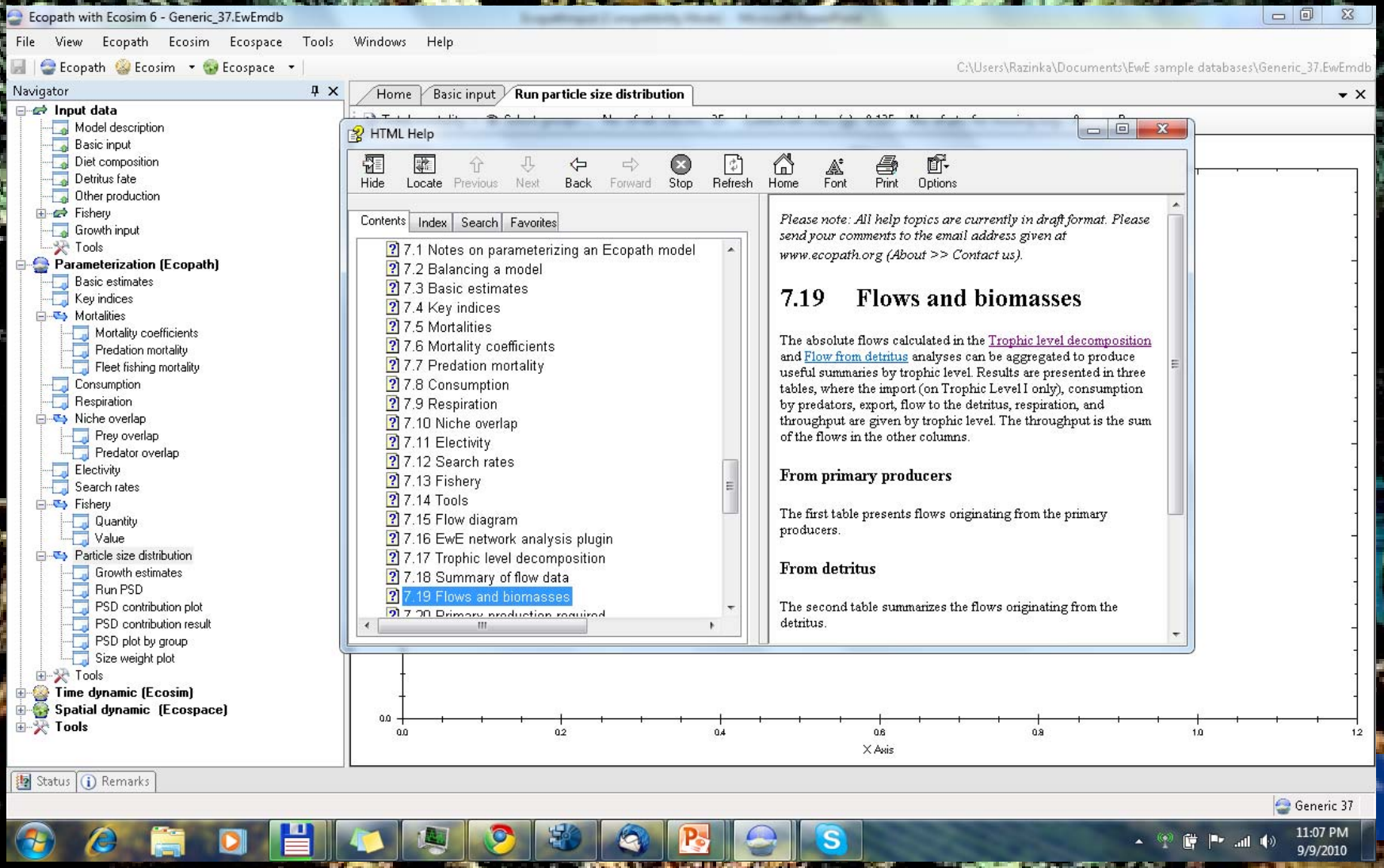
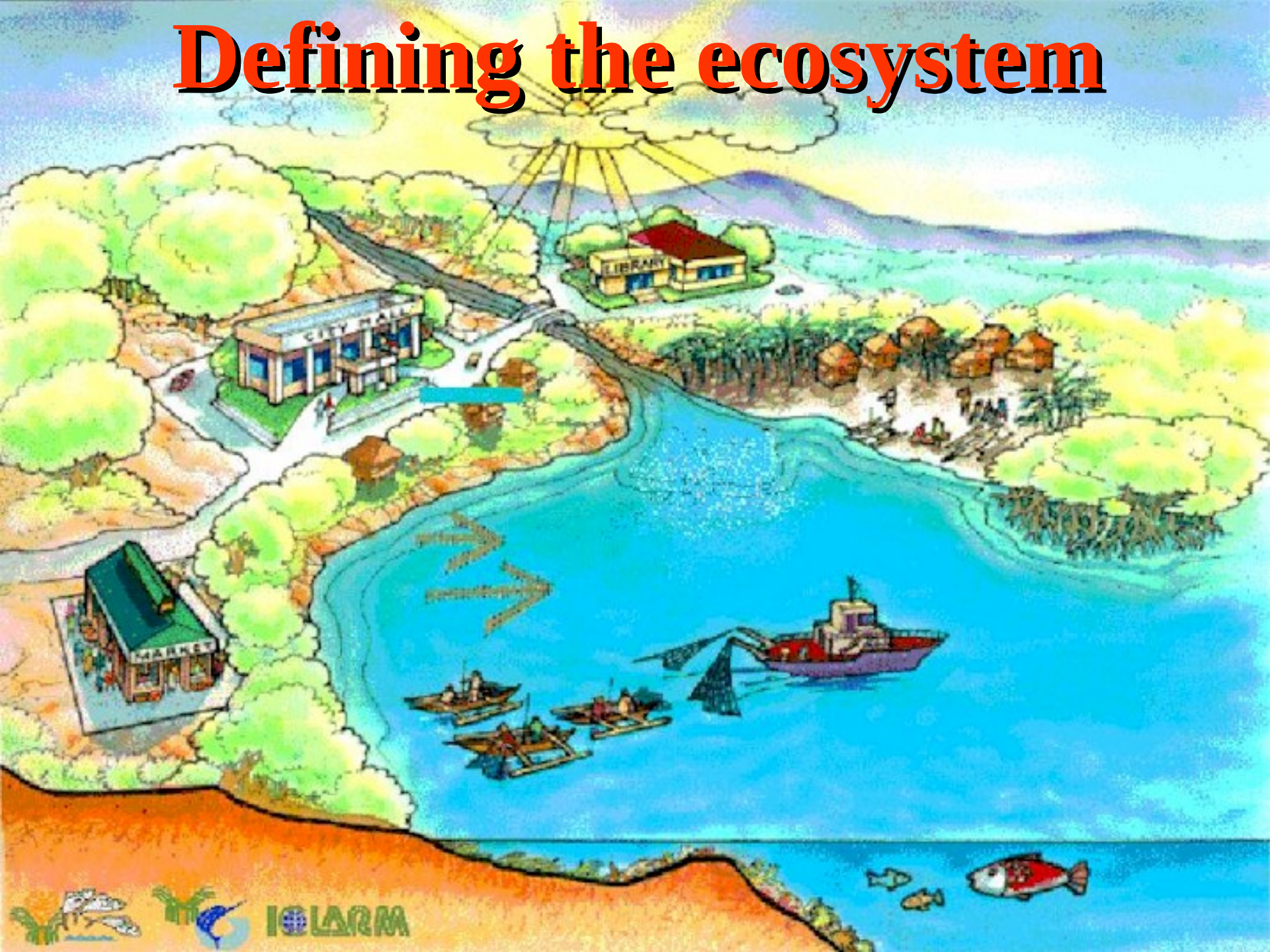
Running Ecopath

