ARISTOTLE
UNIVERSITY OF
THESSALONIKI

MARINE FISHERIES
and FISH BIOLOGY

ODYSSEA

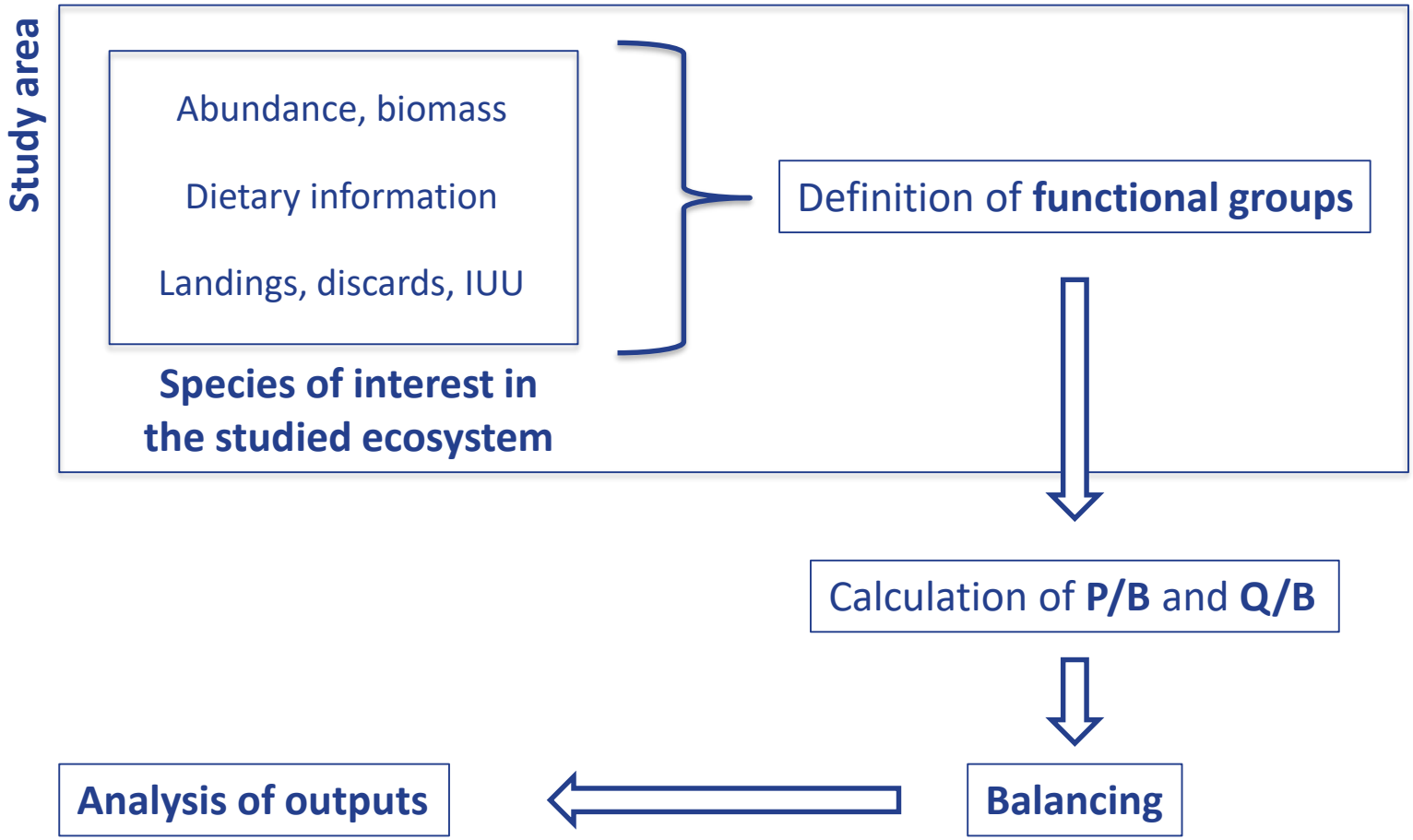
WP4 – Ecosystem modelling workshop
Ecopath with Ecosim

Thermaikos case study

Donna Dimarchopoulou

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

Steps in constructing an Ecopath base model (Thermaikos Gulf)



Modelled area: ~ **3200** km^2

high **trawling** and **purse seining**

fishing effort

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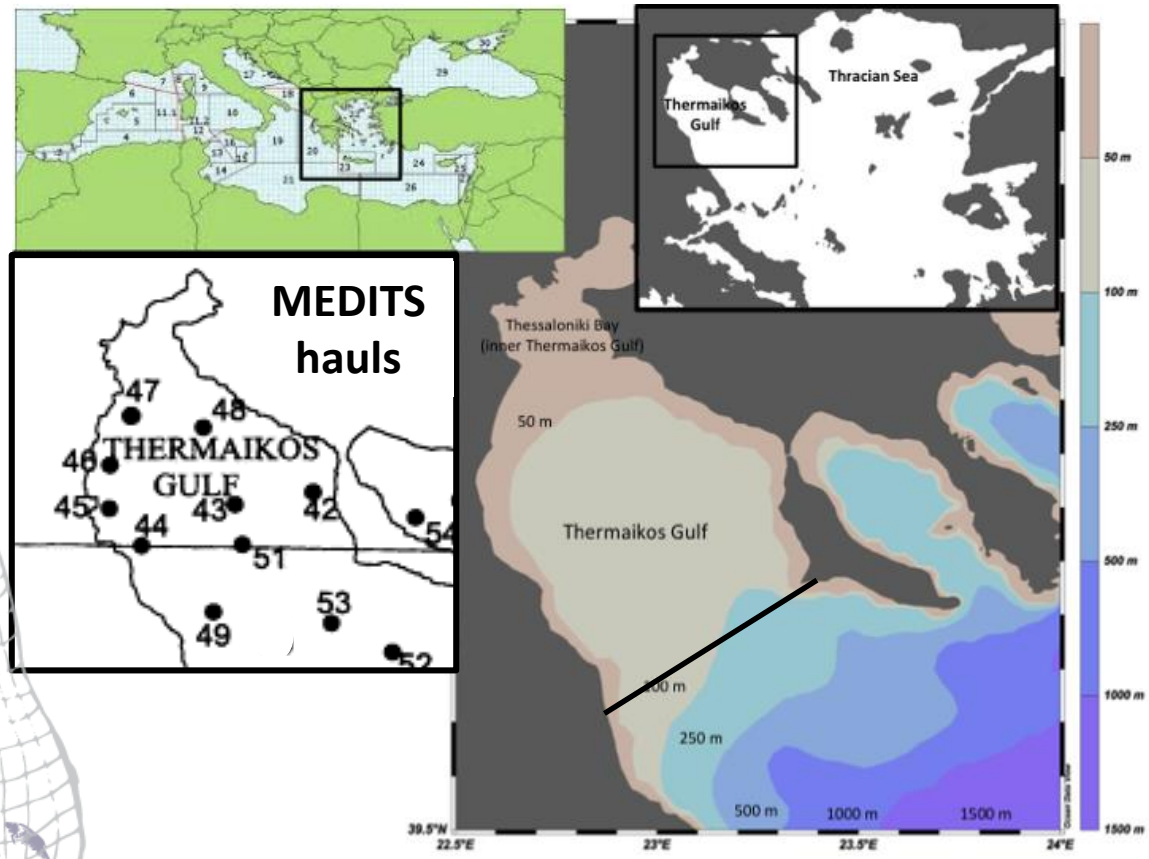
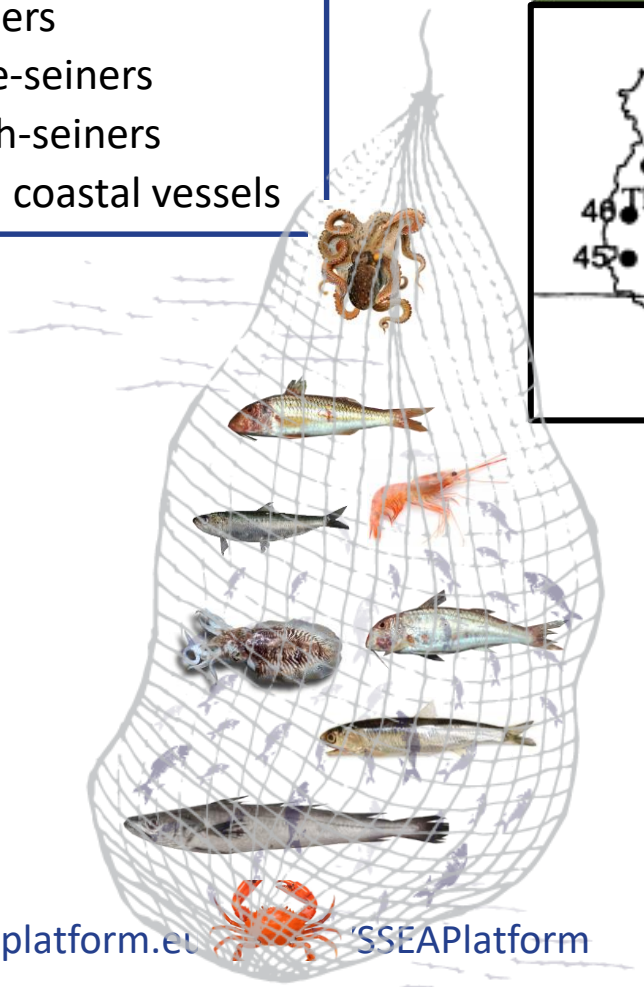
Study area – Thermaikos Gulf



4 fishing fleets

- trawlers
- purse-seiners
- beach-seiners
- small coastal vessels



Year of the model

- average of **1998-2000**
- good data availability

~ **108** taxa plus other invertebrates

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33 functional groups (FGs)

Low trophic level	Invertebrates	Fish	Other
Phytoplankton	Zooplankton	Red mullets	Sea turtle
Discards	Benthic small crustaceans	Anglerfish	Seabirds
Detritus	Polychaetes	Flatfishes	Dolphins
	Shrimps	Other gadiforms	
	Crabs	Hake	
	Benthic invertebrates	Demersal fishes 1	
	Octopuses & cuttlefish	Demersal fishes 2	
	Squids	Demersal fishes 3	
		Demersal fishes 4	
		Picarels and bogue	
		Sharks	
		Rays & skates	
		Anchovy	
		Sardine	
		Horse mackerels	
		Mackerels	
		Other small pelagics	
		Medium pelagics	
		Large pelagics	

Functional groups

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Shrimps
Melicertus kerathurus
Parapenaeus longirostris

