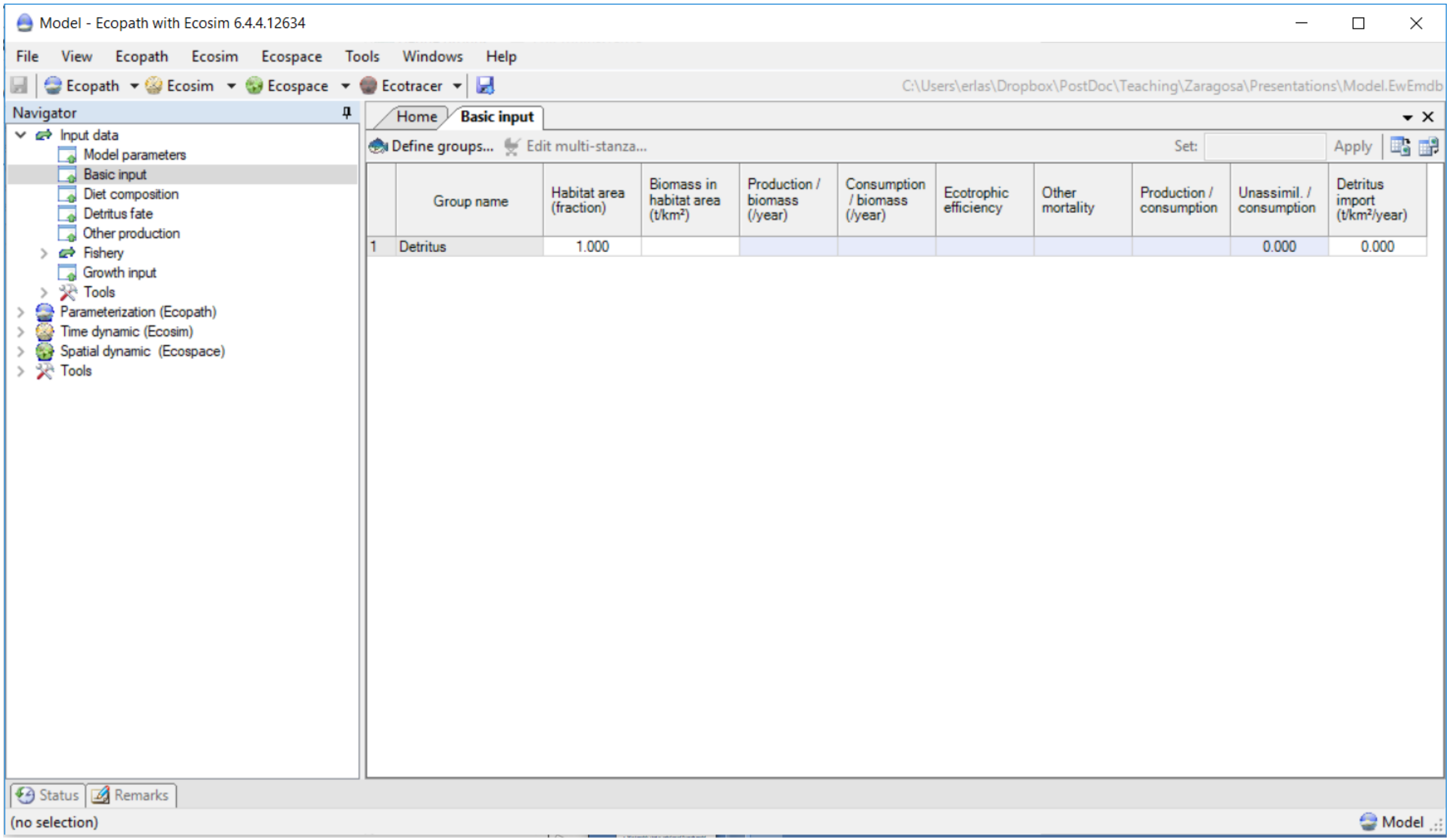
- The Ecopath parameters
  - B = Biomass
  - P/B = Z = production over biomass
  - C/B = Consumption over biomass
  - EE = Ecotrophic efficiency
  - DC = diet composition

- Other parameters
  - BA = Bioaccumulation
  - E = Emigration

Data requirements

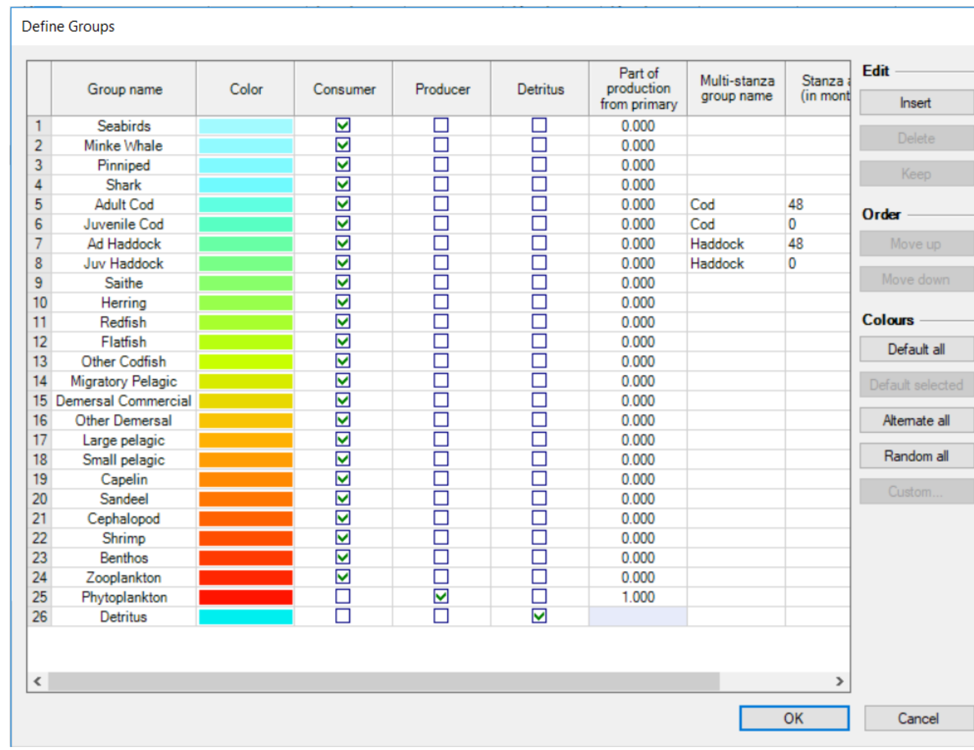
- Biomass
- Production/Biomass
- Consumption/Biomass
- Diets
- Catches
- Discards

The EwE software



Define groups

- Functional groups
- Even across trophic levels
- Include important groups even if there is no data on them.
- Stanza groups
- Ontogeny