- Ecopath with Ecosim is freely available for download through www.ecopath.org

Ecopath includes extended help



Defining the ecosystem

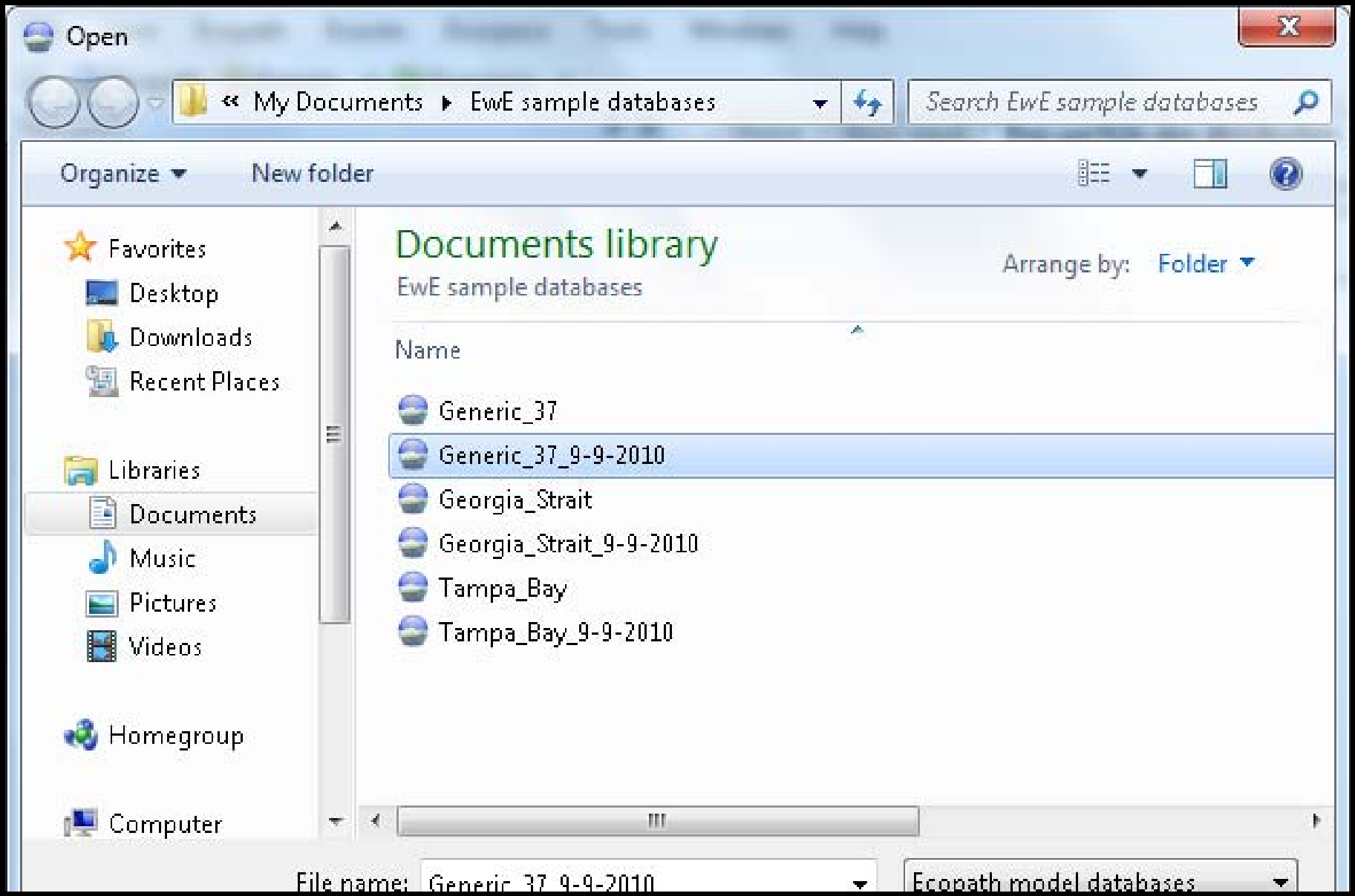


Odum's definition:

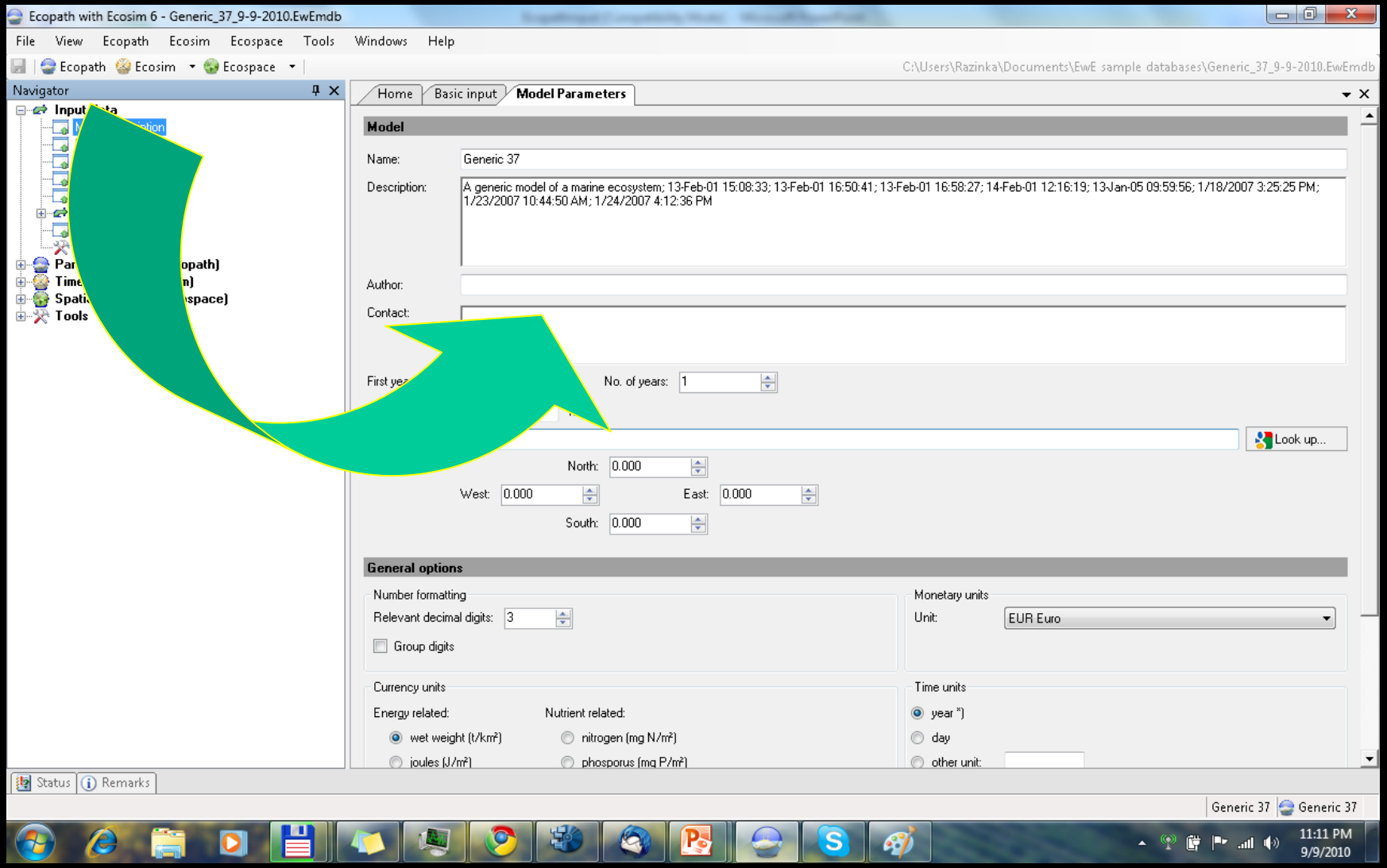
- "any entity or natural unit that includes living and nonliving parts interacting to produce a stable system in which the exchange of materials between the living and nonliving parts follows circular paths is an ecological system or ecosystem. The ecosystem is the largest functional unit in ecology, since it includes both organisms (biotic communities) and abiotic environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth. A lake is an example of an ecosystem."

Odum. E.P. 1953. Fundamentals of Ecology.