Red mullets
Mullus barbatus
Mullus surmuletus

Large pelagics
Thunnus thynnus
Xiphias gladius

Horse mackerels
Trachurus trachurus
Trachurus mediterraneus

Sharks
Mustelus spp.
Squalidae
Scyliorhinus canicula

Picarels and bogue
Spicara smaris
Spicara maena
Spicara flexuosa
Boops boops

Anglerfish
Lophius budegassa
Lophius piscatorius

Mackerels
Scomber colias
Scomber scombrus

Medium pelagics
Auxis thazard
Katsuwonus pelamis
Pomatomus saltatrix
Sarda sarda
Seriola dumerili

Rays and skates
Leucoraja naevus
Raja clavata
Raja radula
Torpedo marmorata
Rhinobatidae

Other small pelagics
Mugilidae
Belone belone
Sardinella aurita

Biomass (t/km²)

- acoustic surveys
- trawling surveys

Diet composition

- literature reviews on feeding habits of Mediterranean fish

Stergiou & Karpouzi 2002;

Karachle & Stergiou 2017;

Tsagarakis et al. 2010

Landings & discards (t/km²/year)

- Hellenic Statistical Authority
- discard ratio

Tsagarakis et al. 2014 “Mediterranean fishery discards”

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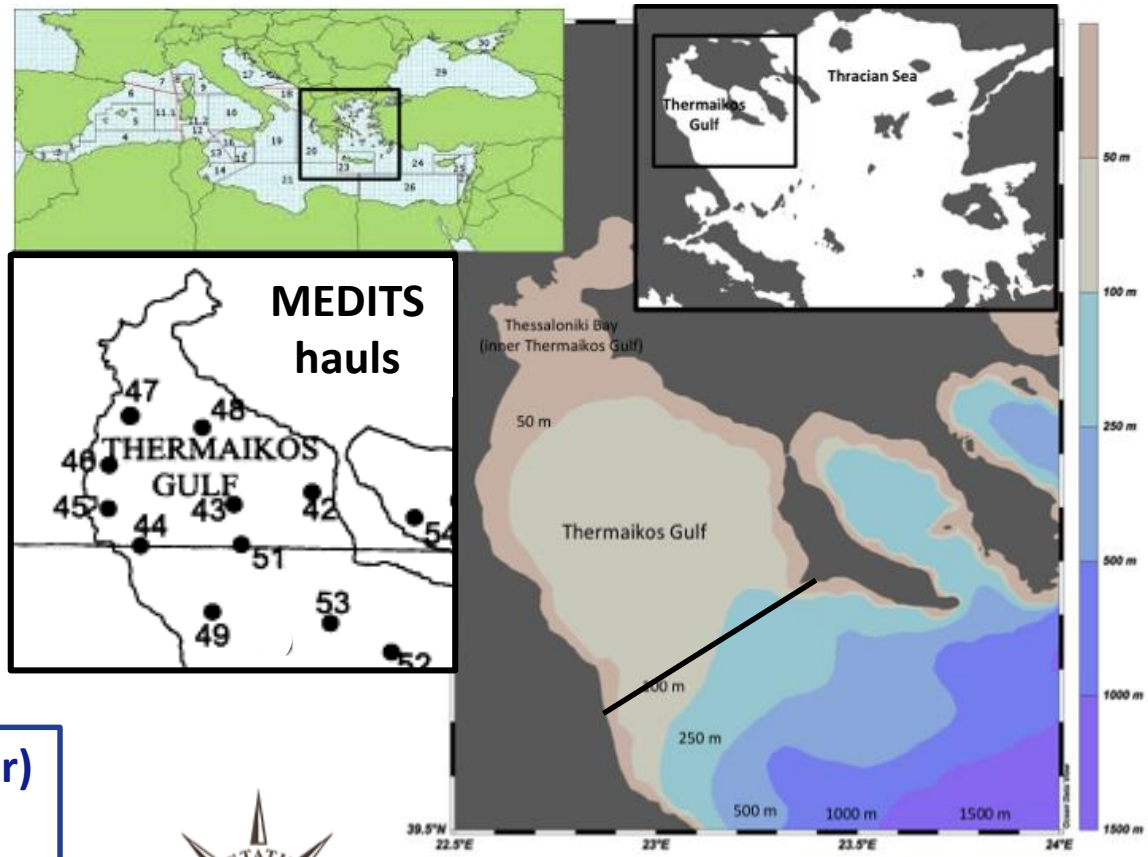
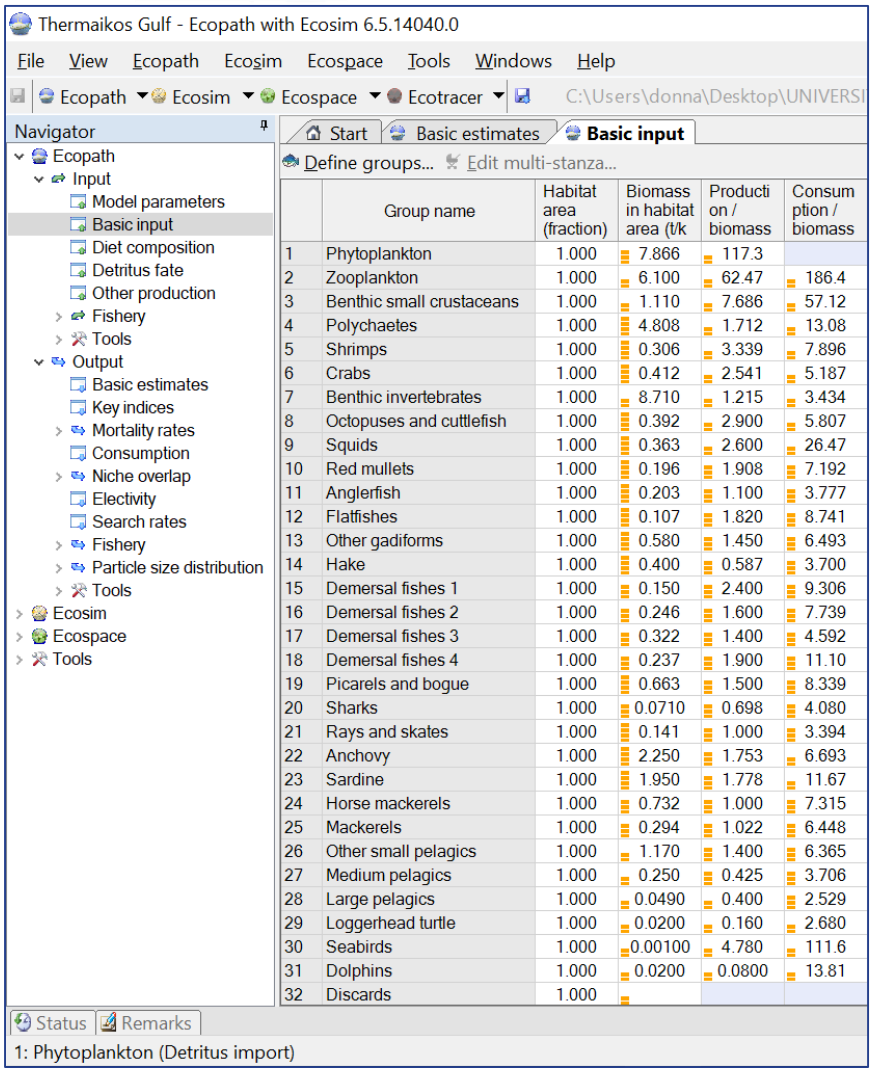
Study area – Thermaikos Gulf



P/B, Q/B (year⁻¹)

- FishBase
- empirical equations
- literature

Biomass (t/km^2)



	Group name	Habitat area (fraction)	Biomass in habitat area (t/k	Production / biomass	Consumption / biomass
1	Phytoplankton	1.000	7.866	117.3	
2	Zooplankton	1.000	6.100	62.47	186.4
3	Benthic small crustaceans	1.000	1.110	7.686	57.12
4	Polychaetes	1.000	4.808	1.712	13.08
5	Shrimps	1.000	0.306	3.339	7.896
6	Crabs	1.000	0.412	2.541	5.187
7	Benthic invertebrates	1.000	8.710	1.215	3.434
8	Octopuses and cuttlefish	1.000	0.392	2.900	5.807
9	Squids	1.000	0.363	2.600	26.47
10	Red mullets	1.000	0.196	1.908	7.192
11	Anglerfish	1.000	0.203	1.100	3.777
12	Flatfishes	1.000	0.107	1.820	8.741
13	Other gadiforms	1.000	0.580	1.450	6.493
14	Hake	1.000	0.400	0.587	3.700
15	Demersal fishes 1	1.000	0.150	2.400	9.306
16	Demersal fishes 2	1.000	0.246	1.600	7.739
17	Demersal fishes 3	1.000	0.322	1.400	4.592
18	Demersal fishes 4	1.000	0.237	1.900	11.10
19	Picarels and bogue	1.000	0.663	1.500	8.339
20	Sharks	1.000	0.0710	0.698	4.080
21	Rays and skates	1.000	0.141	1.000	3.394
22	Anchovy	1.000	2.250	1.753	6.693
23	Sardine	1.000	1.950	1.778	11.67
24	Horse mackerels	1.000	0.732	1.000	7.315
25	Mackerels	1.000	0.294	1.022	6.448
26	Other small pelagics	1.000	1.170	1.400	6.365
27	Medium pelagics	1.000	0.250	0.425	3.706
28	Large pelagics	1.000	0.0490	0.400	2.529
29	Loggerhead turtle	1.000	0.0200	0.160	2.680
30	Seabirds	1.000	0.00100	4.780	111.6
31	Dolphins	1.000	0.0200	0.0800	13.81
32	Discards	1.000			

Catch per species /
Swept area (gear characteristics: wing opening * duration of the haul)