	Group name	Color	Consumer	Producer	Detritus	Part of production from primary	Multi-stanza group name	Stanza a (in mont
1	Seabirds		☑	☐	☐	0.000		
2	Minke Whale		☑	☐	☐	0.000		
3	Pinniped		☑	☐	☐	0.000		
4	Shark		☑	☐	☐	0.000		
5	Adult Cod		☑	☐	☐	0.000	Cod	48
6	Juvenile Cod		☑	☐	☐	0.000	Cod	0
7	Ad Haddock		☑	☐	☐	0.000	Haddock	48
8	Juv Haddock		☑	☐	☐	0.000	Haddock	0
9	Saithe		☑	☐	☐	0.000		
10	Herring		☑	☐	☐	0.000		
11	Redfish		☑	☐	☐	0.000		
12	Flatfish		☑	☐	☐	0.000		
13	Other Codfish		☑	☐	☐	0.000		
14	Migratory Pelagic		☑	☐	☐	0.000		
15	Demersal Commercial		☑	☐	☐	0.000		
16	Other Demersal		☑	☐	☐	0.000		
17	Large pelagic		☑	☐	☐	0.000		
18	Small pelagic		☑	☐	☐	0.000		
19	Capelin		☑	☐	☐	0.000		
20	Sandeel		☑	☐	☐	0.000		
21	Cephalopod		☑	☐	☐	0.000		
22	Shrimp		☑	☐	☐	0.000		
23	Benthos		☑	☐	☐	0.000		
24	Zooplankton		☑	☐	☐	0.000		
25	Phytoplankton		☐	☑	☐	1.000		
26	Detritus		☐	☐	☑			

Age classes

- Multiple stanza
- Z and diet composition for each stanza
- B and Q/B calculated except for the leading stanza
  - Growth follows von Bertalanffy
  - The population has reached stable age-size structure
  - Feeding rates vary with age as 2/3 power of body weight
- Fecundity is assumed proportional to body weight above a weight at maturity

Age classes

Edit Multi-Stanza Groups

Stanza group: 1: Cod

Curvature parameter, K (annual), from VBGF: 0.0830

Recruitment power: 1.000

Relative biomass accumulation rate (BA/B): -0.0150

Wmaturity/Winf: 0.190

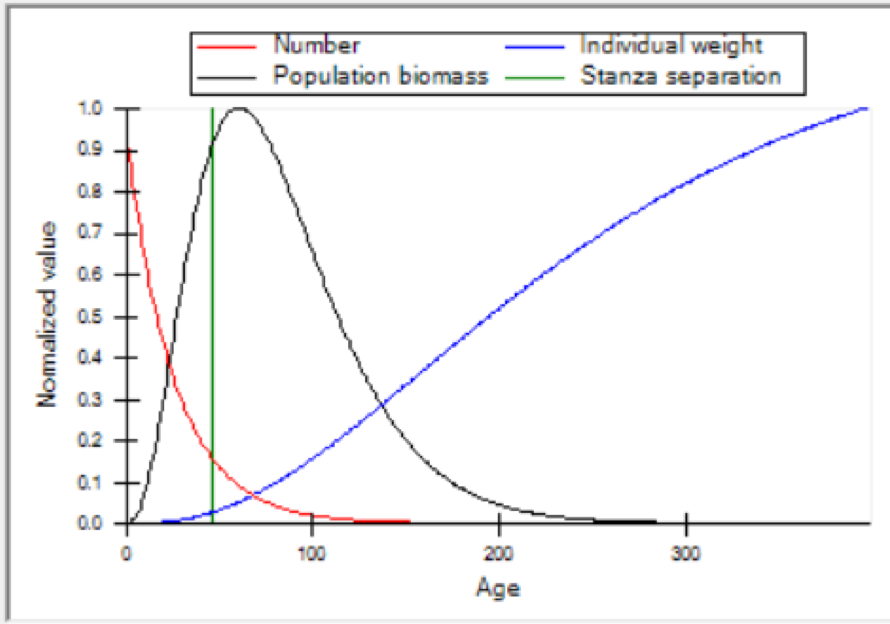
☐ Fixed fecundity

Ecosim

Forcing function for hatchery stocking: (none)

Ecospace

☑ Recruit where spawned in Ecospace



	Group name	Age, start (months)	Leading	Biomass (t/km²)	Z (/year)	Leading	Consumption / biomass (/year)
6	Juvenile Cod	0	☐	0.903	0.480	☐	4.577
5	Adult Cod	48	☑	3.640	0.480	☑	2.000

Calculate | OK | Cancel

Basic input

Home | **Basic input** | Basic estimates | Model Parameters | Diet composition

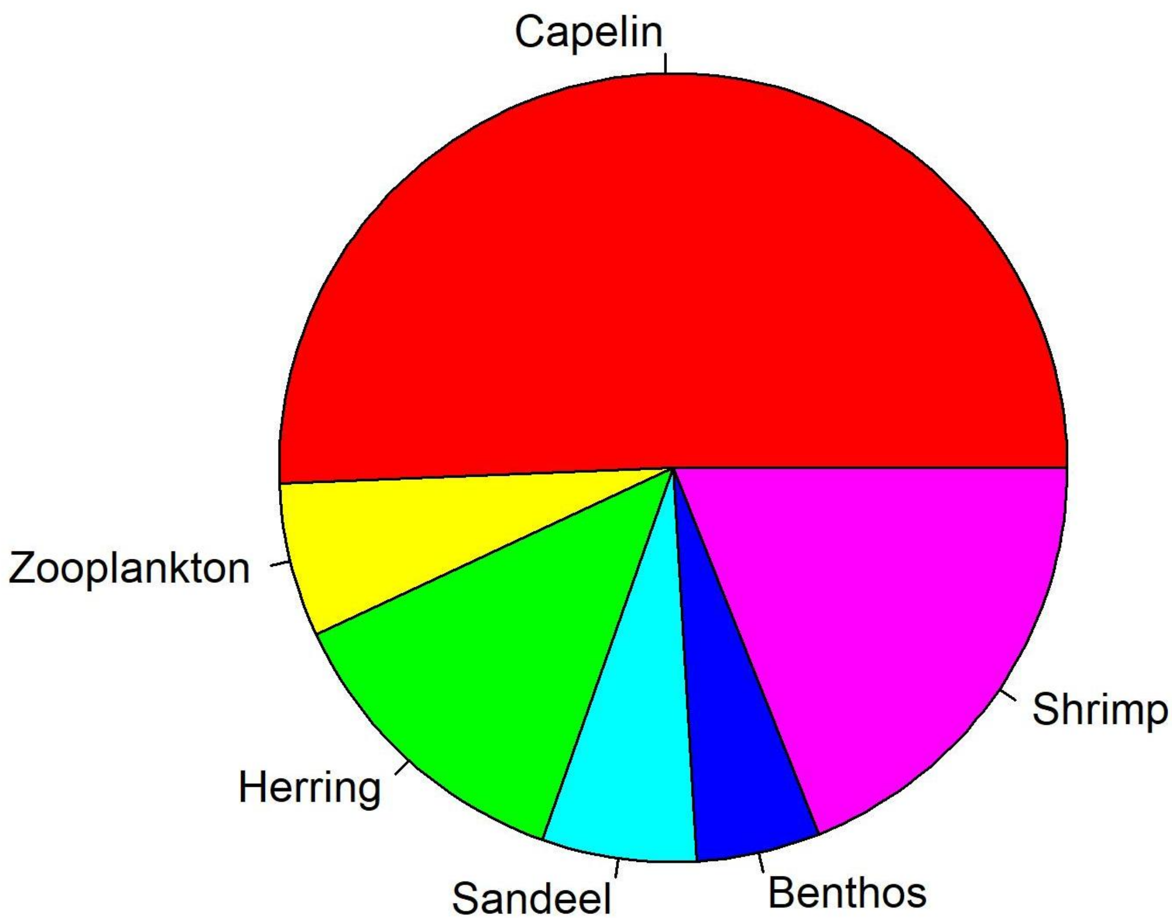
Define groups... Edit multi-stanza... Set