Open a model from the database



Model information

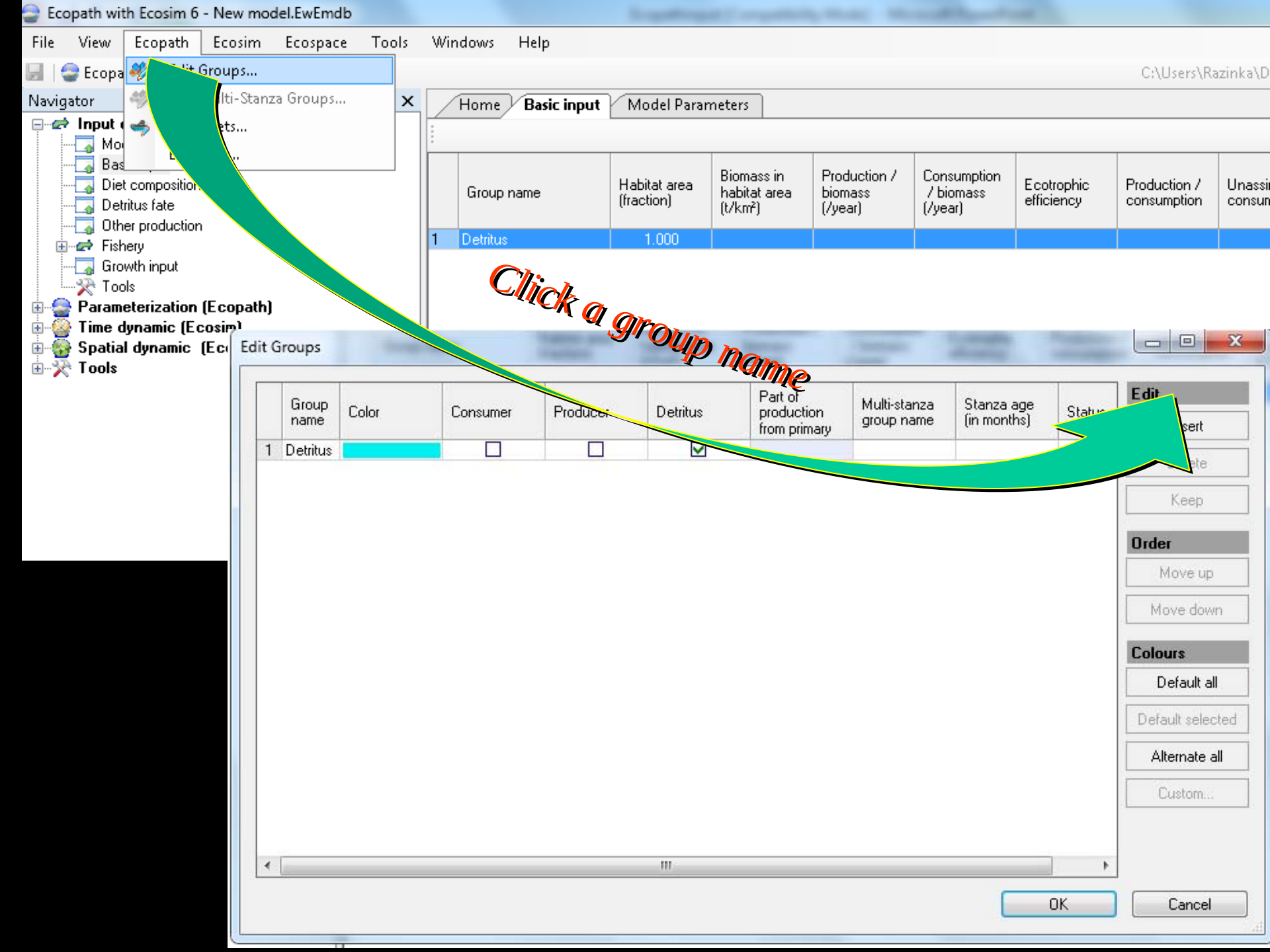


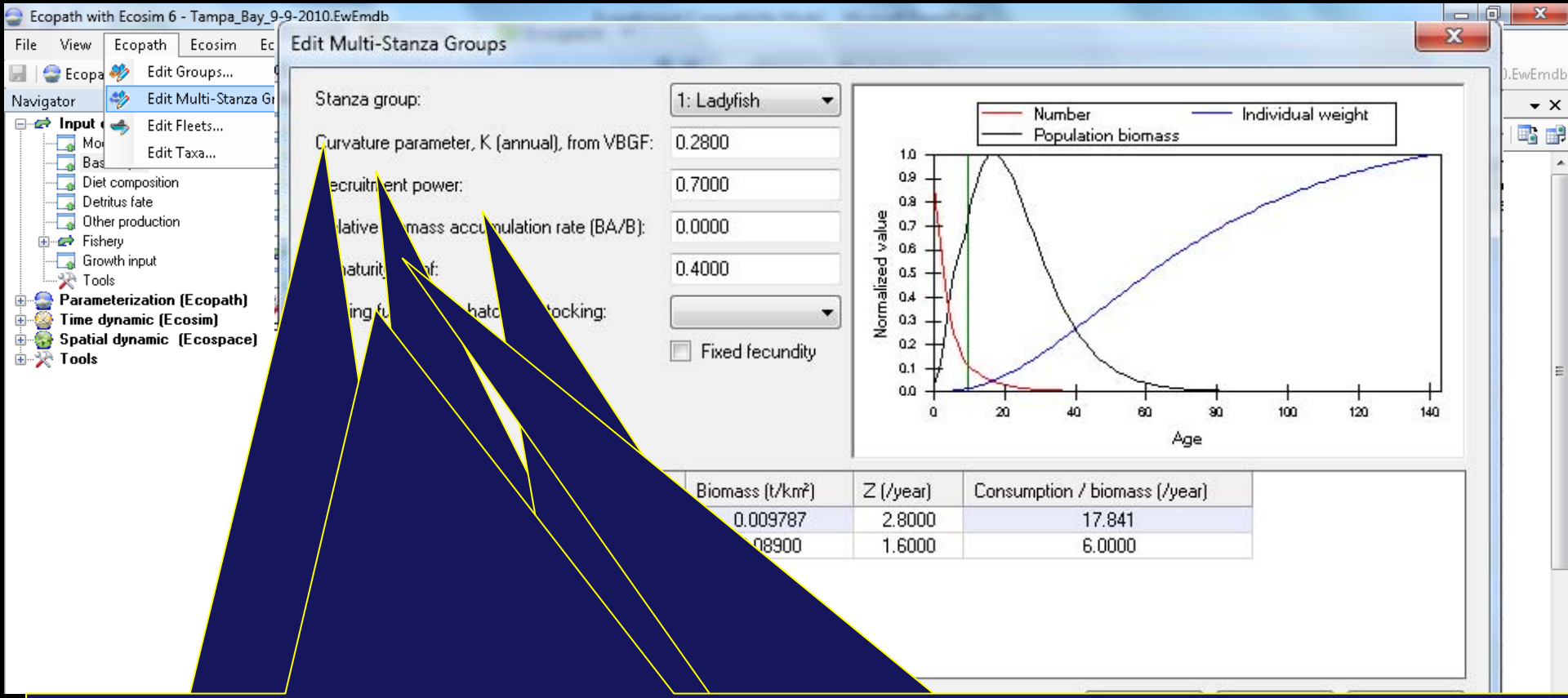
Defining the ecosystem groups

- Use functional ecological groupings;
- At least one group must be a detritus group;
- Use ecological similarities (niche overlap) rather than taxonomy to aggregate species;
- Groupings must conform with data availability;
- Leaving out a group known to occur because of lack of data is worse than using guesstimates!
- As a rule for ecosystem models: include all trophic levels (but go easy on bacteria).

Top predators are special

- They are important in models, as they help to constrain the parameters of other consumers -- as primary production does from below;
- Ecosim simulations are more realistic if the top predator groups are split into adult and juvenile sub-groupings to capture ontogenetic diet shifts.


Ecopath with Ecosim 6 - New model.EwEmdb
File
View
Ecopath
Ecosim
Ecospace
Tools
Windows
Help
Groups...
Navigator
Input
Diet composition
Detritus fate
Other production
Fishery
Growth input
Tools
Parameterization (Ecopath)
Time dynamic (Ecosim)
Spatial dynamic (Ec
Tools
Home
Basic input
Model Parameters
Group name
Habitat area (fraction)
Biomass in habitat area (t/km²)
Production / biomass (/year)
Consumption / biomass (/year)
Ecotrophic efficiency
Production / consumption
1
Detritus
1.000
Click a group name
Edit Groups
Group name
Color
Consumer
Producer
Detritus
Part of production from primary
Multi-stanza group name
Stanza age (in months)
1
Detritus
Edit
Keep
Order
Move up
Move down
Colours
Default all
Default selected
Alternate all
Custom...
OK
Cancel



Forcing function number for hatchery stocking
Multi-stanza populations can be designated as hatchery populations (see Hatchery populations in Ecosim), and hatchery production can be varied over time in Ecosim using time forcing functions. To turn off natural reproduction select the hatchery forcing function from the pull-down menu in the Forcing function number for hatchery stocking box.

Data requirements for Ecopath models

The basic input:

- B Biomass ($t \cdot km^{-2}$)
- P/B Production / Biomass ($t \cdot km^{-2} \cdot year^{-1}$)
- Q/B Consumption / Biomass ($t \cdot km^{-2} \cdot year^{-1}$)
- EE Ecotrophic efficiency (proportion)

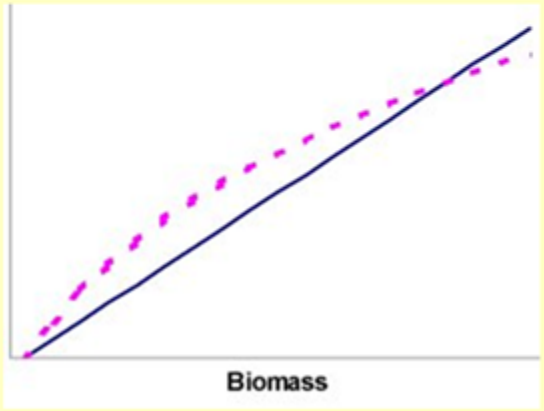
- For basic input, and for diets and catches, it is possible to use ranges for all parameters (see Ecoranger).