For each species **average biomass** from 3 years **(1998-2000)**

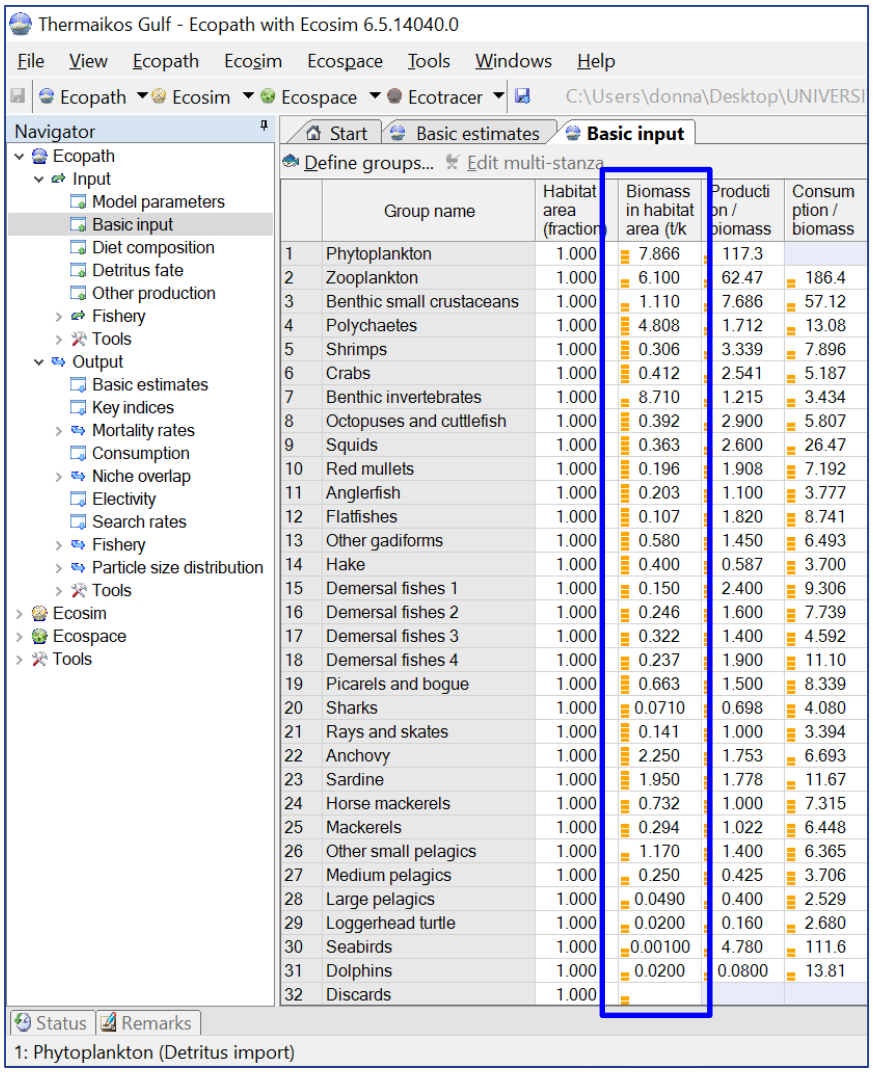
For the **FG**, **sum of the biomasses** of all species

For the final biomass value of the FG application of **catchability factor**

(Sánchez & Olaso 2014)

- 10% **demersal** species
- 15-20% **benthic** species

Biomass (t/km^2)



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12	Flatfishes	1.000	0.107	1.820	8.741
13	Other gadiforms	1.000	0.580	1.450	6.493
14	Hake	1.000	0.400	0.587	3.700
15	Demersal fishes 1	1.000	0.150	2.400	9.306
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Catch per species /
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For each species **average biomass** from 3 years **(1998-2000)**

For the **FG**, **sum of the biomasses** of all species

For the final biomass value of the FG application of **catchability factor**

(Sánchez & Olaso 2014)

- 10% **demersal** species
- 15-20% **benthic** species

The **pedigree** of an Ecopath input categorizes the origin a given input (the **type of data** on which it is based), and specifies the likely **uncertainty** associated with the input, i.e. the **reliability** of the data.

Biomass

- Estimated by Ecopath
- From other model
- Guesstimate
- Approximate or indirect method
- Sampling/locally, low precision
- Sampling/locally, high precision

P/B, Q/B

- Estimated by Ecopath
- Guesstimate
- From other model
- Empirical relationship
- Similar species, similar system, low precision
- Similar species, same system, low precision
- Same species, similar system, high precision
- Same species, same system, high precision

The **pedigree** of an Ecopath input categorizes the origin a given input (the **type of data** on which it is based), and specifies the likely **uncertainty** associated with the input, i.e. the **reliability** of the data.

Diet composition

- General knowledge of related group/species
- From other model
- General knowledge for same group/species
- Qualitative diet composition study
- Quantitative but limited diet composition study
- Quantitative detailed diet composition study

Catch

- Guesstimate
- From other model
- FAO statistics
- National statistics
- Local study, low precision/incomplete
- Local study, high precision/complete

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Diet composition | Definition of fleets | Landings | Discards | **Pedigree**

Set: Apply

Assignment

	Group name	Biomass in habitat area	Production / biomass	Consumption / biomass	Diet	Catch
1	Phytoplankton					
2	Zooplankton					
3	Benthic small crustaceans					
4	Polychaetes					
5	Shrimps					
6	Crabs					
7	Benthic invertebrates					
8	Octopuses and cuttlefish					
9	Squids					
10	Red mullets					
11	Anglerfish					
12	Flatfishes					
13	Other gadiforms					
14	Hake					
15	Demersal fishes 1					
16	Demersal fishes 2					
17	Demersal fishes 3					
18	Demersal fishes 4					
19	Picarels and bogue					
20	Sharks					
21	Rays and skates					
22	Anchovy					
23	Sardine					
24	Horse mackerels					
25	Mackerels					
26	Other small pelagics					
27	Medium pelagics					
28	Large pelagics					
29	Loggerhead turtle					
30	Seabirds					
31	Dolphins					
32	Discards					

Weighted averages for FGs
% weight

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Diet composition

Thermaikos Gulf - Ecopath with Ecosim 6.5.14040.0

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Ecopath Ecosim Ecospace Ecotracer C:\Users\donna\Desktop\UNIVERSITY\Research projects\PROTOMEDEA\Ecopath\Thermaikos\Therm_eco...\Thermaikos_Base_model_1998_2000_No5_minors_after_tsag.ewe

Navigator

- Ecopath
  - Input
    - Model parameters
    - Basic input
    - Diet composition
    - Detritus fate
    - Other production
    - Fishery
    - Tools
  - Output
    - Basic estimates
    - Key indices
    - Mortality rates
    - Consumption
    - Niche overlap
    - Electivity
    - Search rates
    - Fishery
    - Particle size distribution
    - Tools
- Ecosim
- Ecospace
- Tools

Start | Basic estimates | Basic input | Diet composition

Sum diets to one Set: Apply

	Prey \ predator	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	Phytoplankton	0.600	0.0200													0.0200	0.00900						0.131
2	Zooplankton	0.200	0.0970		0.103	0.00500		0.0900	0.175	0.140	0.0180	0.161	0.300	0.137	0.107	0.150	0.152	0.773	0.900	0.142	0.0350	1.000	0.849
3	Benthic small crustaceans		0.0300		0.230	0.0600		0.140	0.128	0.184	0.0300	0.121	0.305	0.0630	0.131	0.200	0.0780	0.100	0.0500		0.00600		0.0200
4	Polychaetes		0.0200	0.0300	0.200	0.410	0.0200	0.0600	0.0750	0.132	0.0600	0.0220			0.661	0.120	0.0950	0.0190	0.0450	0.0500	0.100		
5	Shrimps				0.0300	0.0200		0.01000	0.00500	0.0400	0.0200	0.0120	0.01000	0.0730	0.0180	0.0500	0.0840	0.0450	0.00500	0.01000	0.100		
6	Crabs				0.0260	0.0250		0.0500	0.0130	0.0800		0.0120	0.0320			0.0900	0.0380	0.0360		0.100	0.100		
7	Benthic invertebrates		0.0300	0.0600	0.280	0.310	0.0300	0.530	0.0200	0.0240	0.100	0.0400	0.00800	0.0200	0.0830	0.0200	0.145	0.0270		0.200	0.0350		
8	Octopuses and cuttlefish				0.0200			0.0500	0.0350		0.100	0.0400	0.00500	0.0400		0.0150	0.0480			0.0800	0.0120		
9	Squids								0.0450					0.115						0.0680	0.00800		
10	Red mullets								0.00900		0.0200		0.0310			0.0400					0.0550		
11	Anglerfish										0.0200									0.0200			
12	Flatfishes										0.0200	0.01000		0.0120						0.0540	0.00800		
13	Other gadiforms								0.0220		0.100	0.120	0.00600	0.0300		0.0800	0.0220			0.0480	0.0400		
14	Hake								0.00200		0.0360			0.0400						0.0460	0.0260		
15	Demersal fishes 1					0.00300			0.00100			0.0800	0.0300	0.0200		0.0150				0.0430	0.0800		
16	Demersal fishes 2							0.0200			0.0500	0.0400		0.0200			0.0500				0.0300		
17	Demersal fishes 3					0.00200		0.0400				0.120	0.01000	0.0400							0.0300		
18	Demersal fishes 4					0.00200			0.00100		0.0360	0.0700	0.0150	0.0400		0.0300	0.01000			0.0280	0.0600		
19	Picarels and bogue							0.01000	0.0230		0.0800		0.0320	0.0300		0.0750	0.0550				0.01000		
20	Sharks								0.00400											0.000100			
21	Rays and skates										0.0500	0.00800								0.0150			
22	Anchovy								0.156		0.0300	0.0400	0.184	0.160			0.114			0.0180	0.195		
23	Sardine								0.163		0.0500	0.00800	0.01000	0.110		0.0300	0.0500			0.0200	0.0500		
24	Horse mackerels								0.0300		0.130	0.0690								0.0480	0.01000		
25	Mackerels								0.00300		0.0500	0.0200				0.0300	0.0500						
26	Other small pelagics								0.0900					0.0500		0.0300							
27	Medium pelagics																						
28	Large pelagics																						
29	Loggerhead turtle																						
30	Seabirds																						
31	Dolphins																						
32	Discards		0.00300		0.0150	0.01000							0.0130							0.01000	0.01000		

Status | Remarks

1: Phytoplankton (Detritus import) Thermaikos Gulf

Stergiou & Karpouzi 2002 "Feeding habits and trophic levels of Mediterranean fish"

Karachle & Stergiou 2017 "An update on the feeding habits of fish in the Mediterranean Sea (2002-2015)"