	Group name	Habitat area (fraction)	Biomass in habitat area (t/km²)	Z (/year)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Other mortality	Production / consumption	Unassimil. / consumption	Detritus import (t/km²/year)
1	Seabirds	1.000	0.0617		0.110	35.79				0.200	
2	Minke Whale	1.000	0.376		0.0600	5.000				0.200	
3	Pinniped	1.000	0.00770		0.0900	15.00				0.200	
4	Shark	1.000	0.100		0.0400	0.500				0.200	
⊟	Cod										
5	Adult Cod	1.000	3.640	0.480		2.000				0.200	
6	Juvenile Cod	1.000	0.903	0.480		4.577				0.000	
⊟	Haddock										
7	Ad Haddock	1.000	0.542	0.500		2.000				0.200	
8	Juv Haddock	1.000	0.517	0.930		4.218				0.200	
9	Saithe	1.000	0.324		0.600	4.474				0.200	
10	Herring	1.000	4.193		0.770	6.284				0.200	
11	Redfish	1.000	2.076		0.340	3.489				0.200	
12	Flatfish	1.000	1.390		0.320	2.900				0.200	
13	Other Codfish	1.000	0.285		0.380	2.800				0.200	
14	Migratory Pelagic	1.000	2.080		0.900	9.060				0.200	
15	Demersal Commercial	1.000	0.883		0.360	1.400				0.200	
16	Other Demersal	1.000	1.563		0.620	4.200				0.200	
17	Large pelagic	1.000			0.150	2.200	0.950			0.200	
18	Small pelagic	1.000			0.820	7.110	0.950			0.200	
19	Capelin	1.000	10.000		1.390	5.000				0.200	
20	Sandeel	1.000			0.670	7.030	0.950			0.200	
21	Cephalopod	1.000			2.440	12.00	0.950			0.200	
22	Shrimp	1.000			1.250	5.000	0.950			0.200	
23	Benthos	1.000			2.000	10.000	0.950			0.200	
24	Zooplankton	1.000			5.000	20.00	0.950			0.200	
25	Phytoplankton	1.000			100.00		0.500			0.000	
26	Detritus	1.000	27.00							0.000	0.000

Other production

	Group name	Immigration (t/km^2/year)	Emigration (t/km^2/year)	Emigration rate (/year)	Biom. accumul. (t/km^2/year)	Biom. acc. rate (/year)
1	Seabirds	0.000	0.000	0.000	0.000	0.000
2	Minke Whale	0.000	0.000	0.000	0.000	0.000
3	Pinniped	0.000	0.000	0.000	0.000	0.000
4	Shark	0.000	0.000	0.000	0.000	0.000
⊟	Cod					
5	Adult Cod	0.000	0.000	0.000	-0.0546	
6	Juvenile Cod	0.000	0.000	0.000	-0.0135	
⊟	Haddock					
7	Ad Haddock	0.000	0.000	0.000	0.000	0.000
8	Juv Haddock	0.000	0.000	0.000	0.000	0.000
9	Saithe	0.000	0.000	0.000	0.000	0.000
10	Herring	0.000	0.000	0.000	0.000	0.000
11	Redfish	0.000	0.000	0.000	0.000	0.000
12	Flatfish	0.000	0.000	0.000	0.000	0.000
13	Other Codfish	0.000	0.000	0.000	0.000	0.000
14	Migratory Pelagic	0.000	0.000	0.000	0.000	0.000
15	Demersal Comme	0.000	0.000	0.000	0.000	0.000
16	Other Demersal	0.000	0.000	0.000	0.000	0.000
17	Large pelagic	0.000	0.000	0.000	0.000	0.000
18	Small pelagic	0.000	0.000	0.000	0.000	0.000
19	Capelin	0.000	0.000	0.000	0.000	0.000
20	Sandeel	0.000	0.000	0.000	0.000	0.000
21	Cephalopod	0.000	0.000	0.000	0.000	0.000
22	Shrimp	0.000	0.000	0.000	0.000	0.000
23	Benthos	0.000	0.000	0.000	0.000	0.000
24	Zooplankton	0.000	0.000	0.000	0.000	0.000
25	Phytoplankton	0.000	0.000	0.000	0.000	0.000
26	Detritus	0.000	0.000	0.000	0.000	0.000

Diet composition



Diet composition

Home | Basic input | Basic estimates | Model Parameters | **Diet composition**

Sum diets to one

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Seabirds															
2	Minke Whale															
3	Pinniped															
4	Shark															
5	Adult Cod		0.0720	0.00590	0.102											
6	Juvenile Cod		0.00800	0.355	0.102	0.00981	0.00881	0.000401				0.0186		0.0309	0.000745	0.0216
7	Ad Haddock		0.0600		0.00130	0.00590										
8	Juv Haddock		0.0400		0.00130	0.0139	0.0156		0.000100	0.0127			0.00570	0.0232		0.0119
9	Saithe		0.00200	0.0712	0.0274	0.00120		0.000100						0.00241		
10	Herring		0.0650	0.0611		0.0857	0.0785	0.00411	0.0168			0.0283	0.000102	0.190		0.0225
11	Redfish			0.0331	0.287	0.00871	0.000801	0.00220	0.000100				0.0156	0.0581		0.0521
12	Flatfish				0.0106	0.0325	0.00621	0.00291	0.00560			0.000700	0.000713	0.0109		0.0278
13	Other Codfish		0.0200	0.0407	0.120	0.00791	0.00331	0.000401		0.0331			0.00112	0.0616		0.0246
14	Migratory Pelagic					0.0399	0.00461	0.000501	0.000900					0.0865	0.000213	0.000879
15	Demersal Commercial			0.127	0.0337	0.0131	0.00110	0.000100					0.0123	0.0268		0.0170
16	Other Demersal			0.0865		0.0518	0.0225	0.00792	0.000700	0.00330			0.0110	0.193	0.000106	0.00494
17	Large pelagic													0.000210		
18	Small pelagic					0.00140	0.00100	0.000501	0.000700					0.0176	0.00149	0.0159
19	Capelin	0.347	0.100	0.0458		0.385	0.410	0.0502	0.000400	0.249		0.296	0.0936	0.0269	0.145	0.0292
20	Sandeel	0.441	0.470	0.153		0.0548	0.0387	0.132	0.147	0.561		0.0930	0.249	0.0325	0.0148	0.0208
21	Cephalopod					0.00951	0.00361	0.00381	0.00150	0.00790			0.00275	0.00534	0.00213	0.0457
22	Shrimp					0.147	0.202	0.0417	0.162	0.0114		0.0856	0.00977	0.0576	0.0541	0.00868
23	Benthos					0.0234	0.0605	0.594	0.458	0.00130		0.00370	0.314	0.0234	0.00394	0.398
24	Zooplankton	0.0650	0.0800			0.0538	0.134	0.0501	0.175	0.121	1.000	0.474	0.0221	0.0289	0.778	0.237
25	Phytoplankton					0.000100	0.000100						0.00143			0.0236
26	Detritus	0.147														
27	Import	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	Sum	1.000	0.917	0.980	0.686	0.945	0.992	0.891	0.968	1.000	1.000	1.000	0.739	0.876	1.000	0.962
29	(1 - Sum)	0.000	0.083	0.020	0.314	0.055	0.008	0.109	0.032	0.000	0.000	0.000	0.261	0.124	0.000	0.038