Basic input

Home | **Basic input**

Set:

	Group name	Habitat area (fraction)	Biomass in habitat area (t/km²)	Z (/year)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Production / consumption	Unassimil. / consumption	Detritus import (t/km²/year)
⊟	Snook									
1	0-12 Snook	1.0000	0.0002196	5.0000		25.512			0.2000	
2	3-12 Snook	1.0000	0.01872	2.0000		6.2680			0.2000	
3	12-48 Snook	1.0000	0.2299	0.9000		2.3628			0.2000	
4	48-90 Snook	1.0000	0.09962	0.6200		1.4982			0.2000	
5	90+ Snook	1.0000	0.02000	0.6000		1.3000			0.2000	
⊟	Red Drum									
6	0-3 Red Drum	1.0000	0.0002739	8.0000		7.520			0.2000	
7	3-8 Red Drum	1.0000	0.004158	3.5000		08			0.2000	
8	8-18 Red Drum	1.0000	0.02726	1.1000					2000	
9	18-36 Red Drum	1.0000	0.1083	0.6000						
10	36+ Red Drum	1.0000	0.3000	0.550						
⊟	Sea Trout									
11	0-3 Sea Trout	1.0000	0.00009097	6.000						
12	3-18 Sea Trout	1.0000	0.02597	1.400						
13	18+ Sea Trout	1.0000	0.2200	0.700						
⊟	Sand Trout									
14	0-3 Sand Trout	1.0000	0.00001969	5.000						
15	3-12 Sand Trout	1.0000	0.002523	1.200						
16	12+ Sand Trout	1.0000	0.1000	0.700						
⊟	Mullet									
17	0-6 Mullet	1.0000	0.06486	6.7000						
18	6-18 Mullet	1.0000	0.5225	1.8000					000	
19	18+ Mullet	1.0000	2.8000	0.8000		8.0000			0.2000	
⊟	Mackrel									
20	Mackrel 0-3	1.0000	0.00000124	4.0000		82.559			0.2000	
21	Mackrel 3+	1.0000	0.01830	0.5000		6.0000			0.2000	



Data requirements for Ecopath models

For each group, provide estimates in green, and the program will estimate those in red. Choose one:

1). B, P/B, Q/B, EE, DCs, ...

2). B, P/B, Q/B, EE, DCs, ...

3). B, P/B, Q/B, EE, DCs, ...

4). B, P/B, Q/B, EE, DCs, ...

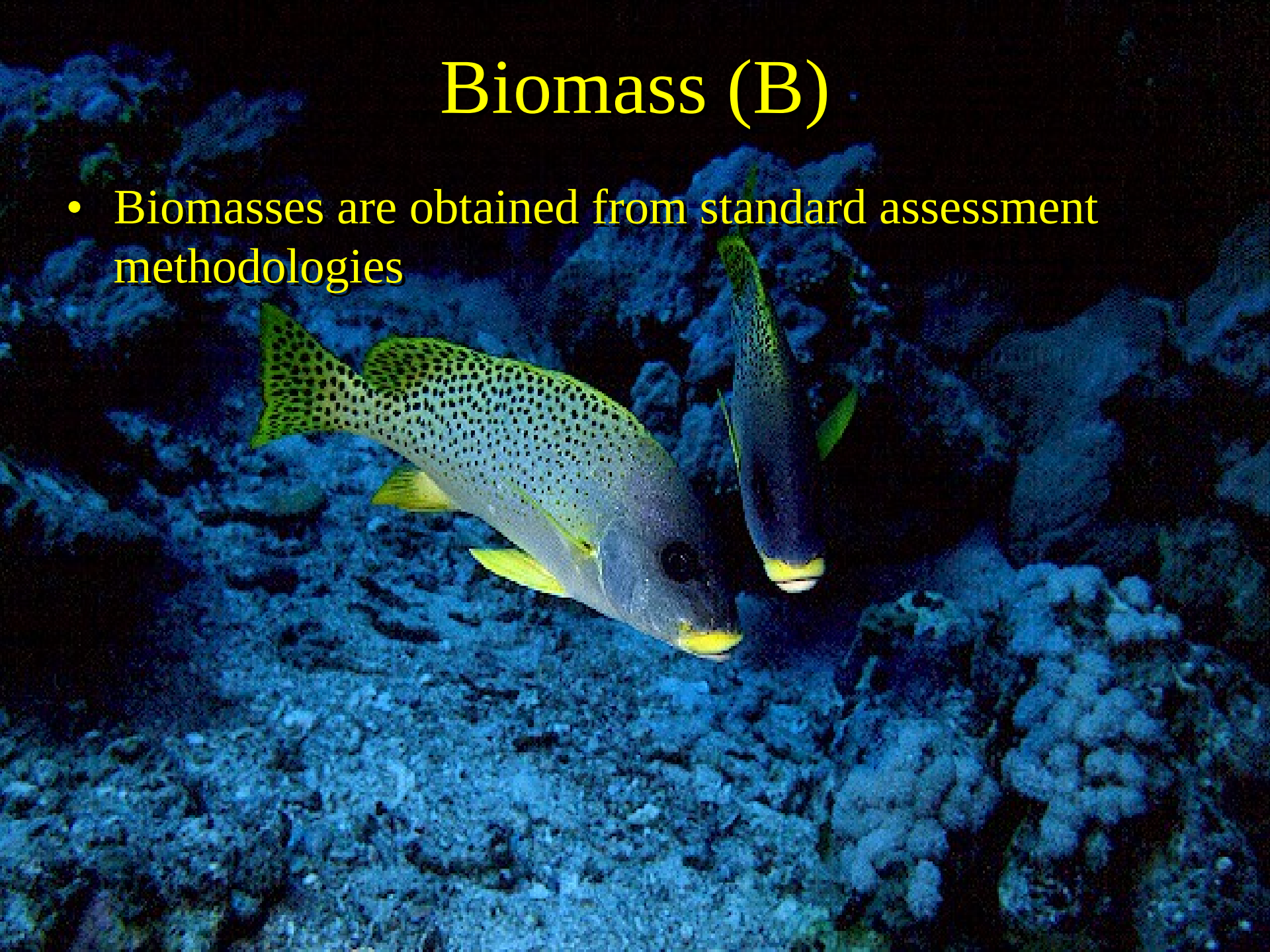
Ranked ease of estimation:

P/B and Q/B > B > DCs >> EE

hence EE often left unknown (Option 1).

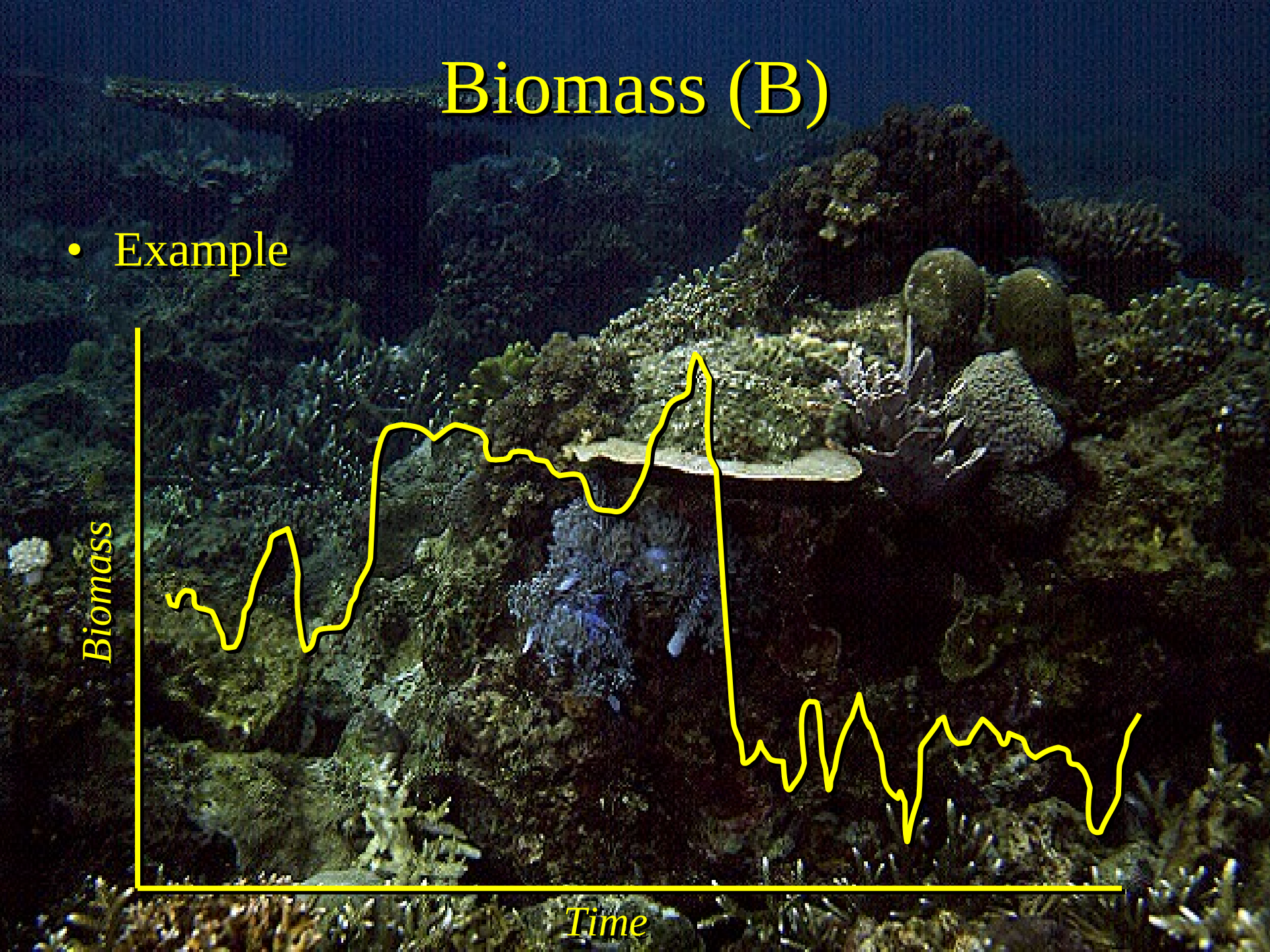
Biomass (B)