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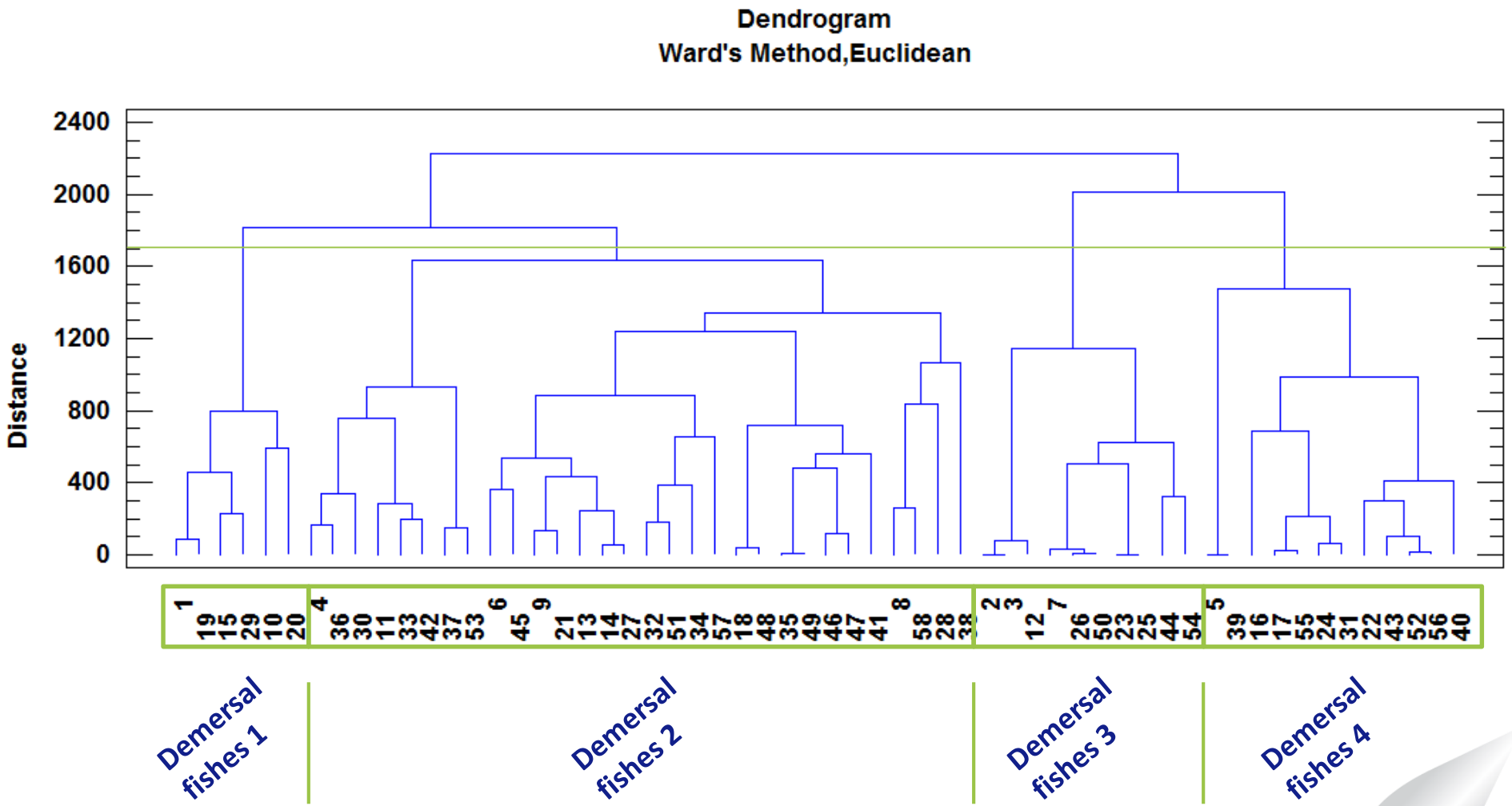
Uncategorized demersal fishes

Species	AA	Species	AA	Species	AA
Callionymus risso	1	*Gobius vittatus*	21	*Scorpaena scrofa*	41
Capros aper	2	*Helicolenus dactylopterus*	22	*Serranus hepatus*	42
Cepola macrophthalma	3	*Hoplostethus mediterraneus*	23	*Serranus cabrilla*	43
Chelidonichthys cuculus	4	*Hymenocephalus italicus*	24	*Serranus scriba*	44
Chelidonichthys lucerna	5	*Lepidopus caudatus*	25	*Sparus aurata*	45
Chimaera monstrosa	6	*Lepidotrigla cavillone*	26	*Spondyliosoma cantharus*	46
Coelorinchus caelorinchus	7	*Lithognathus mormyrus*	27	*Symphodus cinereus*	47
Conger conger	8	*Merlangius merlangus*	28	*Symphodus mediterraneus*	48
Coris julis	9	*Oblada melanura*	29	*Symphodus ocellatus*	49
Deltentosteus quadrimaculatus	10	*Ophichthys rufus*	30	*Symphodus rostratus*	50
Dentex dentex	11	*Ophidion barbatum*	31	*Symphodus tinca*	51
Diplodus annularis	12	*Pagellus acarne*	32	*Syngnathus acus*	52
Diplodus puntazzo	13	*Pagellus bogaraveo*	33	*Trachinus draco*	53
Diplodus sargus	14	*Pagellus erythrinus*	34	*Trigla lyra*	54
Diplodus vulgaris	15	*Pagrus auriga*	35	*Trigloporus lastoviza*	55
Eutrigla gurnardus	16	*Pagrus pagrus*	36	*Umbrina cirrosa*	56
Gnathophis mystax	17	*Pomatomus saltatrix*	37	*Uranoscopus scaber*	57
Gobius bucchichi	18	*Sarpa salpa*	38	*Zeus faber*	58
Gobius cruentatus	19	*Scorpaena notata*	39		
Gobius niger	20	*Scorpaena porcus*	40		

Diet composition



Landings / discards (t/km²/year)

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Navigator

- Ecopath
  - Input
    - Model parameters
    - Basic input
    - Diet composition
    - Detritus fate
    - Other production
  - Fishery
    - Definition of fleets
    - Landings
    - Discards
    - Discard mortality rate
    - Discard fate
    - Off-vessel price
    - Non-market price
  - Tools
  - Output
    - Basic estimates
    - Key indices
    - Mortality rates
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    - Search rates
    - Fishery
    - Particle size distribution
    - Tools
- Ecosim
- Ecospace
- Tools

Start | Basic estimates | Basic input | Diet composition | Definition of f

	Group name	Trawlers (t/km²/year)	Purse seiners (t/km	Beach seiners (t/km²	Small scale (t/km²/year)	Total
1	Phytoplankton					0.000
2	Zooplankton					0.000
3	Benthic small crustaceans					0.000
4	Polychaetes					0.000
5	Shrimps	0.0320			0.0590	0.091
6	Crabs	0.00300			0.00600	0.009
7	Benthic invertebrates					0.000
8	Octopuses and cuttlefish	0.00824	0.000039	0.000105	0.191	0.200
9	Squids	0.01000		0.00100	0.00400	0.015
10	Red mullets	0.00800			0.0310	0.039
11	Anglerfish	0.0140			0.00500	0.019
12	Flatfishes	0.00200	0.00200		0.0920	0.096
13	Other gadiforms	0.0340			0.0170	0.051
14	Hake	0.0170			0.0540	0.071
15	Demersal fishes 1		0.00200		0.00800	0.010
16	Demersal fishes 2	0.0190	0.00500		0.0770	0.101
17	Demersal fishes 3	0.00200	0.00400	0.00100	0.0740	0.081
18	Demersal fishes 4	0.00100	0.00300	0.00100	0.0920	0.097
19	Picarels and bogue		0.0220	0.00200	0.0170	0.041
20	Sharks	0.00150	0.000500		0.00350	0.005
21	Rays and skates	0.00700			0.0380	0.045
22	Anchovy	0.00100	0.392	0.00300	0.199	0.595
23	Sardine	0.00100	0.341	0.0170	0.489	0.848
24	Horse mackerels	0.00600	0.0530	0.00200	0.105	0.166
25	Mackerels		0.0340	0.00100	0.0190	0.054
26	Other small pelagics		0.0860	0.00200	0.320	0.408
27	Medium pelagics		0.00200		0.0150	0.017
28	Large pelagics	0.000035	0.00100	0.000082	0.00883	0.010
29	Loggerhead turtle					0.000
30	Seabirds					0.000
31	Dolphins					0.000
32	Discards					0.000
33	Detritus					0.000

Status | Remarks

(derived value selected)

th Ecosim 6.5.14040.0

Ecospace Tools Windows Help

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Start | Basic estimates | Basic input | Diet composition | Definition of f

	Group name	Trawlers (t/km²)	Purse seiners (t/km	Beach seiners (t/km²	Small scale (t/km²)	Total
1	Phytoplankton					0.000
2	Zooplankton					0.000
3	Benthic small crustaceans					0.000
4	Polychaetes					0.000
5	Shrimps	0.0140			0.00600	0.020
6	Crabs	0.00100			0.00100	0.002
7	Benthic invertebrates	0.00480			0.00350	0.008
8	Octopuses and cuttlefish	0.00900			0.0450	0.054
9	Squids	0.00400				0.004
10	Red mullets	0.00400			0.00300	0.007
11	Anglerfish	0.00600			0.00100	0.007
12	Flatfishes				0.00900	0.009
13	Other gadiforms	0.00800			0.00100	0.009
14	Hake	0.00700			0.00500	0.012
15	Demersal fishes 1				0.00600	0.006
16	Demersal fishes 2	0.00400			0.00800	0.012
17	Demersal fishes 3	0.00100			0.00800	0.009
18	Demersal fishes 4				0.01000	0.010
19	Picarels and bogue		0.00100		0.00200	0.003
20	Sharks	0.00100	0.00100		0.00300	0.005
21	Rays and skates	0.00400			0.00200	0.006
22	Anchovy		0.0180		0.0200	0.038
23	Sardine		0.0160	0.00200	0.0490	0.067
24	Horse mackerels	0.00400	0.00300		0.01000	0.017
25	Mackerels		0.00200		0.00200	0.004
26	Other small pelagics		0.00400		0.0310	0.035
27	Medium pelagics				0.00100	0.001
28	Large pelagics				0.00700	0.007
29	Loggerhead turtle				0.00250	0.002
30	Seabirds					0.000
31	Dolphins				0.000340	0.000
32	Discards					0.000
33	Detritus					0.000

P/B – production/biomass (year^{-1})

Turnover rate

P/B = Z = F + M

F from stock assessment: **F = C/B**

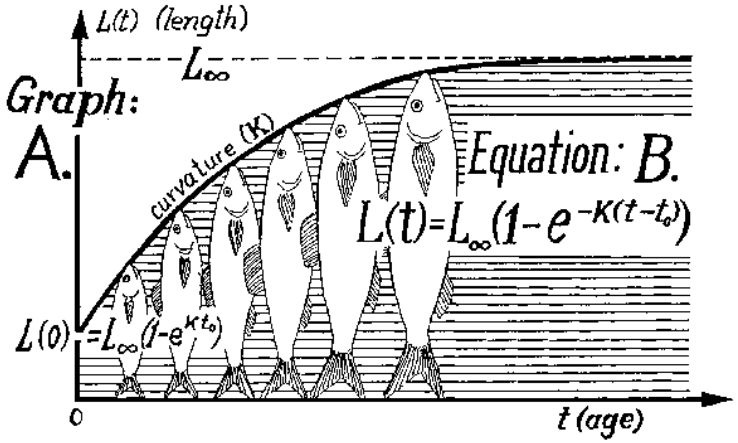
M from empirical equation (Pauly, 1980)

$$M = K^{0.65} \cdot L_{\infty}^{-0.279} \cdot T^{0.463}$$

K is the growth rate (/year)

L_{∞} is the asymptotic length (total length, cm)

Tc is the mean habitat (water) temperature, in °C



weighted averages for each FG

Non-fish FGs: values from other models with adjusted T, literature

Q/B – food consumption (year^{-1})

Q/B from **FishBase Life-history tool**

fishbase.se/popdyn/KeyfactsSummary_1.php?ID=1327&genusname=Mullus&speciesname=surmuletus&fc=332&vstockcode=1345

Values shown below are defaults. Please double-check, replace with better values as appropriate, and 'Recalculate'.