Unbalanced model

	Group name	Trophic level	Habitat area (fraction)	Biomass in habitat area (t/km²)	Biomass (t/km²)	Z (/year)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Production / consumption
1	Seabirds	3.854	1.000	0.0617	0.0617		0.110	35.79	0.032	0.003
2	Minke Whale	4.316	1.000	0.376	0.376		0.0600	5.000	0.000	0.012
3	Pinniped	4.782	1.000	0.00770	0.00770		0.0900	15.00	0.135	0.006
4	Shark	5.031	1.000	0.100	0.100		0.0400	0.500	0.009	0.080
	Cod									
5	Adult Cod	4.253	1.000	3.640	3.640	0.480		2.000	0.251	0.240
6	Juvenile Cod	4.081	1.000	0.903	0.903	0.480		4.577	0.940	0.105
	Haddock									
7	Ad Haddock	3.585	1.000	0.542	0.542	0.500		2.000	0.828	0.250
8	Juv Haddock	3.630	1.000	0.517	0.517	0.930		4.218	0.709	0.220
9	Saithe	4.175	1.000	0.324	0.324		0.600	4.474	0.134	0.134
10	Herring	3.250	1.000	4.193	4.193		0.770	6.284	0.565	0.123
11	Redfish	3.785	1.000	2.076	2.076		0.340	3.489	0.463	0.097
12	Flatfish	3.853	1.000	1.390	1.390		0.320	2.900	1.019	0.110
13	Other Codfish	4.476	1.000	0.285	0.285		0.380	2.800	2.985	0.136
14	Migratory Pelagic	3.467	1.000	2.080	2.080		0.900	9.060	0.490	0.099
15	Demersal Commercial	3.685	1.000	0.883	0.883		0.360	1.400	0.856	0.257
16	Other Demersal	3.612	1.000	1.563	1.563		0.620	4.200	0.809	0.148
17	Large pelagic	3.893	1.000	0.547	0.547		0.150	2.200	0.950	0.068
18	Small pelagic	3.250	1.000	0.183	0.183		0.820	7.110	0.950	0.115
19	Capelin	3.250	1.000	10.000	10.000		1.390	5.000	0.932	0.278
20	Sandeel	3.250	1.000	10.767	10.767		0.670	7.030	0.950	0.095
21	Cephalopod	3.405	1.000	0.182	0.182		2.440	12.00	0.950	0.203
22	Shrimp	3.203	1.000	4.959	4.959		1.250	5.000	0.950	0.250
23	Benthos	2.327	1.000	29.878	29.878		2.000	10.000	0.950	0.200
24	Zooplankton	2.250	1.000	303.109	303.109		5.000	20.00	0.950	0.250
25	Phytoplankton	1.000	1.000	73.954	73.954		100.00		0.500	
26	Detritus	1.000	1.000	27.00	27.00				0.270	

Ecotrophic efficiency

$$EE_i = \frac{Y_i + E_i + BA_i + M2_i}{P_i}$$

- EE is the proportion of the production that is explained by the model.
- 1-EE is the proportion of the production that is lost to processes not explained by the model (e.g. diseases)
- If EE > 1 the model is said to be unbalanced
- Groups with EE > 1 have production that is lower than what is lost (predation and fishing)
- Often set as 0.95 for groups with no biomass estimates
- Top Predators EE close to 0 and Primary producers EE = 0.5

To balance a model

- Most models start as unbalanced Ecopath model.
- Why groups have EE > 1:
  - Their biomass is too low
  - Their P/B is too low
  - Their predators have too high biomass
  - Their predators have too high C/B
  - The diet composition is off
- Not obvious which parameters should be changed.
- Very subjective process => the final model depends on the modeller.

Ecopath for Norwegain Sea

Group	Biomass ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	Ecotrophic Efficiency	Biomass accumulation ($t \cdot km^{-1} \cdot year^{-1}$)	Trophic level
Toothed whales	0.067	0.06	4.90	(0.000)	0.000	4.2
Baleen whales	0.134	0.03	6.56	(0.249)	0.000	3.9
Seals	0.087	0.07	14.52	(0.042)	0.000	4.0
Seabirds	0.005	1.00	99.29	(0.000)	0.000	4.2
Cod 4+	0.448	1.20	2.50	(0.681)	-0.105	4.2
Cod juveniles	(0.351)	1.00	3.50	0.900	0.000	4.1
Haddock	0.134	1.00	2.80	(0.571)	-0.036	3.2
Saithe	0.181	1.00	5.00	(0.861)	0.016	3.5
Other benthic fish	0.700	1.00	5.00	(0.685)	0.000	3.5
Redfish	0.257	0.35	4.50	(0.895)	0.000	3.4
Blue whiting	0.925	0.60	6.00	(0.341)	0.020	3.4
Mackerel	0.180	0.60	6.00	(0.576)	0.009	3.1
Herring 4+	3.261	0.38	4.47	(0.092)	-0.430	3.2
Herring juveniles	(0.326)	0.80	4.47	0.950	-0.002	3.1
Polar cod	(0.472)	1.50	5.00	0.950	0.000	3.4
Capelin	(1.132)	1.00	5.00	0.950	0.000	3.3
Large pelagic fish	(1.652)	0.50	2.50	0.950	0.000	3.1
Small pelagic fish	(0.068)	1.50	5.50	0.950	0.000	3.6
Mesopel fish	(2.079)	2.00	10.00	0.950	0.000	3.3
Squid	2.632	2.44	12.00	(0.059)	0.000	3.3
Benthos	66.000	1.50	9.75	(0.997)	0.000	2.3
Prawns	0.300	1.25	5.00	(0.851)	0.000	2.9
Krill	47.000	2.50	15.00	(0.217)	0.000	2.3
Amphipods	16.000	2.50	15.00	(0.421)	0.000	2.8
Large zooplankton	(16.882)	4.00	15.00	0.950	0.000	2.2
Small zooplankton	50.000	10.00	25.00	(0.909)	0.000	2.0
Jellyfish	4.000	3.00	10.00	(0.339)	0.000	3.2
Seaweeds	4.400	0.65	-	(0.000)	0.000	1.0
Phytoplankton	15.000	117.73	-	0.950	0.000	1.0