- Biomasses are obtained from standard assessment methodologies

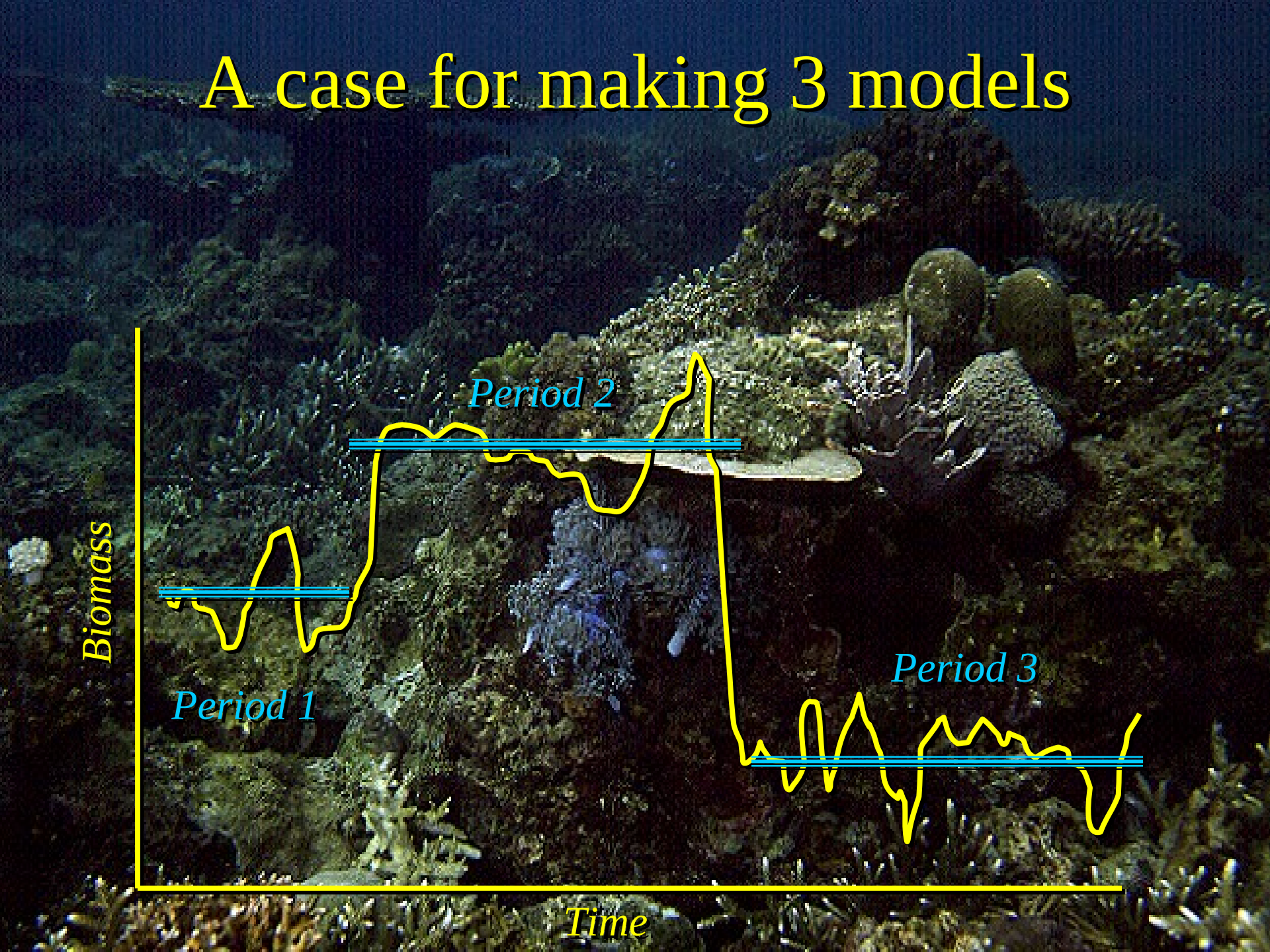


Biomass (B)

- Example



A case for making 3 models



P/B - Production/biomass

- From catch composition data using standard stock assessment methodologies;
- Natural mortality of fish from Pauly's (1980) empirical equation:

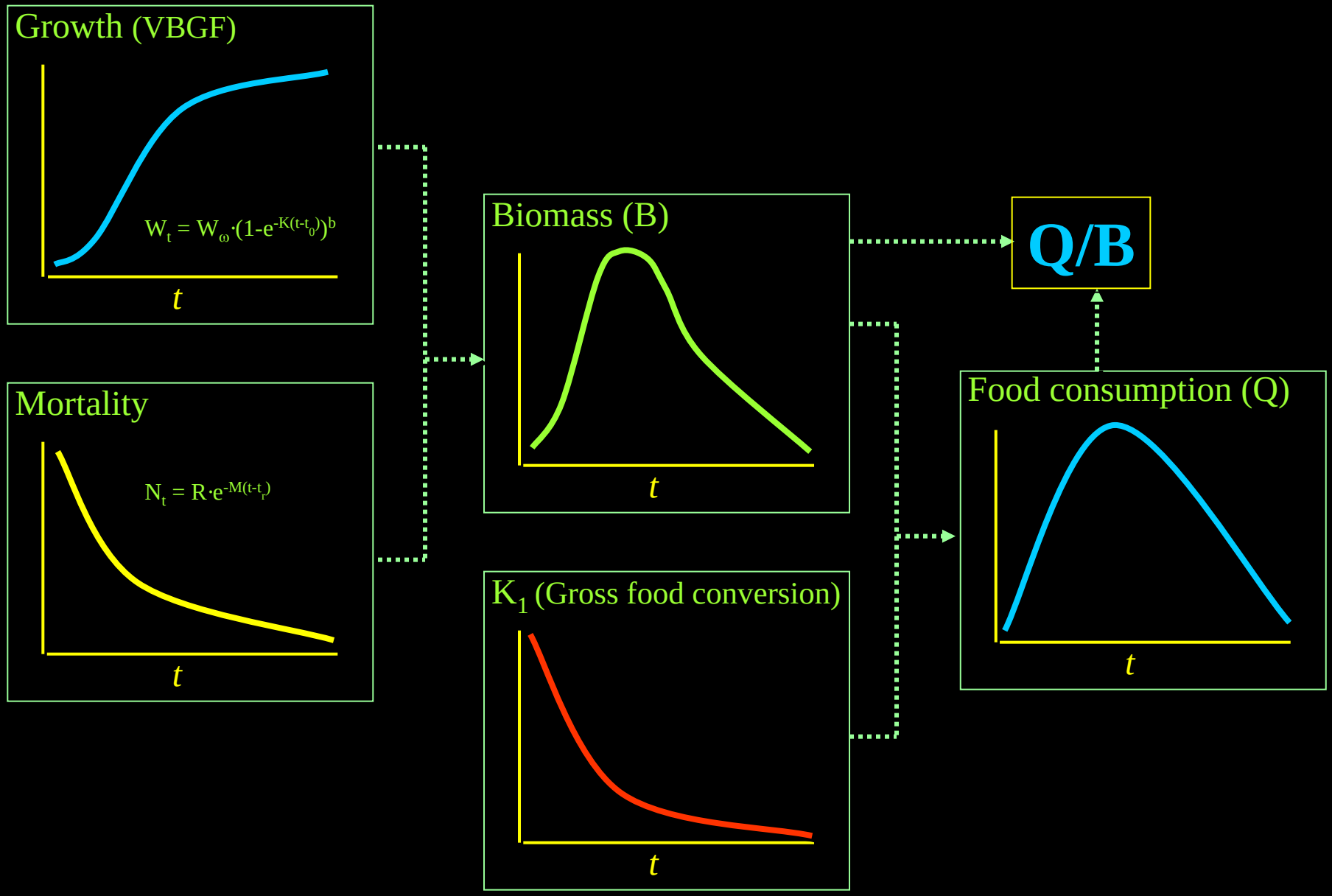
$$M = K^{0.65} \cdot L_{oo}^{-0.279} \cdot T^{0.463}$$

- F = catch / biomass;
- P/B = Z = F + M.