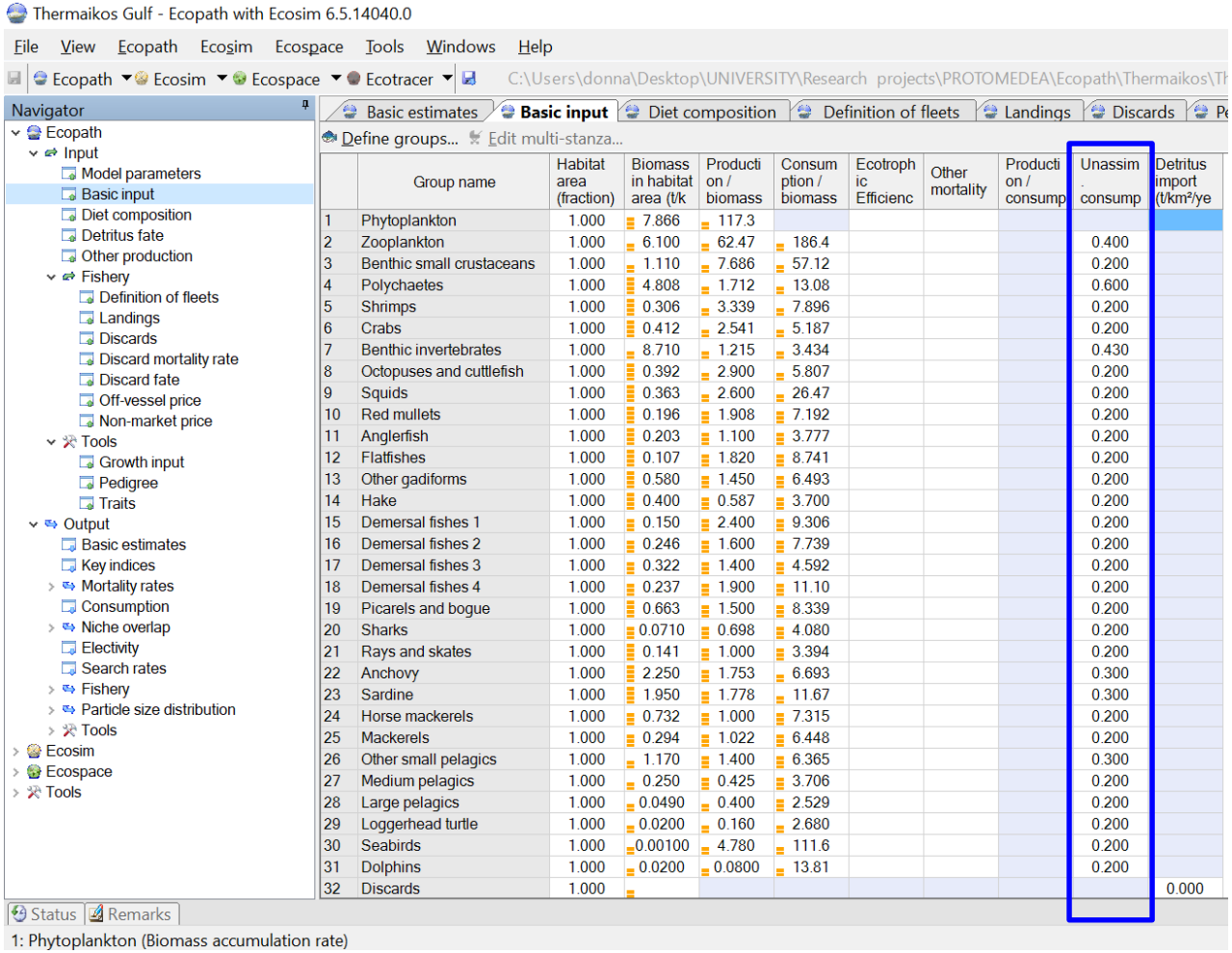
About this page...

Life History Data on *Mullus surmuletus*
Surmullet

Family:	Mullidae Goatfishes	
Trophic level:	3.5 +/- s.e. 0.29 Estimated from diet data. Diet	
Food consumption (Q/B):	6.6 times the body weight per year	Enter Winf, temperature, aspect ratio (A), and food type to estimate Q/B Winf = 450 g Temp. = 17.5 °C A = 1.9 Detrivore Herbivore Omnivore Carnivore
Estimate growth		
Note: The estimates are derived from default values taken from FishBase and will thus not be appropriate for every population. You can change these values and recalculate the life history parameters.		Recalculate Back to Search Species summary

*Non-fish FGs: values from other models with adjusted T, literature

Unassimilated consumption



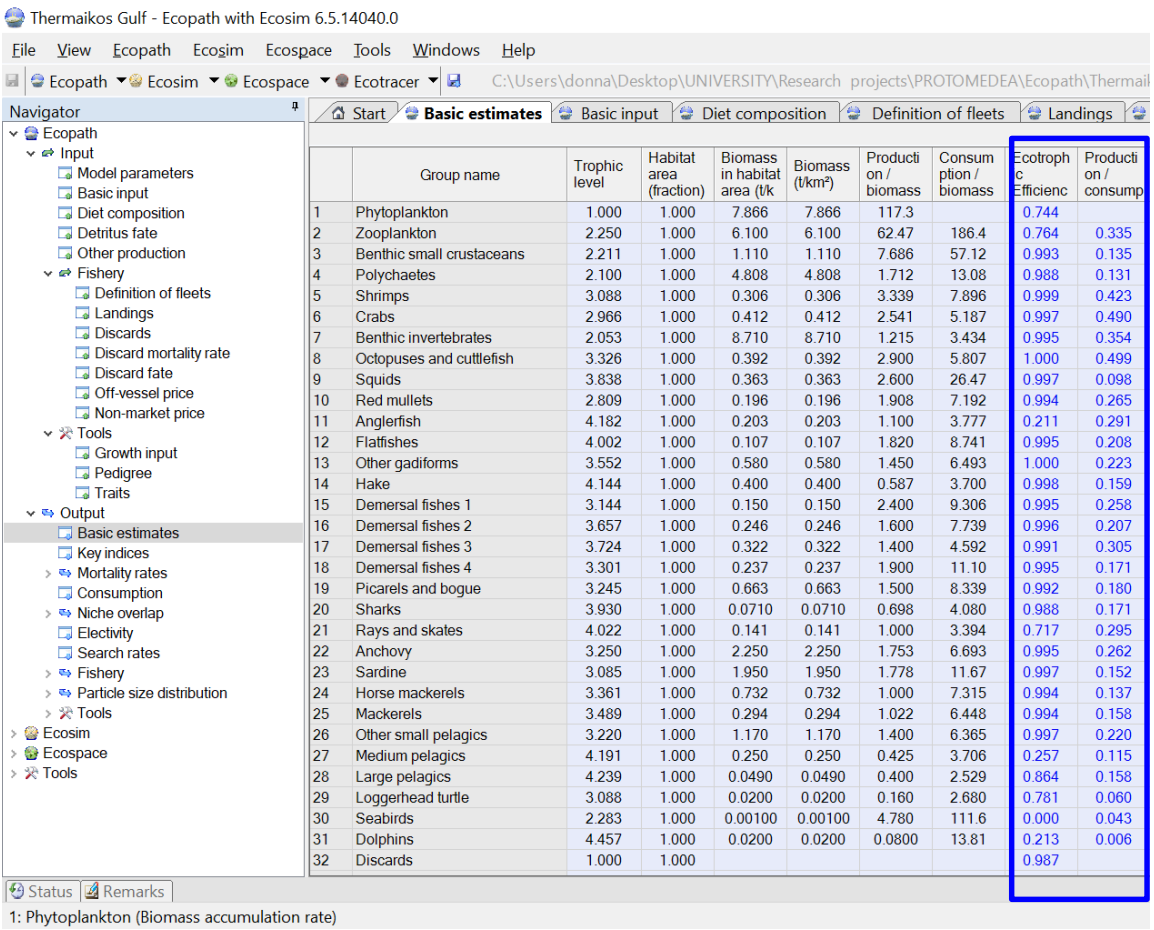
	Group name	Habitat area (fraction)	Biomass in habitat area (t/k	Production / biomass	Consumption / biomass	Ecotrophic Efficienc	Other mortality	Production / consump	Unassim. consump	Detritus import (t/km²/ye
1	Phytoplankton	1.000	7.866	117.3						
2	Zooplankton	1.000	6.100	62.47	186.4				0.400	
3	Benthic small crustaceans	1.000	1.110	7.686	57.12				0.200	
4	Polychaetes	1.000	4.808	1.712	13.08				0.600	
5	Shrimps	1.000	0.306	3.339	7.896				0.200	
6	Crabs	1.000	0.412	2.541	5.187				0.200	
7	Benthic invertebrates	1.000	8.710	1.215	3.434				0.430	
8	Octopuses and cuttlefish	1.000	0.392	2.900	5.807				0.200	
9	Squids	1.000	0.363	2.600	26.47				0.200	
10	Red mullets	1.000	0.196	1.908	7.192				0.200	
11	Anglerfish	1.000	0.203	1.100	3.777				0.200	
12	Flatfishes	1.000	0.107	1.820	8.741				0.200	
13	Other gadiforms	1.000	0.580	1.450	6.493				0.200	
14	Hake	1.000	0.400	0.587	3.700				0.200	
15	Demersal fishes 1	1.000	0.150	2.400	9.306				0.200	
16	Demersal fishes 2	1.000	0.246	1.600	7.739				0.200	
17	Demersal fishes 3	1.000	0.322	1.400	4.592				0.200	
18	Demersal fishes 4	1.000	0.237	1.900	11.10				0.200	
19	Picarels and bogue	1.000	0.663	1.500	8.339				0.200	
20	Sharks	1.000	0.0710	0.698	4.080				0.200	
21	Rays and skates	1.000	0.141	1.000	3.394				0.200	
22	Anchovy	1.000	2.250	1.753	6.693				0.300	
23	Sardine	1.000	1.950	1.778	11.67				0.300	
24	Horse mackerels	1.000	0.732	1.000	7.315				0.200	
25	Mackerels	1.000	0.294	1.022	6.448				0.200	
26	Other small pelagics	1.000	1.170	1.400	6.365				0.300	
27	Medium pelagics	1.000	0.250	0.425	3.706				0.200	
28	Large pelagics	1.000	0.0490	0.400	2.529				0.200	
29	Loggerhead turtle	1.000	0.0200	0.160	2.680				0.200	
30	Seabirds	1.000	0.00100	4.780	111.6				0.200	
31	Dolphins	1.000	0.0200	0.0800	13.81				0.200	
32	Discards	1.000								0.000

Default value of **0.2** for **carnivorous fish groups** if other estimates are not available (Winberg 1956)

For **herbivores**, the proportion not assimilated may be considerably higher, e.g. up to **0.4** in **zooplankton**

The **fraction of the food** that is not assimilated (it is **not physiologically useful**), consists of urine and feces and is directed to **detritus**.