Taken from Dommasnes (2001)

The Ecosim part

- **Balanced Ecopath model is the start**

- **The growth rate in Ecosim is defined as:**

$$\frac{\partial B_i}{\partial t} = g_i \sum_{j}^{n} c_{ji} - \sum_{j}^{n} c_{ij} + E_i - (M0_i + F_i)B_i$$

$$c_{ij} = Q_{ij} * \frac{V_{ij} * Y_j}{V_{ij} - 1 + Y_j} * \frac{D_{ij} * Y_i}{D_{ij} - 1 + Y_i}$$

Vulnerabilities

- **The vulnerability paramter is used to model top-down control (predator control) or bottom up control (prey control)**

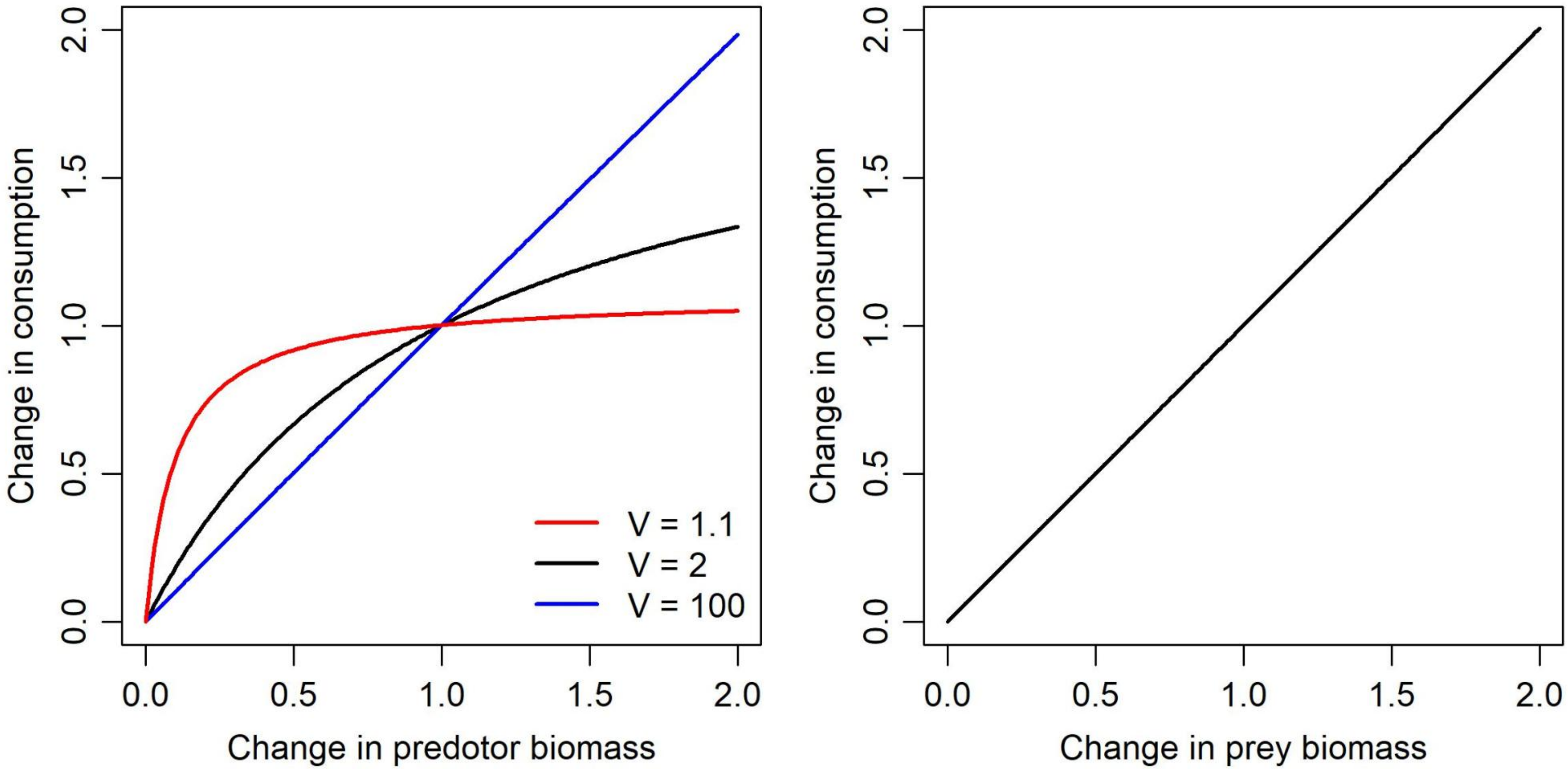
- **The vulnerability represent how a change in predator biomass will cause a change in predation mortality for a given prey**

Default vulnerability is 2

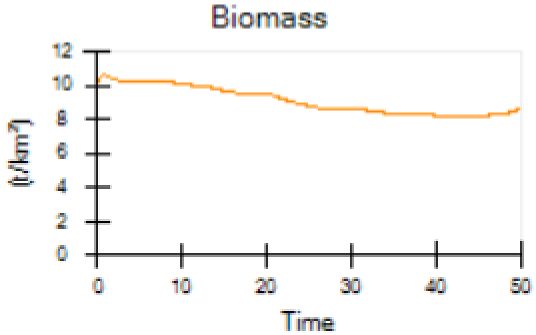
	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Seabirds																								
2	Minke Whale																								
3	Pinniped																								
4	Shark																								
5	Adult Cod		2.000	2.000	2.000																				
6	Juvenile Cod		2.000	2.000	2.000	2.000	2.000	2.000				2.000		2.000	2.000	2.000		2.000							
7	Ad Haddock		2.000		2.000	2.000																			
8	Juv Haddock		2.000		2.000	2.000	2.000		2.000	2.000			2.000	2.000		2.000									
9	Saithe		2.000	2.000	2.000	2.000		2.000						2.000											
10	Herring		2.000	2.000		2.000	2.000	2.000	2.000			2.000	2.000	2.000		2.000	2.000	2.000							
11	Redfish			2.000	2.000	2.000	2.000	2.000	2.000				2.000	2.000		2.000		2.000							
12	Flatfish				2.000	2.000	2.000	2.000	2.000			2.000	2.000	2.000		2.000	2.000	2.000							
13	Other Codfish		2.000	2.000	2.000	2.000	2.000	2.000		2.000			2.000	2.000		2.000	2.000								
14	Migratory Pelagic					2.000	2.000	2.000	2.000					2.000	2.000	2.000		2.000							
15	Demersal Commercial			2.000	2.000	2.000	2.000	2.000					2.000	2.000		2.000									
16	Other Demersal			2.000		2.000	2.000	2.000	2.000	2.000			2.000	2.000	2.000	2.000	2.000								
17	Large pelagic													2.000			2.000	2.000							
18	Small pelagic					2.000	2.000	2.000	2.000					2.000	2.000	2.000	2.000	2.000							
19	Capelin	2.000	2.000	2.000		2.000	2.000	2.000	2.000	2.000		2.000	2.000	2.000	2.000	2.000		2.000							
20	Sandeel	2.000	2.000	2.000		2.000	2.000	2.000	2.000	2.000		2.000	2.000	2.000	2.000	2.000	2.000								
21	Cephalopod					2.000	2.000	2.000	2.000	2.000			2.000	2.000	2.000	2.000	2.000	2.000							
22	Shrimp					2.000	2.000	2.000	2.000	2.000		2.000	2.000	2.000	2.000	2.000	2.000	2.000				2.000			
23	Benthos					2.000	2.000	2.000	2.000	2.000		2.000	2.000	2.000	2.000	2.000	2.000					2.000	2.000	2.000	
24	Zooplankton	2.000	2.000			2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
25	Phytoplankton					2.000	2.000						2.000			2.000								2.000	2.000
26	Detritus	2.000																					2.000	2.000	2.000