Q/B - Food consumption

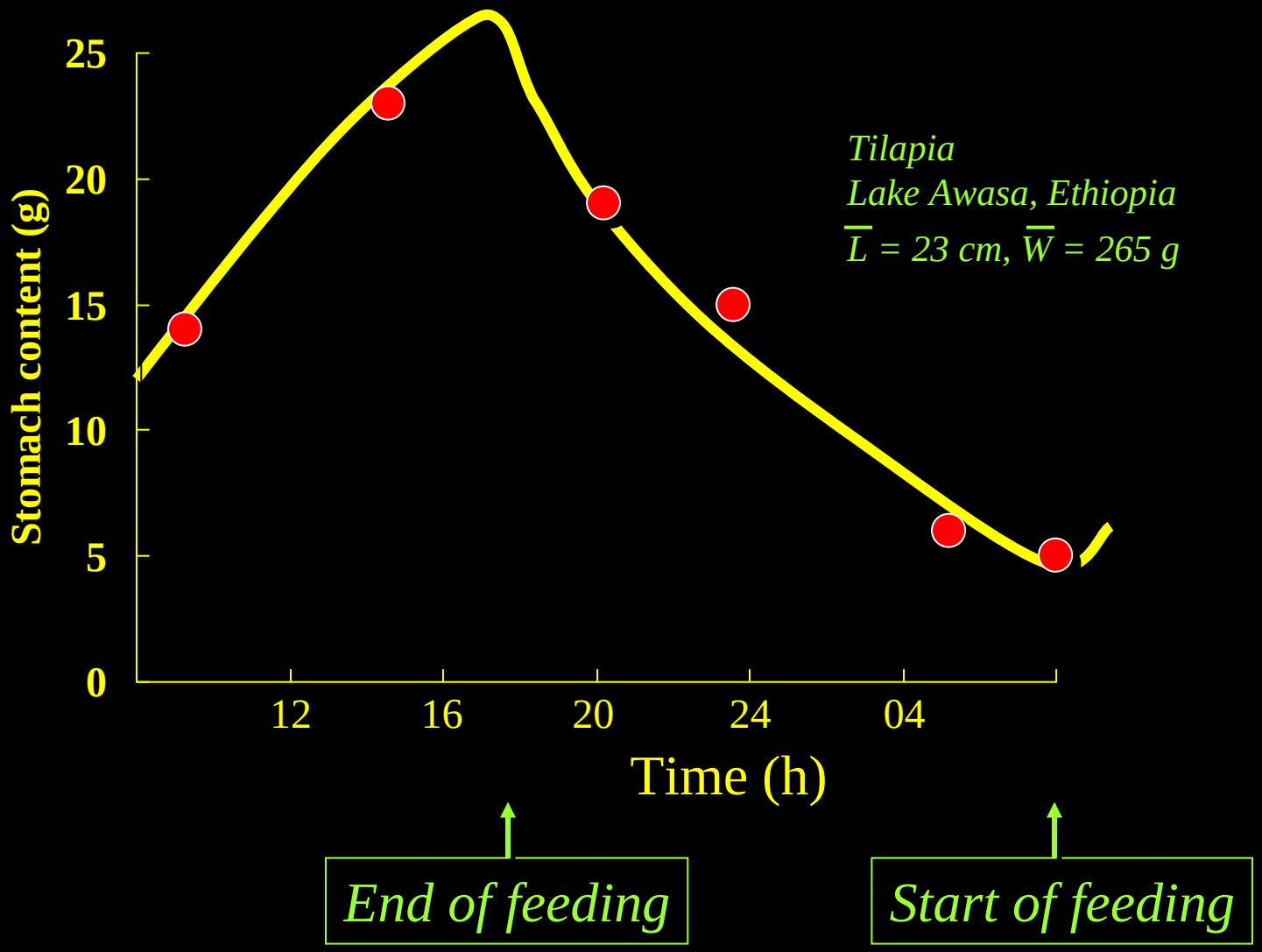
Five years in the lab, or ?

Food consumption (Q/B)

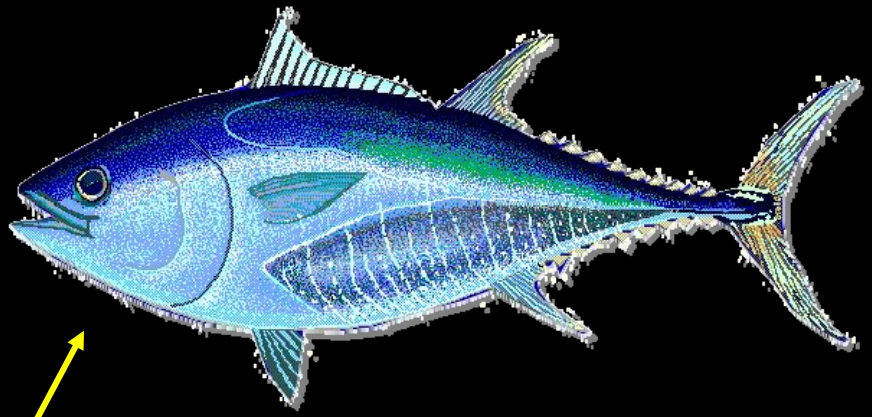


Food consumption

Welcome to Maxim's

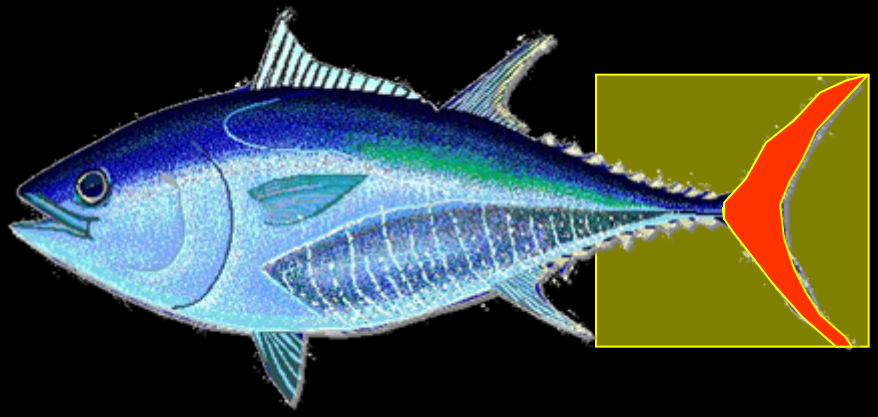


Food consumption - The tail story



The faster swimming fish eats more

Food consumption - The tail story



Aspect ratio: $\frac{Yellow}{Red}$

$A_R = 9.8$

$A_R = 1.3$

$$Q/B = 3 \cdot W_\omega^{-0.2} \cdot T^{0.6} \cdot A_R^{0.5} \cdot 3\, e^{Ft}$$

W_ω = asymptotic weight
T = temperature
A_R = aspect ratio =
F_t = foodtype (0 f. carn.)

Food consumption

The tail story: when not to

Only for symmetrical tails used for propulsion

Ecotrophic efficiency (EE)

- EE is the proportion of the production that is used in the system (for predation or export);
- 1-EE corresponds to ‘other mortality’;
- It is advisable to let Ecopath estimate EE;
- For most groups EE will be close to 1, except, e.g., phytoplankton in bloom situations where EE may be closer to 0.5, kelps with EE’s ≈ 0.1, and unexploited top predators where EE may be (close to) 0;
- *“Small pelagics don’t die of old age”.*

Other input for Ecopath models

For up to 50 groups:

- Assimilation rate
- Diet compositions
- Immigration rate
- Emigration rate
- Biomass accumulation rate
- Detritus fate

For up to 10 fleets:

- Landings
- Discards
- Discard fate
- Fixed cost of fishing
- Variable cost
- Market price by fleet and group
- Non-market value

Default values are supplied (20% for non-assimilated, 0 for other)

Non-assimilated food (U)