ECOPATH outputs



	Group name	Trophic level	Habitat area (fraction)	Biomass in habitat area (t/k	Biomass (t/km²)	Production / biomass	Consumption / biomass	Ecotrophic Efficienc	Production / consump
1	Phytoplankton	1.000	1.000	7.866	7.866	117.3		0.744	
2	Zooplankton	2.250	1.000	6.100	6.100	62.47	186.4	0.764	0.335
3	Benthic small crustaceans	2.211	1.000	1.110	1.110	7.686	57.12	0.993	0.135
4	Polychaetes	2.100	1.000	4.808	4.808	1.712	13.08	0.988	0.131
5	Shrimps	3.088	1.000	0.306	0.306	3.339	7.896	0.999	0.423
6	Crabs	2.966	1.000	0.412	0.412	2.541	5.187	0.997	0.490
7	Benthic invertebrates	2.053	1.000	8.710	8.710	1.215	3.434	0.995	0.354
8	Octopuses and cuttlefish	3.326	1.000	0.392	0.392	2.900	5.807	1.000	0.499
9	Squids	3.838	1.000	0.363	0.363	2.600	26.47	0.997	0.098
10	Red mullets	2.809	1.000	0.196	0.196	1.908	7.192	0.994	0.265
11	Anglerfish	4.182	1.000	0.203	0.203	1.100	3.777	0.211	0.291
12	Flatfishes	4.002	1.000	0.107	0.107	1.820	8.741	0.995	0.208
13	Other gadiforms	3.552	1.000	0.580	0.580	1.450	6.493	1.000	0.223
14	Hake	4.144	1.000	0.400	0.400	0.587	3.700	0.998	0.159
15	Demersal fishes 1	3.144	1.000	0.150	0.150	2.400	9.306	0.995	0.258
16	Demersal fishes 2	3.657	1.000	0.246	0.246	1.600	7.739	0.996	0.207
17	Demersal fishes 3	3.724	1.000	0.322	0.322	1.400	4.592	0.991	0.305
18	Demersal fishes 4	3.301	1.000	0.237	0.237	1.900	11.10	0.995	0.171
19	Picarels and bogue	3.245	1.000	0.663	0.663	1.500	8.339	0.992	0.180
20	Sharks	3.930	1.000	0.0710	0.0710	0.698	4.080	0.988	0.171
21	Rays and skates	4.022	1.000	0.141	0.141	1.000	3.394	0.717	0.295
22	Anchovy	3.250	1.000	2.250	2.250	1.753	6.693	0.995	0.262
23	Sardine	3.085	1.000	1.950	1.950	1.778	11.67	0.997	0.152
24	Horse mackerels	3.361	1.000	0.732	0.732	1.000	7.315	0.994	0.137
25	Mackerels	3.489	1.000	0.294	0.294	1.022	6.448	0.994	0.158
26	Other small pelagics	3.220	1.000	1.170	1.170	1.400	6.365	0.997	0.220
27	Medium pelagics	4.191	1.000	0.250	0.250	0.425	3.706	0.257	0.115
28	Large pelagics	4.239	1.000	0.0490	0.0490	0.400	2.529	0.864	0.158
29	Loggerhead turtle	3.088	1.000	0.0200	0.0200	0.160	2.680	0.781	0.060
30	Seabirds	2.283	1.000	0.00100	0.00100	4.780	111.6	0.000	0.043
31	Dolphins	4.457	1.000	0.0200	0.0200	0.0800	13.81	0.213	0.006
32	Discards	1.000	1.000					0.987	

P/Q typically varies between **0.1 and 0.30**

Consumption of most groups is about 3-10 times higher than their production

May be lower for top predators and higher for very small organisms

It “travels well”

EE is the proportion of production that is used in the system (predation or fishing)

1-EE is “other mortality”

EE **close to 1** usually, except for

Phytoplankton in bloom (0.5)

Kelp and macro-algae (0.1)

Unexploited predators (~0)

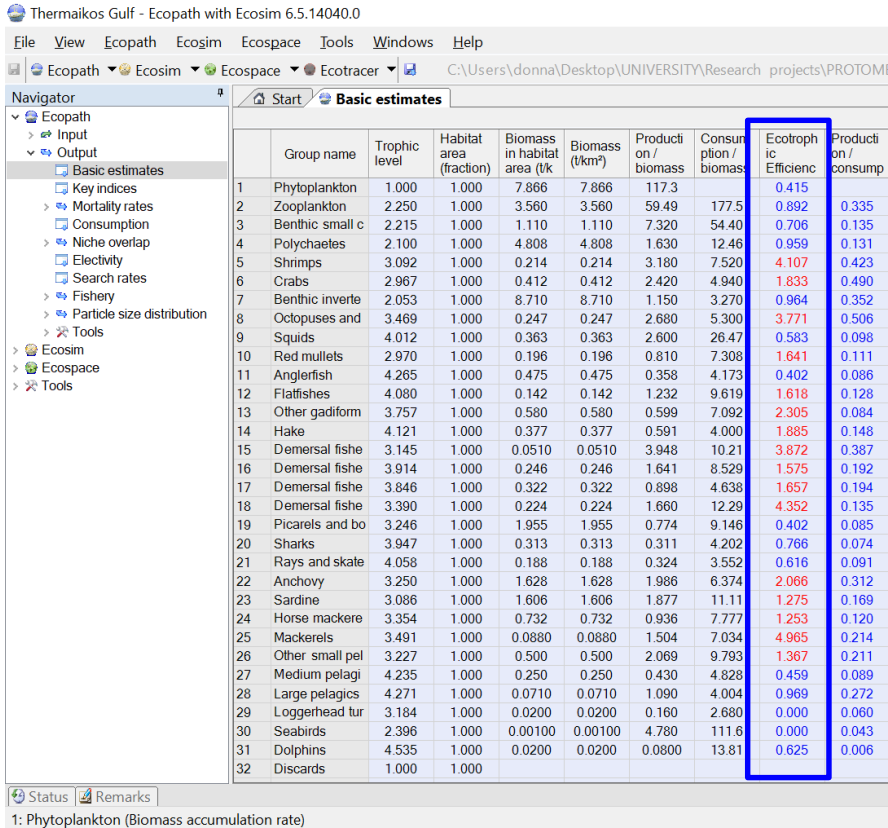
***EE* < 1.0:** The EE can never > 1

It is not possible for more biomass to be passed on to the next trophic level than was originally produced

- Maybe a FG has **too low biomass**
- Maybe the **conversion factors** used are wrong
- Maybe **too much predation** is exerted on a FG
- Maybe a FG is **fished too much**

Look for **big problems initially**, evaluate which parameters are **most uncertain**, change those

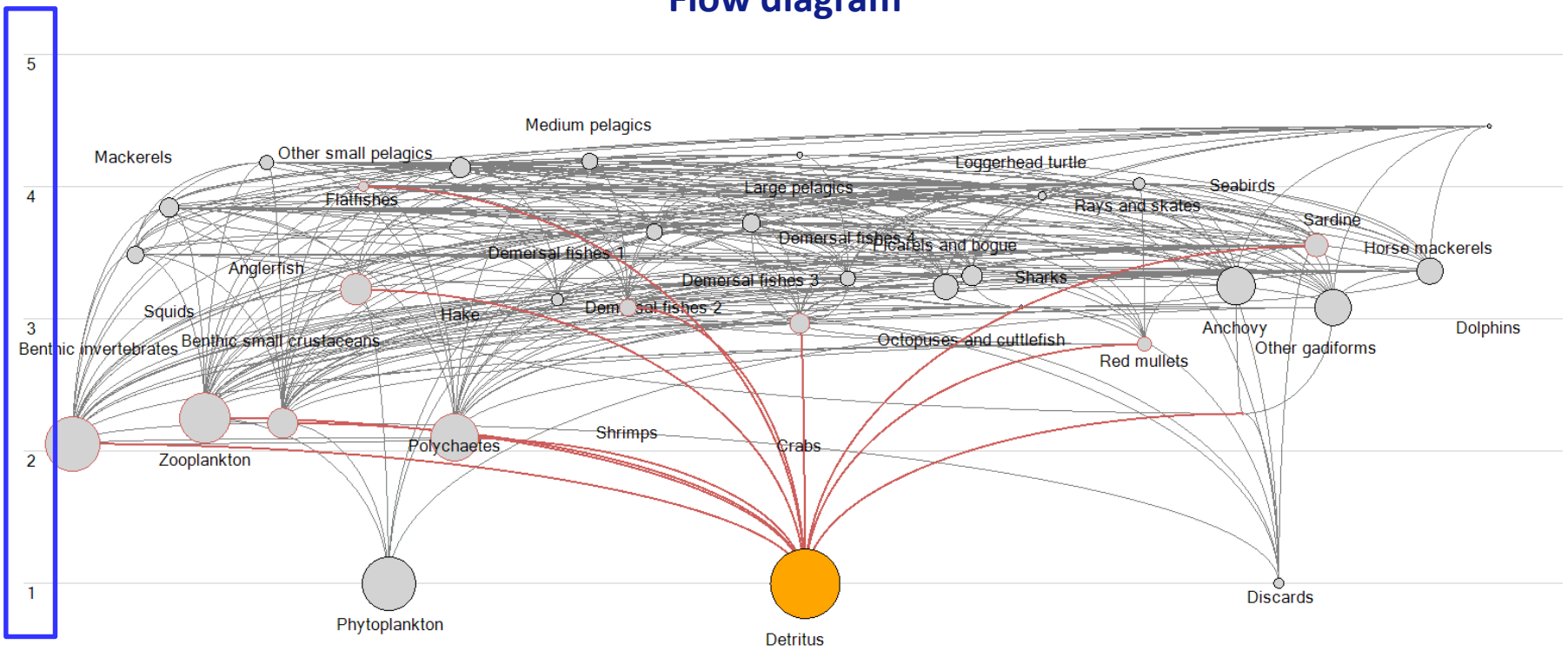
Modify the data that has **less quality** (use pedigree)