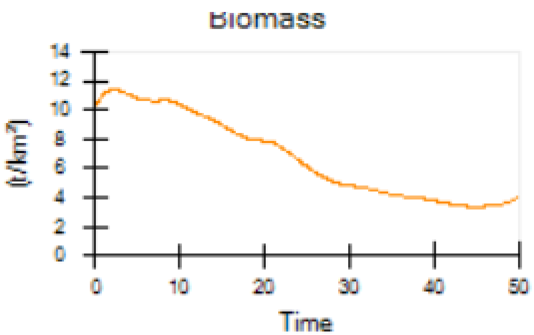
Predator-Prey interactions

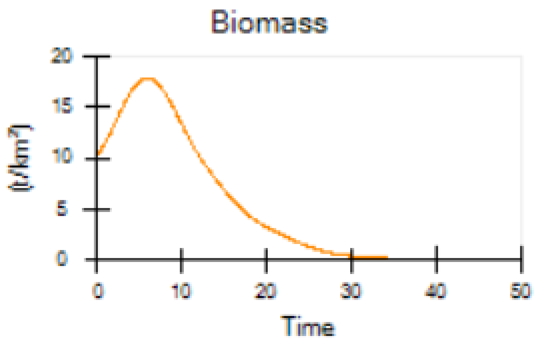
$$c_{ij} = Q_{ij} * \frac{V_{ij} * Y_j}{V_{ij} - 1 + Y_j} * \frac{D_{ij} * Y_i}{D_{ij} - 1 + Y_i}$$



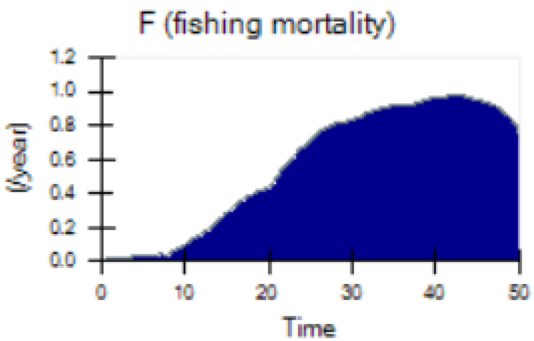
The Vulnerabilities and production







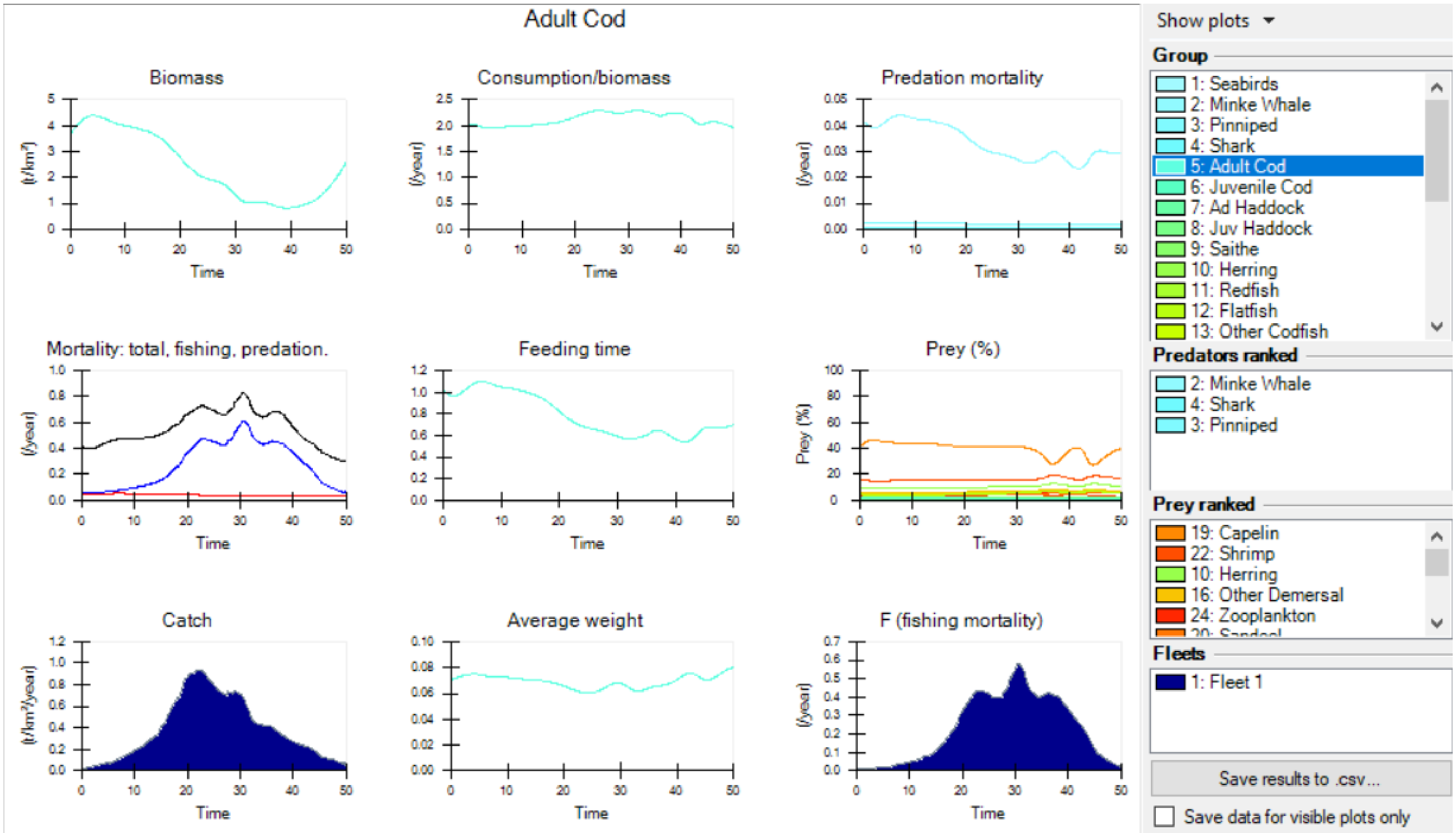
- **The simulation of capelin biomass for three different vulnerabilities.**
- **Which has low vulnerability?**



Fitting the model

- Time-series with harvest rate.
- Environmental forcing.
- The model can be fitted to time-series of biomass and catches by estimating the vulnerability parameters.