- Remember the Ecopath Master Equation (II):

  $$Q = P + R + U$$

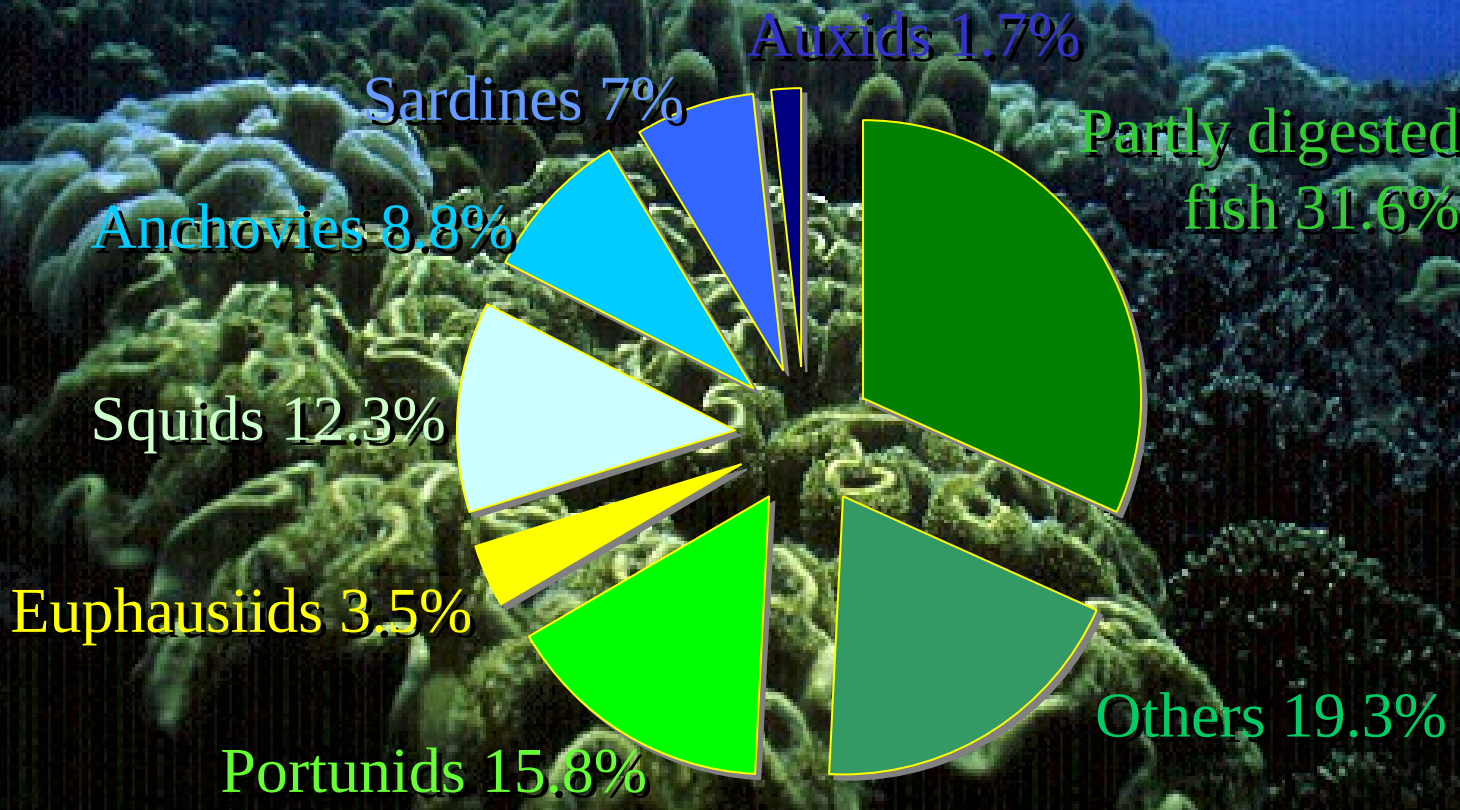
- Q and P are estimated first
- Respiration (R) is then calculated as

  $$R = (Q - P) - U$$

  i.e.; changing U only impacts R
- The default value of 20% for U is generally acceptable, except for herbivores and detritivores where 40% leads to more reasonable R/B ratios.

Diet compositions

e.g., for a tuna



Use volume or weight!

Migration

- Immigration and emigration are rates ($t \cdot km^{-2} \cdot year^{-1}$);
- Net migration enters into the production equation (Master Equation I);
- Net migration is also used by Ecosim.

Migrations

Home | Basic input | Diet composition | **Other production**

	Group name	Immigration (t/km²/year)	Emigration (t/km²/year)	Emigration rate (/year)	Biom. accumul. (t/km²/year)	Biom. acc. rate (/year)
1	Transient Orcas	0.000	0.000	0.000	0.000	0.000
2	Dolphins (Res. Orca)	0.000	0.000	0.000	0.00100	0.000
3	Seals Sealions	0.000	0.000	0.000	0.000	0.000
4	Halibut	0.000	0.000	0.000	0.000	0.000
5	Lingcod	0.000	0.000	0.000	0.000	0.000
6	Dogfish Shark	0.000	0.000	0.000	0.000	0.000
7	A. Hake	0.000	0.000	0.000	0.000	0.000
8	J. Hake	0.000	0.000	0.000	0.000	0.000
9	A. Res. Coho	0.000	0.000	0.000	0.000	0.000
10	J. Res. Coho	0.000	0.000	0.000	0.000	0.000
11	A. Res. Chinook	0.000	0.000	0.000	0.000	0.000
12	J. Res. Chinook	0.000	0.000	0.000	0.000	0.000
13	Demersal Fishes	0.000	0.000	0.000	0.000	0.000
14	Sea Birds	0.000	0.000	0.000	0.000	0.000
15	Small Pelagics	0.000	0.000	0.000	0.000	0.000
16	Eulachon	0.000	0.000	0.000	0.000	0.000
17	A. Herring	0.000	0.000	0.000	0.000	0.000
18	J. Herring	0.000	0.000	0.000	0.000	0.000
19	Jellyfish	0.000	0.000	0.000	0.000	0.000
20	Predatory Invertebrates	0.000	0.000	0.000	0.000	0.000
21	Shellfish	0.000	0.000	0.000	0.000	0.000
22	Grazing Invertebrates	0.000	0.000	0.000	0.000	0.000
23	C. Zoolplankton	0.000	0.000	0.000	0.000	0.000
24	H. Zoolplankton	0.000	0.000	0.000	0.000	0.000
25	Kelp/Sea Grass	0.000	0.000	0.000	0.000	0.000
26	Phytoplankton	0.000	0.000	0.000	0.000	0.000

Diet composition

Home | Basic input | **Diet composition**

Sum to one — Set: — Apply

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Transient Orcas																				
2	Dolphins (Res. Orca)	0.0200																			
3	Seals Sealions	0.967																			
4	Halibut		0.00100																		
5	Lingcod		0.0100	0.0217		0.00311															
6	Dogfish Shark		0.00100			0.00311															
7	A. Hake		0.200	0.253		0.129	0.0452							0.0270							
8	J. Hake			0.0656		0.001000	0.0510	0.0500				0.00122		0.0110				0.000998			
9	A. Res. Coho		0.0461	0.0278		0.000997	0.000955														
10	J. Res. Coho			0.0700		0.00997	0.00400	0.01000		0.00200		0.00400						0.00200			
11	A. Res. Chinook		0.0461	0.0402																	
12	J. Res. Chinook			0.110			0.0900			0.00120		0.00122						0.000998			
13	Demersal Fishes		0.159	0.260	0.179	0.339	0.161			0.00120		0.00732		0.01000	0.0749			0.000998		0.000909	
14	Sea Birds	0.00300													0.000999						
15	Small Pelagics	0.01000	0.191	0.0827	0.498	0.0228		0.01000	0.0250	0.260		0.0999		0.0952	0.0769			0.00499	0.00100		
16	Eulachon		0.00201	0.00908	0.00498	0.0207	0.00478	0.00500		0.0180		0.0170		0.0476	0.00400			0.00998	0.00100	0.00545	
17	A. Herring		0.0501	0.0575	0.194	0.301	0.00478	0.00100		0.0600		0.110			0.0190						
18	J. Herring				0.00498	0.00933		0.00100	0.00500	0.200	0.000999	0.360	0.00513		0.00999			0.00998		0.00545	
19	Jellyfish																			0.0527	
20	Predatory Invertebrates		0.146			0.0415	0.00955				0.0120		0.0513	0.144							0.0338
21	Shellfish			0.00101			0.0487							0.143	0.158				0.0531		0.276
22	Grazing Invertebrates		0.147	0.00101				0.133			0.0120		0.0205	0.285	0.536	0.100					0.315
23	C. Zoolplankton				0.119	0.0799	0.580	0.740	0.120	0.380	0.731	0.394	0.615	0.190		0.500	0.450	0.192	0.212	0.105	
24	H. Zoolplankton					0.0394		0.0500	0.850	0.0780	0.244	0.00599	0.308	0.0476	0.0300	0.400	0.500	0.382	0.637	0.739	
25	Kelp/Sea Grass																				
26	Phytoplankton														0.00500		0.0500		0.0961	0.0909	
27	Detritus														0.0849						0.375

Estimation of diet compositions

- 'Import' is feeding on prey groups that are not explicitly included in the ecosystem;
- Example: If marine mammals in a model of the near-surface open ocean feed on mesopelagics in the Deep Scattering Layer, then treat the mesopelagics as import;
- Diet compositions are often species-specific, and may need averaging. Use weighted averages;
- Still, it is often necessary to modify the diet compositions to ensure mass-balance.

Biomass accumulation (B_{acc})

- Ecopath is <u>not</u> a steady-state model, biomasses can change over time;
- B_{acc} is entered as rates ($\pm$ t · km^{-2} ·year^{-1});
- Default 0, has been used in nearly all models (an exception: North Sea Model of Christensen, 1995);
- Use B_{acc} if you have data showing change in biomass at start and end of the period to be modeled;
- If B_{acc} values are entered, Ecosim will show change over time even without any change in fishing.

Detritus fate

- At least one detritus group is required. It must be entered after the living groups on the Ecopath input form;
- All living groups produce detritus, from excretion and egestion, and from ‘other mortality’;
- It is therefore necessary to specify to which detritus group the detritus generated by a living group is directed.