	Group name	Trophic level	Habitat area (fraction)	Biomass in habitat area (t/k	Biomass (t/km²)	Production / biomass	Consumption / biomass	Ecotrophic Efficienc	Production / consump
1	Phytoplankton	1.000	1.000	7.866	7.866	117.3		0.415	
2	Zooplankton	2.250	1.000	3.560	3.560	59.49	177.5	0.892	0.335
3	Benthic small c	2.215	1.000	1.110	1.110	7.320	54.40	0.706	0.135
4	Polychaetes	2.100	1.000	4.808	4.808	1.630	12.46	0.959	0.131
5	Shrimps	3.092	1.000	0.214	0.214	3.180	7.520	4.107	0.423
6	Crabs	2.967	1.000	0.412	0.412	2.420	4.940	1.833	0.490
7	Benthic inverte	2.053	1.000	8.710	8.710	1.150	3.270	0.964	0.352
8	Octopuses and	3.469	1.000	0.247	0.247	2.680	5.300	3.771	0.506
9	Squids	4.012	1.000	0.363	0.363	2.600	26.47	0.583	0.098
10	Red mullets	2.970	1.000	0.196	0.196	0.810	7.308	1.641	0.111
11	Anglerfish	4.265	1.000	0.475	0.475	0.358	4.173	0.402	0.086
12	Flatfishes	4.080	1.000	0.142	0.142	1.232	9.619	1.618	0.128
13	Other gadiform	3.757	1.000	0.580	0.580	0.599	7.092	2.305	0.084
14	Hake	4.121	1.000	0.377	0.377	0.591	4.000	1.885	0.148
15	Demersal fishe	3.145	1.000	0.0510	0.0510	3.948	10.21	3.872	0.387
16	Demersal fishe	3.914	1.000	0.246	0.246	1.641	8.529	1.575	0.192
17	Demersal fishe	3.846	1.000	0.322	0.322	0.898	4.638	1.657	0.194
18	Demersal fishe	3.390	1.000	0.224	0.224	1.660	12.29	4.352	0.135
19	Picarels and bo	3.246	1.000	1.955	1.955	0.774	9.146	0.402	0.085
20	Sharks	3.947	1.000	0.313	0.313	0.311	4.202	0.766	0.074
21	Rays and skate	4.058	1.000	0.188	0.188	0.324	3.552	0.616	0.091
22	Anchovy	3.250	1.000	1.628	1.628	1.986	6.374	2.066	0.312
23	Sardine	3.086	1.000	1.606	1.606	1.877	11.11	1.275	0.169
24	Horse mackere	3.354	1.000	0.732	0.732	0.936	7.777	1.253	0.120
25	Mackerels	3.491	1.000	0.0880	0.0880	1.504	7.034	4.965	0.214
26	Other small pel	3.227	1.000	0.500	0.500	2.069	9.793	1.367	0.211
27	Medium pelagi	4.235	1.000	0.250	0.250	0.430	4.828	0.459	0.089
28	Large pelagics	4.271	1.000	0.0710	0.0710	1.090	4.004	0.969	0.272
29	Loggerhead tur	3.184	1.000	0.0200	0.0200	0.160	2.680	0.000	0.060
30	Seabirds	2.396	1.000	0.00100	0.00100	4.780	111.6	0.000	0.043
31	Dolphins	4.535	1.000	0.0200	0.0200	0.0800	13.81	0.625	0.006
32	Discards	1.000	1.000						

ODYSSEA

Flow diagram



The **main trophic flows** among the functional groups are illustrated in the output flow diagram where all groups are organized based on their **TLs** and their **habitat** (pelagic or demersal).

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Summary statistics and indicators

Parameter	Thermaikos	Units
Sum of all consumption	1386	t km^{-2} yr^{-1}
Sum of all exports	514	t km^{-2} yr^{-1}
Sum of all respiratory flows	417	t km^{-2} yr^{-1}
Sum of all flows into detritus	868	t km^{-2} yr^{-1}
Total system throughput	3184	t km^{-2} yr^{-1}
Sum of all production	1350	t km^{-2} yr^{-1}
Mean trophic level of the catch	3.314	
Calculated total net primary production	923	t km^{-2} yr^{-1}
Total primary production / total respiration	2.212	
Net system production	506	t km^{-2} yr^{-1}
Total primary production / total biomass	23	
Total biomass / total throughput	0.013	
Total biomass (excluding detritus)	40	t km^{-2}
System Omnivory Index	0.2	
Ecopath pedigree index	0.534	

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Statistics

	Parameter	Thermaikos	Units
+	Sum of all consumption	**1386**	**t km^{-2} yr^{-1}**
+	Sum of all exports	**514**	**t km^{-2} yr^{-1}**
+	Sum of all respiratory flows	**417**	**t km^{-2} yr^{-1}**
+	Sum of all flows into detritus	**868**	**t km^{-2} yr^{-1}**
=	Total system throughput	**3184**	**t km^{-2} yr^{-1}**

The **total system throughput** is the **sum of all flows in a system**.

It is considered to be an indirect indicator of the size of the food web and is estimated as the sum of four flow components, i.e.

Total consumption + Total export + Total respiration + Total flows to detritus

(Export = commercial fishing)

Total system throughput represents the **'size of the entire system in terms of flow'** (Ulanowicz, 1986).

As such, it is an important parameter for **comparisons of flow networks**.

ODYSSEA

Statistics

Parameter	Thermaikos	Units
Total primary production / total respiration	**2.212**	
Net system production	**506**	**t km^{-2} yr^{-1}**
Total primary production / total biomass	**23**	
Total biomass / total throughput	**0.013**	

Total primary production / total respiration and biomass: important ratio for description of the **maturity of an ecosystem** (Odum 1971)

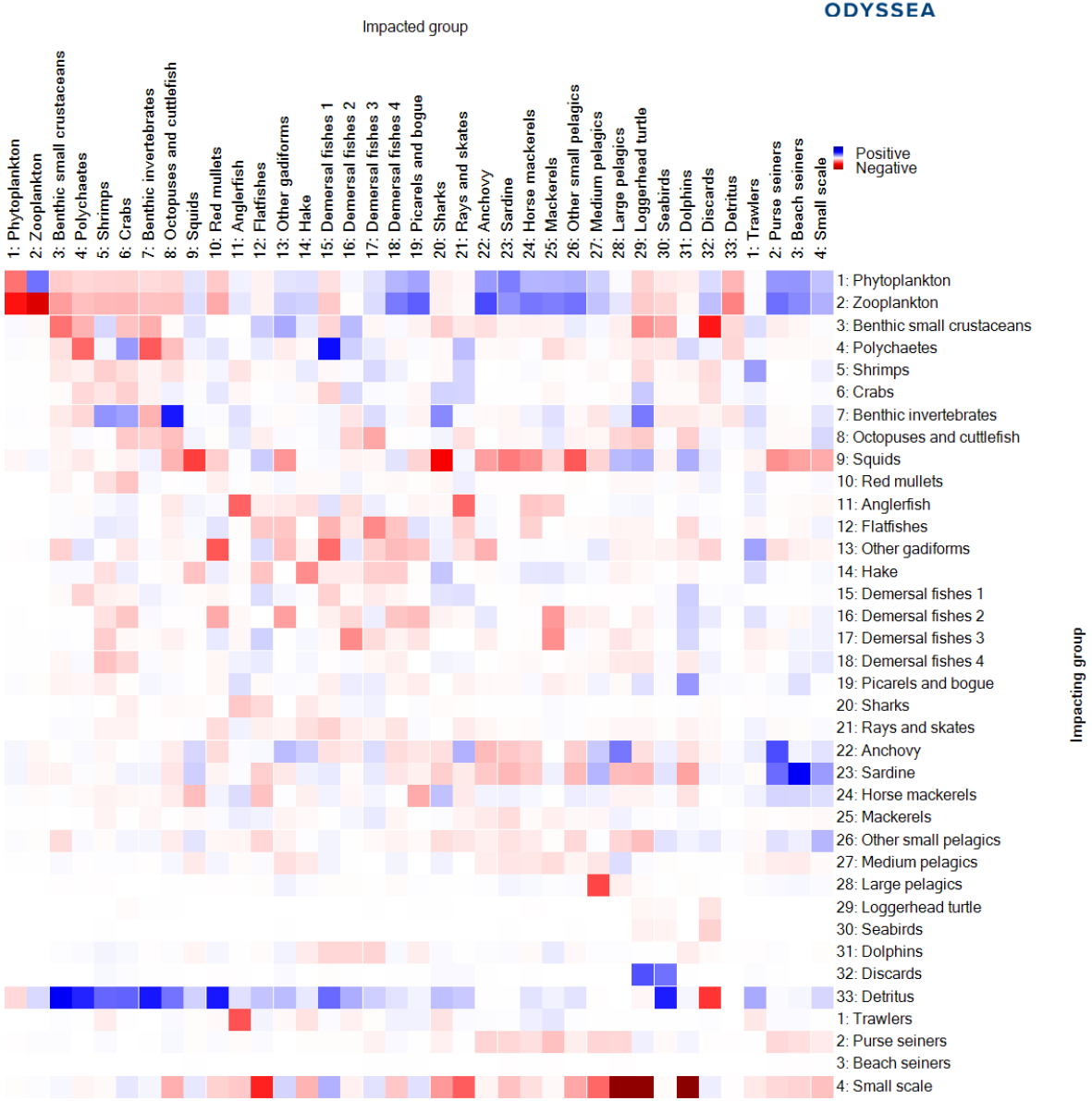
In **early developmental stages** of a system, production is expected to exceed respiration, **>1** and biomass accumulates over time, production to biomass **declines**

Fishing causes the bottom complexity as well as the benthos and fish species composition to change from mature to disturbed ecosystems (Watling and Norse, 1998)

Net system production: difference between total primary production and respiration, large in immature systems, close to 0 in mature