Forward simulation

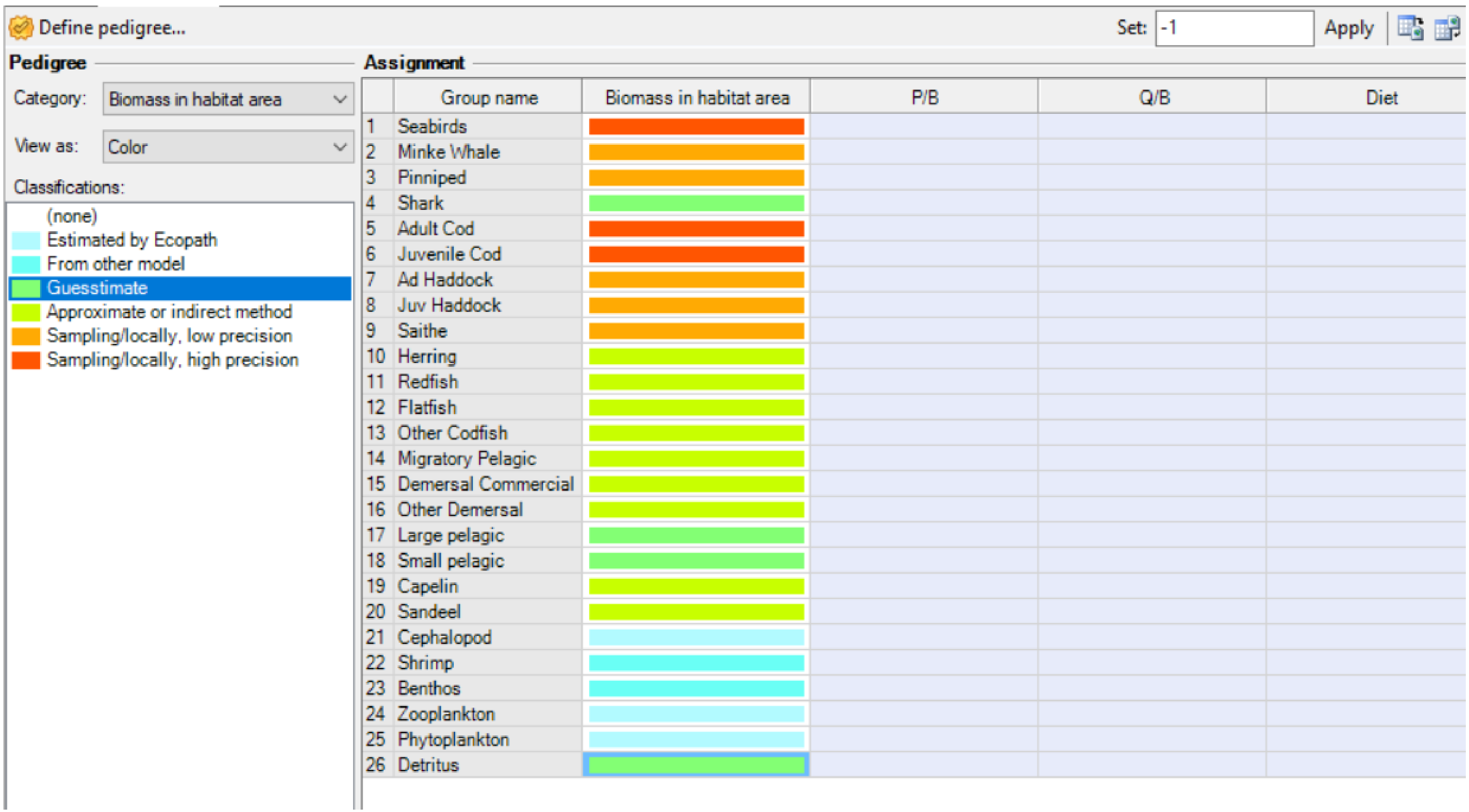


Ecospace

- Dynamically allocates biomass across a grid map.
- Symmetrical movements from a cell to its four adjacent cells, of rate m, modified by whether a cell is defined as preferred habitat or not.
- User-defined increased predation risk and reduced feeding rate in non-preferred habitat.
- A level of fishing effort that is proportional, in each cell, to the overall profitability of fishing in that cell.
- More on Ecospace [here](http://sources.ecopath.org/trac/Ecopath/wiki/EwEugIntroductoryMaterialEcospace#a4Introductorymaterial:Ecospace)

http://sources.ecopath.org/trac/Ecopath/wiki/EwEugIntroductoryMaterialEcospace#a4Introductorymaterial:Ecospace