Detritus fate

Home | Basic input | **Detritus fate**

	Source / fate	Detritus	Export	Sum
1	Baleen whales	1.000	0.000	1.000
2	Toothed whales	1.000	0.000	1.000
3	Seals	1.000	0.000	1.000
4	Birds	1.000	0.000	1.000
5	Sharks, large	1.000	0.000	1.000
6	Sharks, small medium	1.000	0.000	1.000
7	Rays, large	1.000	0.000	1.000
8	Rays, small medium	1.000	0.000	1.000
9	Pelagics, large	1.000	0.000	1.000
10	Pelagics, medium	1.000	0.000	1.000
11	Pelagics, small, carniv.	1.000	0.000	1.000
12	Pelagics, small, herbiv.	1.000	0.000	1.000
13	Benthopelagics, large	0.000	1.000	1.000
14	Benthopelagics, small medium	0.000	1.000	1.000
15	Demersals, large	1.000	0.000	1.000
16	Demersals, medium	1.000	0.000	1.000
17	Demersals, small	1.000	0.000	1.000
18	Reeffish, large	1.000	0.000	1.000
19	Reeffish, medium	1.000	0.000	1.000
20	Flatfish, large	1.000	0.000	1.000
21	Flatfish, small medium	1.000	0.000	1.000
22	Reeffish, small	1.000	0.000	1.000
23	Bathypelagics	1.000	0.000	1.000
24	Bathydemersals	1.000	0.000	1.000
25	Jellyfish	1.000	0.000	1.000
26	Cephalopods	1.000	0.000	1.000
27	Shrimps	1.000	0.000	1.000

Fisheries data

- It is possible to include up to 10 fleets (or gears);
- Parameters for each:
  - variable costs;
  - fixed costs;
  - market prices;
  - landings;
  - discards;
  - fate of discards.

Fishery: up to 10 fleets

Home | Basic input | Detritus fate | **Definition of fleets** | Landings | Discards

	Fleet name	Fixed cost (%)	Effort related cost (%)	Sailing related cost (%)	Profit (%)	Total value (%)
1	Fleet1	0.000	0.000	1.000	99.000	100.000

Landings

- To facilitate studies of policy options up to 10 fleets can be included in Ecopath analyses;
- The landings (exclusive of discards) should be entered as rates ($t \cdot km^{-2} \cdot year^{-1}$);
- Landings with no values should be treated as landings (set price to 0), not as discards, as the latter are fed back into the system.


Discards are
entered as rates
(t · km-2 ·year-1)

Discard fate

- For models with discards it is advisable to have a detritus group called, e.g., ‘dead fish’;
- When so, then direct the discards to this group, and have scavengers feeding on it;
- ‘Dead fish’ are of higher nutritional value than most other detritus (such as excreta from zooplankton).

Cost of fishing

- Fixed value of operating each gear can be entered (monetary currency per time unit);
- Variable cost is entered as relative to the effort in the Ecopath model;
- Spatial fishing costs may be entered in Ecospace;
- Any monetary currency can be used as unit;
- Only simple bio-economical analyses are included.

Landings, discards, prices

Home | Basic input | Detritus fate | Definition of fleets | **Landings**

	Group name	Fleet1	Total
1	Baleen whales		0.000
2	Toothed whales		0.000
3	Seals		0.000
4	Birds		0.000
5	Sharks, large	0.01000	0.010
6	Sharks, small medium	0.0400	0.040
7	Rays, large	0.0120	0.012
8	Rays, small medium	0.0200	0.020
9	Pelagics, large	0.0500	0.050
10	Pelagics, medium	0.400	0.400
11	Pelagics, small, carniv.	0.100	0.100
12	Pelagics, small, herbiv.	0.100	0.100
13	Benthopelagics, large	0.0500	0.050
14	Benthopelagics, small medium	0.200	0.200
15	Demersals, large	0.130	0.130
16	Demersals, medium	0.800	0.800
17	Demersals, small		0.000
18	Reeffish, large	0.0200	0.020
19	Reeffish, medium	0.200	0.200
20	Flatfish, large	0.0250	0.025
21	Flatfish, small medium	0.500	0.500
22	Reeffish, small		0.000
23	Bathypelagics		0.000
24	Bathydemersals		0.000
25	Jellyfish		0.000
26	Cephalopods	0.100	0.100
27	Shrimps	0.200	0.200
28	Lobsters, crabs	0.400	0.400

Home | Basic input | Detritus fate | Definitior

	Group name	Fleet1	Total
1	Baleen whales		0.000
2	Toothed whales		0.000
3	Seals		0.000
4	Birds		0.000
5	Sharks, large		0.000
6	Sharks, small medium		0.000
7	Rays, large		0.000
8	Rays, small medium		0.000
9	Pelagics, large		0.000
10	Pelagics, medium		0.000
11	Pelagics, small, carniv.		0.000
12	Pelagics, small, herbiv.		0.000
13	Benthopelagics, large		0.000
14	Benthopelagics, small medium		0.000
15	Demersals, large		0.000
16	Demersals, medium		0.000
17	Demersals, small		0.000
18	Reeffish, large		0.000
19	Reeffish, medium		0.000
20	Flatfish, large		0.000
21	Flatfish, small medium		0.000
22	Reeffish, small		0.000
23	Bathypelagics		0.000
24	Bathydemersals		0.000
25	Jellyfish		0.000
26	Cephalopods		0.000
27	Shrimps		0.000

	Group name	Fleet1 (EUR/t/km²)
1	Baleen whales	
2	Toothed whales	
3	Seals	
4	Birds	
5	Sharks, large	0.000
6	Sharks, small medium	0.000
7	Rays, large	0.000
8	Rays, small medium	0.000
9	Pelagics, large	0.000
10	Pelagics, medium	0.000
11	Pelagics, small, carniv.	0.000
12	Pelagics, small, herbiv.	0.000
13	Benthopelagics, large	0.000
14	Benthopelagics, small medium	0.000
15	Demersals, large	0.000
16	Demersals, medium	0.000
17	Demersals, small	
18	Reeffish, large	0.000
19	Reeffish, medium	0.000
20	Flatfish, large	0.000
21	Flatfish, small medium	0.000
22	Reeffish, small	
23	Bathypelagics	
24	Bathydemersals	
25	Jellyfish	
26	Cephalopods	0.000

Market prices

- Fleet-specific prices for each group that is harvested;
- Default value is 1 for all groups for all fleets.

Non-market values

- 'Existence' values can be considered, e.g., the value for tourism of having, e.g., marine mammals in a system;
- Default value is 0.

Values should be expressed in monetary units per unit biomass. At present it is assumed that there is a linear relationship between the biomass of a resource and its non-market price (if there is any). Hence, for groups with a non-market price it is assumed that a doubling in biomass will lead to a doubling of the resource's non-market value

Basic input | Detritus fate | Definition of

	Group name	Value/unit biomass
1	Baleen whales	0.000
2	Toothed whales	0.000
3	Seals	0.000
4	Birds	0.000
5	Sharks, large	0.000
6	Sharks, small medium	0.000
7	Rays, large	0.000
8	Rays, small medium	0.000
9	Pelagics, large	0.000
10	Pelagics, medium	0.000
11	Pelagics, small, carniv.	0.000
12	Pelagics, small, herbiv.	0.000
13	Benthopelagics, large	0.000
14	Benthopelagics, small medium	0.000
15	Demersals, large	0.000
16	Demersals, medium	0.000
17	Demersals, small	0.000
18	Reeffish, large	0.000
19	Reeffish, medium	0.000
20	Flatfish, large	0.000
21	Flatfish, small medium	0.000
22	Reeffish, small	0.000
23	Bathypelagics	0.000
24	Bathydemersals	0.000
25	Jellyfish	0.000

Growth input

Basic input | Detritus fate | Definition of fleets | Landings | Discards | Discard mortality rate | Discard fate | Off-vessel price | Non-ma

	Group name	a in LW	b in LW	L at infinity (cm)	W at infinity (g)	K in VBGF (/year)	to in VBGF (year)	Age first capture (year)	Max. age (year)
1	Baleen whales								
2	Toothed whales								
3	Seals								
4	Birds								
5	Sharks, large								
6	Sharks, small medium								
7	Rays, large								
8	Rays, small medium								
9	Pelagics, large								
10	Pelagics, medium								
11	Pelagics, small, carniv.								
12	Pelagics, small, herbiv.								
13	Benthopelagics, large								
14	Benthopelagics, small medium								
15	Demersals, large								
16	Demersals, medium								
17	Demersals, small								
18	Reeffish, large								
19	Reeffish, medium								
20	Flatfish, large								
21	Flatfish, small medium								
22	Reeffish, small								
23	Bathypelagics								
24	Bathydemersals								
25	Jellyfish								
26	Cephalopods								

Parameters based on the von Bertalanffy growth equation (von Bertalanffy 1938).