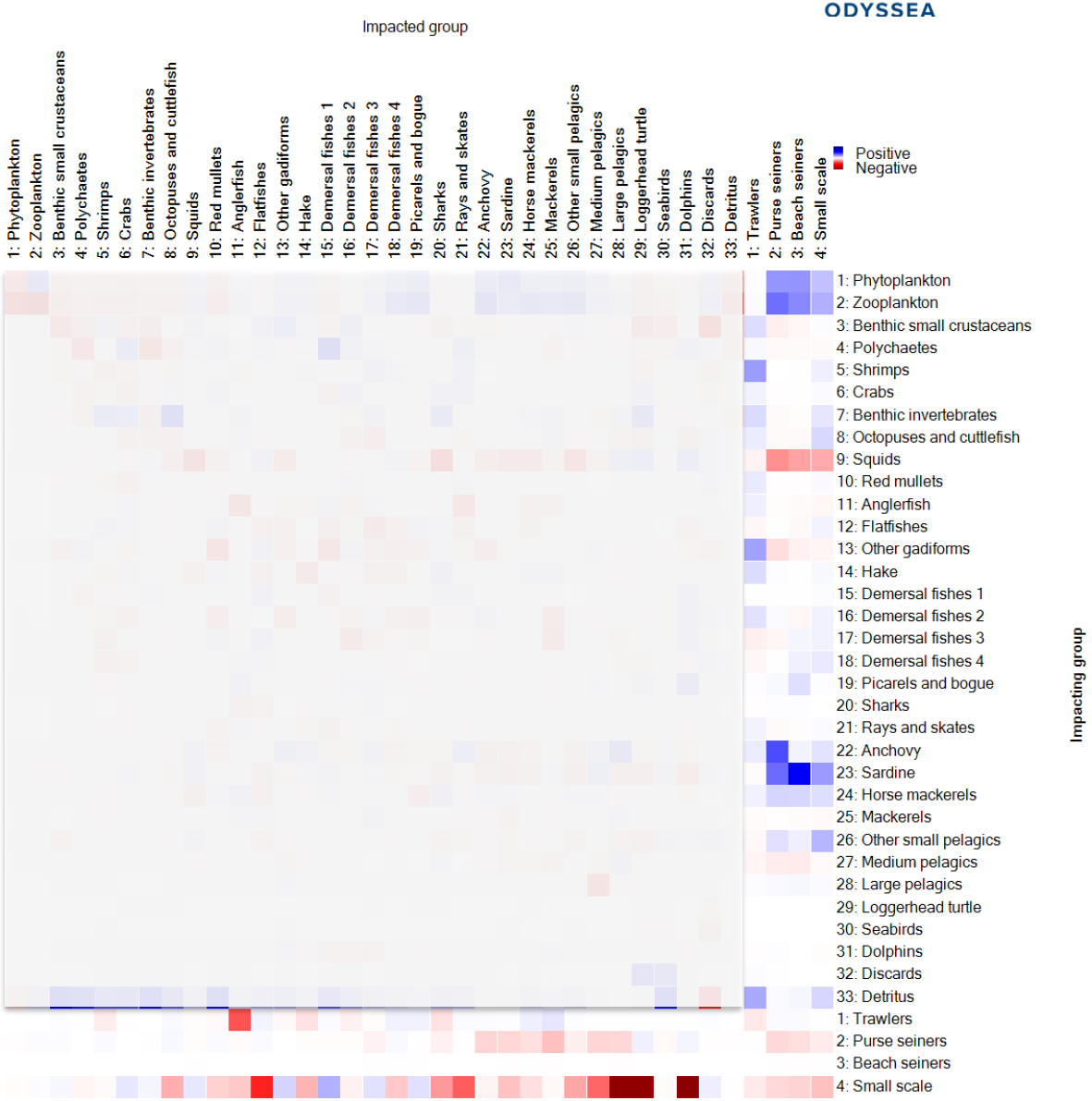
System biomass / throughput: decrease to a minimum for the most immature stages of a system, close to 0

Mixed Trophic Impact plot



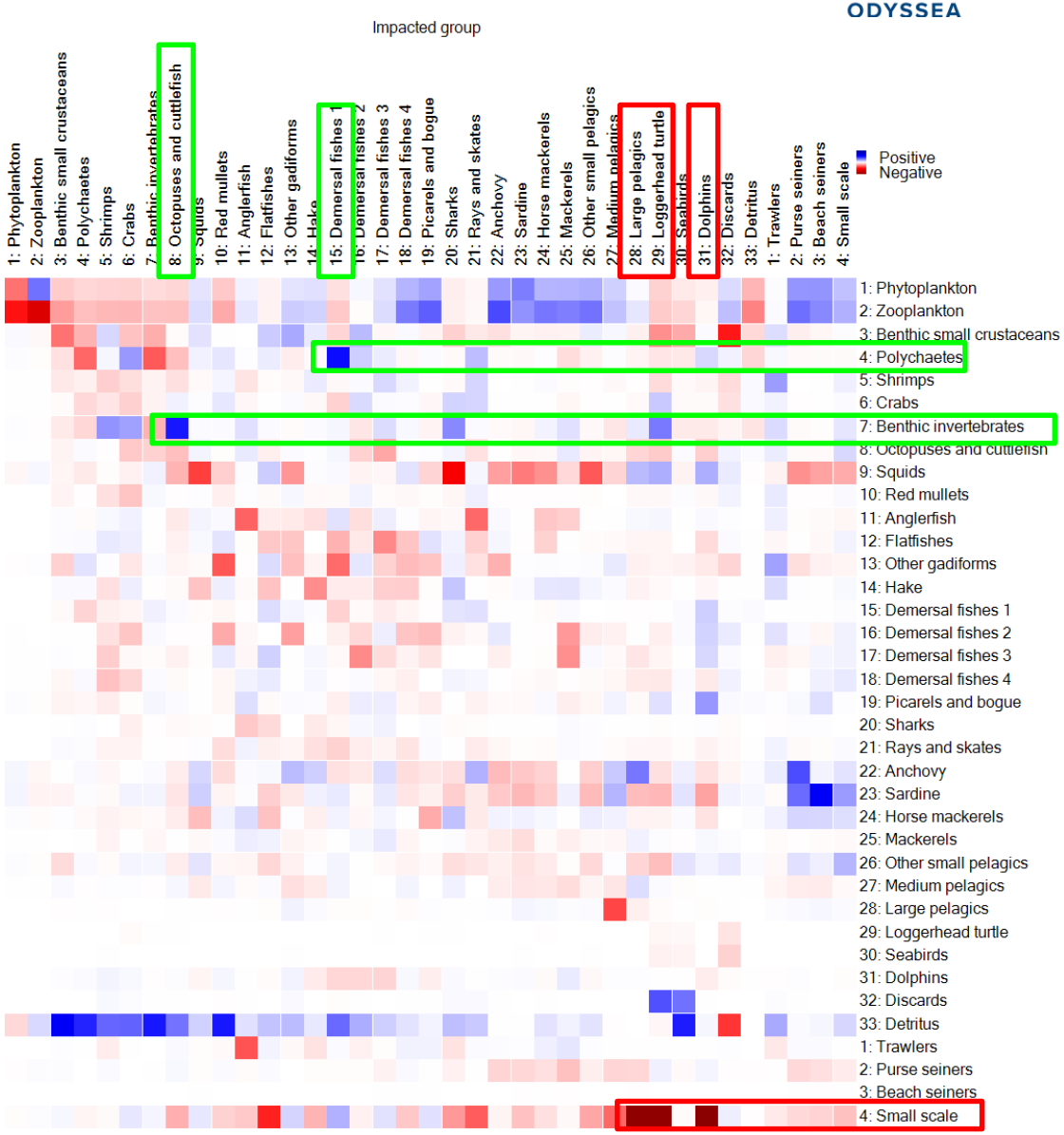
The **relative** direct and indirect **impact** that a hypothetical very **small increase of the biomass** of the impacting groups have on the biomass of the **impacted groups**.

Mixed Trophic Impact plot



Impacts due to **fishing**

Mixed Trophic Impact plot



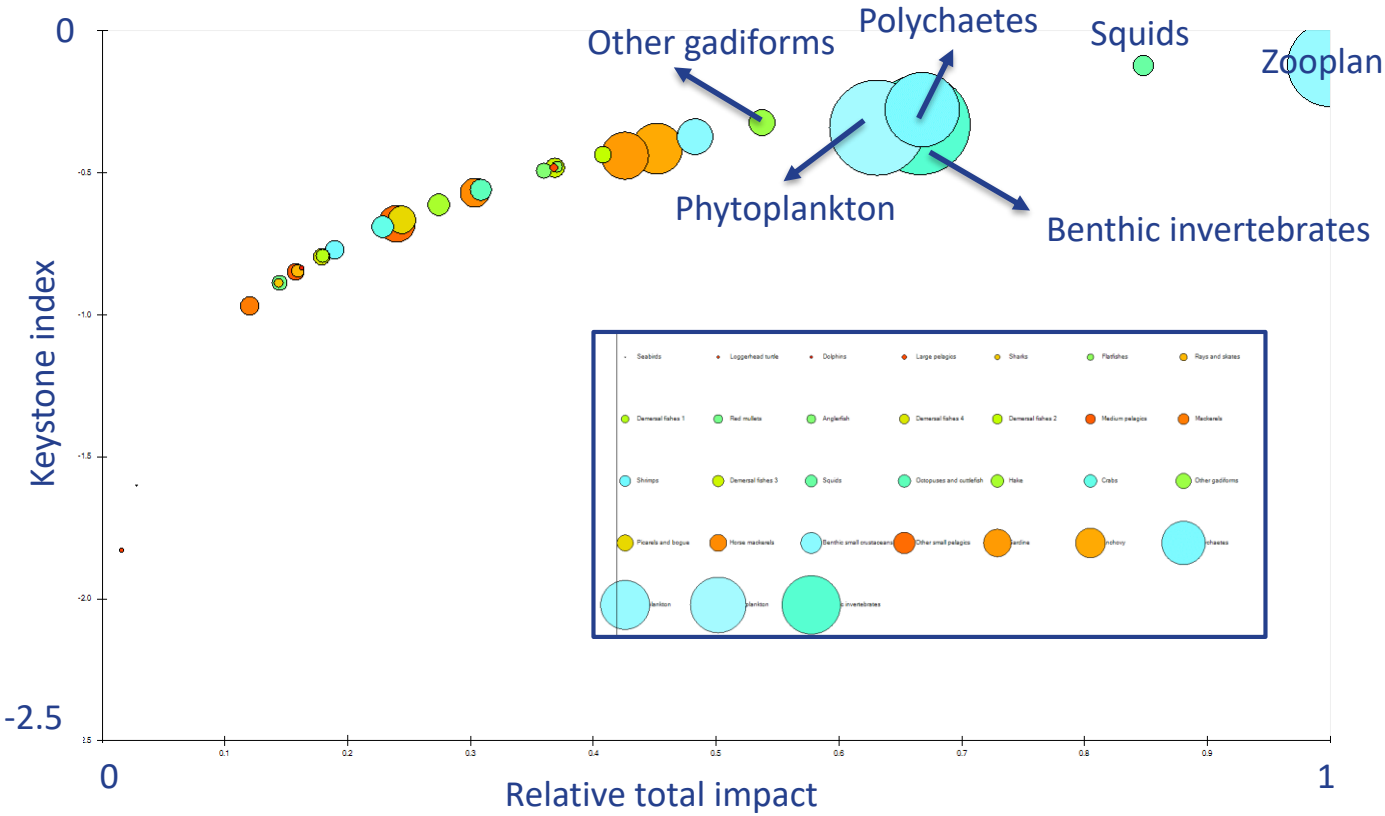
Octopuses & cuttlefish **eat a lot** of benthic invertebrates

Demersal fishes 1 **eat a lot** of polychaetes

Small scale vessels **discard** many large pelagics, turtles and dolphins

Most groups have a **negative impact on themselves**, interpreted here as reflecting increased **within-group competition for resources**.

Keystoneness graph



Squids and **other gadiforms**: high relative total **impact** and **keystoneness** with relatively low biomass

Zooplankton: the most important group (impact), but **not** keystone due to high abundance

Keystone groups >0: play an important role in the food-web with relatively low biomass

Dominant groups: play an important role and have a relative large biomass in the ecosystem