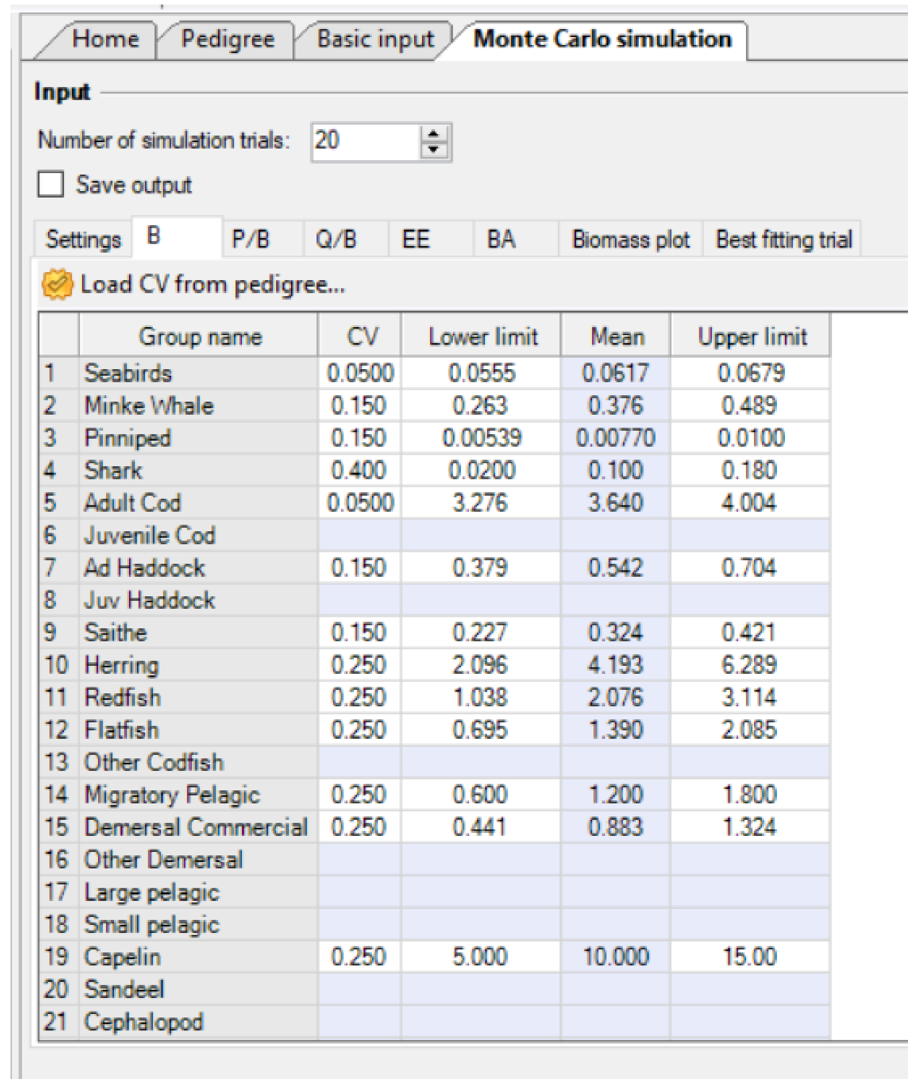
Uncertainty in EwE



Uncertainty in EwE

Ecoranger

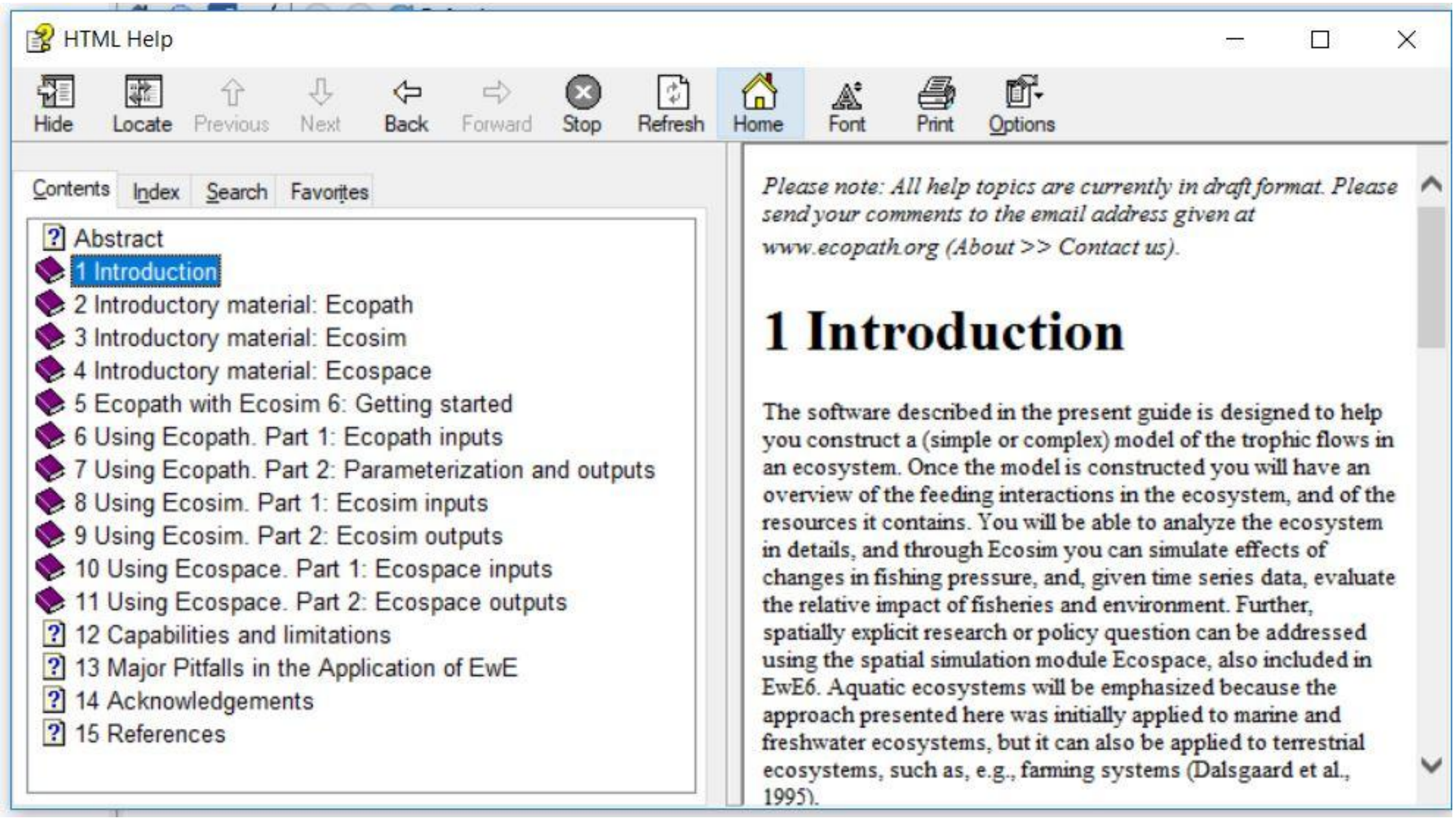
- Monte Carlo resampling routine
- Based on probability distributions for the parameters
- Based on user-defined criteria
- Mass balance constraint
- Pedigree routine to make this easier task



	Group name	CV	Lower limit	Mean	Upper limit
1	Seabirds	0.0500	0.0555	0.0617	0.0679
2	Minke Whale	0.150	0.263	0.376	0.489
3	Pinniped	0.150	0.00539	0.00770	0.0100
4	Shark	0.400	0.0200	0.100	0.180
5	Adult Cod	0.0500	3.276	3.640	4.004
6	Juvenile Cod				
7	Ad Haddock	0.150	0.379	0.542	0.704
8	Juv Haddock				
9	Saithe	0.150	0.227	0.324	0.421
10	Herring	0.250	2.096	4.193	6.289
11	Redfish	0.250	1.038	2.076	3.114
12	Flatfish	0.250	0.695	1.390	2.085
13	Other Codfish				
14	Migratory Pelagic	0.250	0.600	1.200	1.800
15	Demersal Commercial	0.250	0.441	0.883	1.324
16	Other Demersal				
17	Large pelagic				
18	Small pelagic				
19	Capelin	0.250	5.000	10.000	15.00
20	Sandeel				
21	Cephalopod				

EwE manual

- **Manual inside the EwE software**



Useful EwE papers

- Christensen, V., & Walters, C. J. (2004). Ecopath with Ecosim: methods, capabilities and limitations. Ecological modelling, 172(2), 109-139.

- Heymans, J. J., Coll, M., Link, J. S., Mackinson, S., Steenbeek, J., Walters, C., & Christensen, V. (2016). Best practice in Ecopath with Ecosim food-web models for ecosystem-based management. Ecological modelling, 331, 173-184.

- Ainsworth, C. H., & Walters, C. J. (2015). Ten common mistakes made in Ecopath with Ecosim modelling. Ecological Modelling, (308), 14-17.

Where to get EwE

- **The official EwE website**

  http://ecopath.org/

- **The R-version Rpath**

  https://github.com/slucey/RpathDev