***EcoTroph**: modeling marine ecosystem functioning and impact of fishing*

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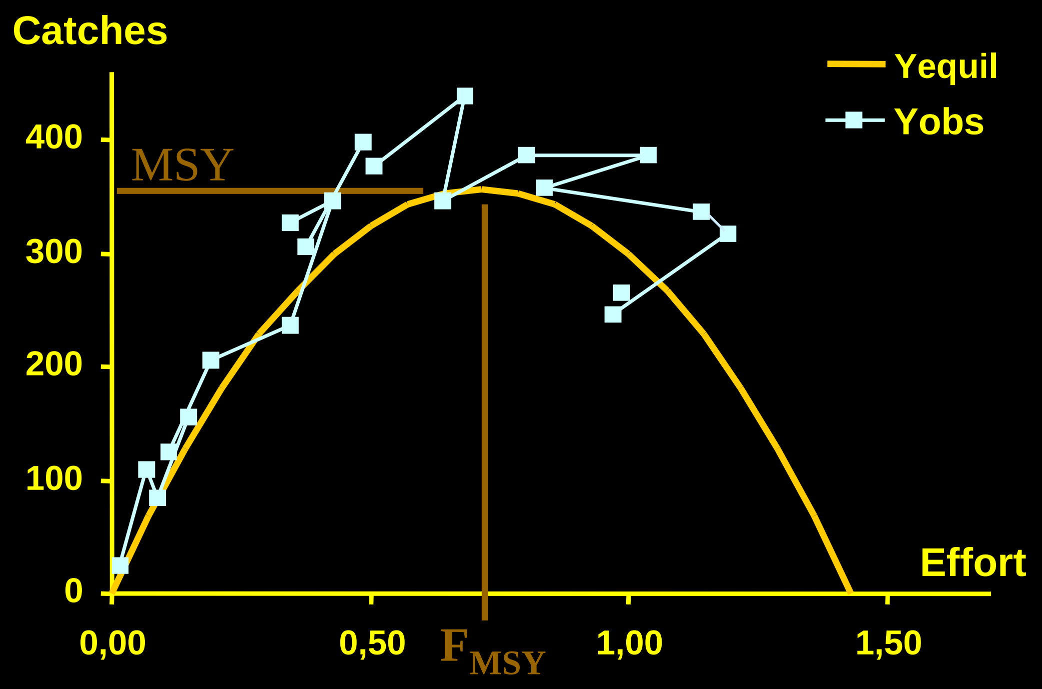
As an introduction …

Development of theoretical models remains needed for EAF

An example within single species approaches:

the Schaefer model

-> a theoretical and practical tool



As an introduction …

Development of theoretical models remains needed for EAF

An example within single species approaches:

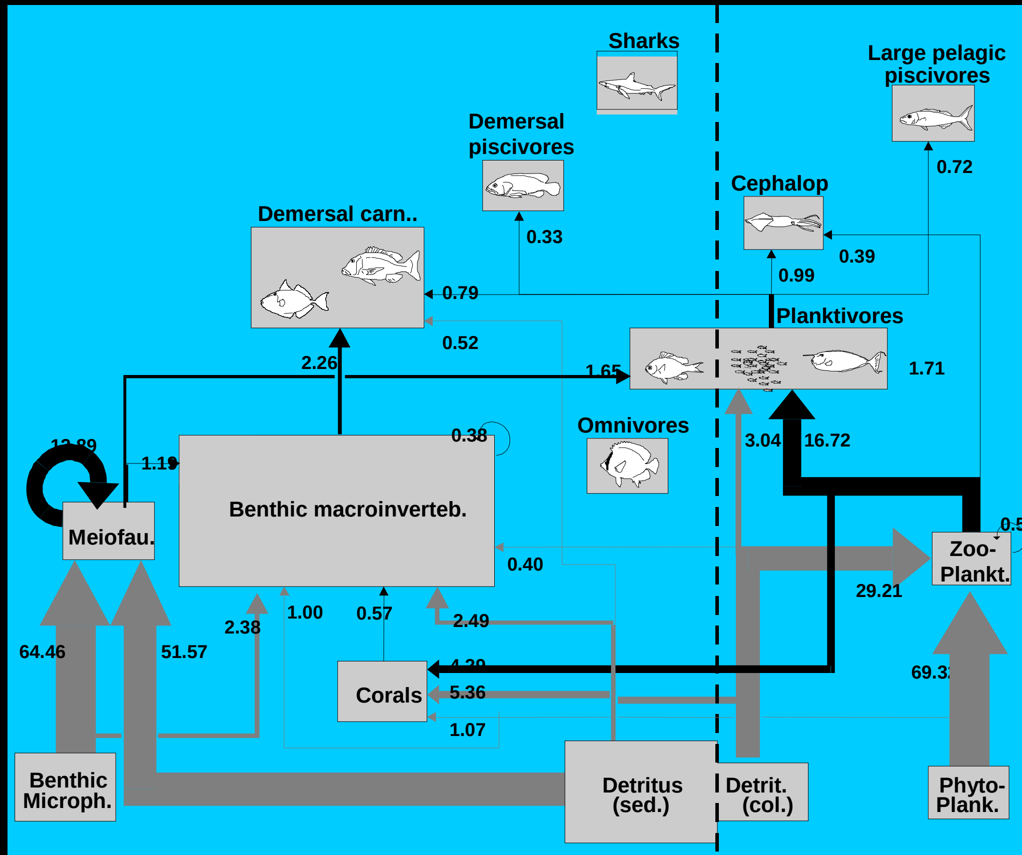
the Schaefer model

-> a theoretical and practical tool

In the field of ecosystem approach:

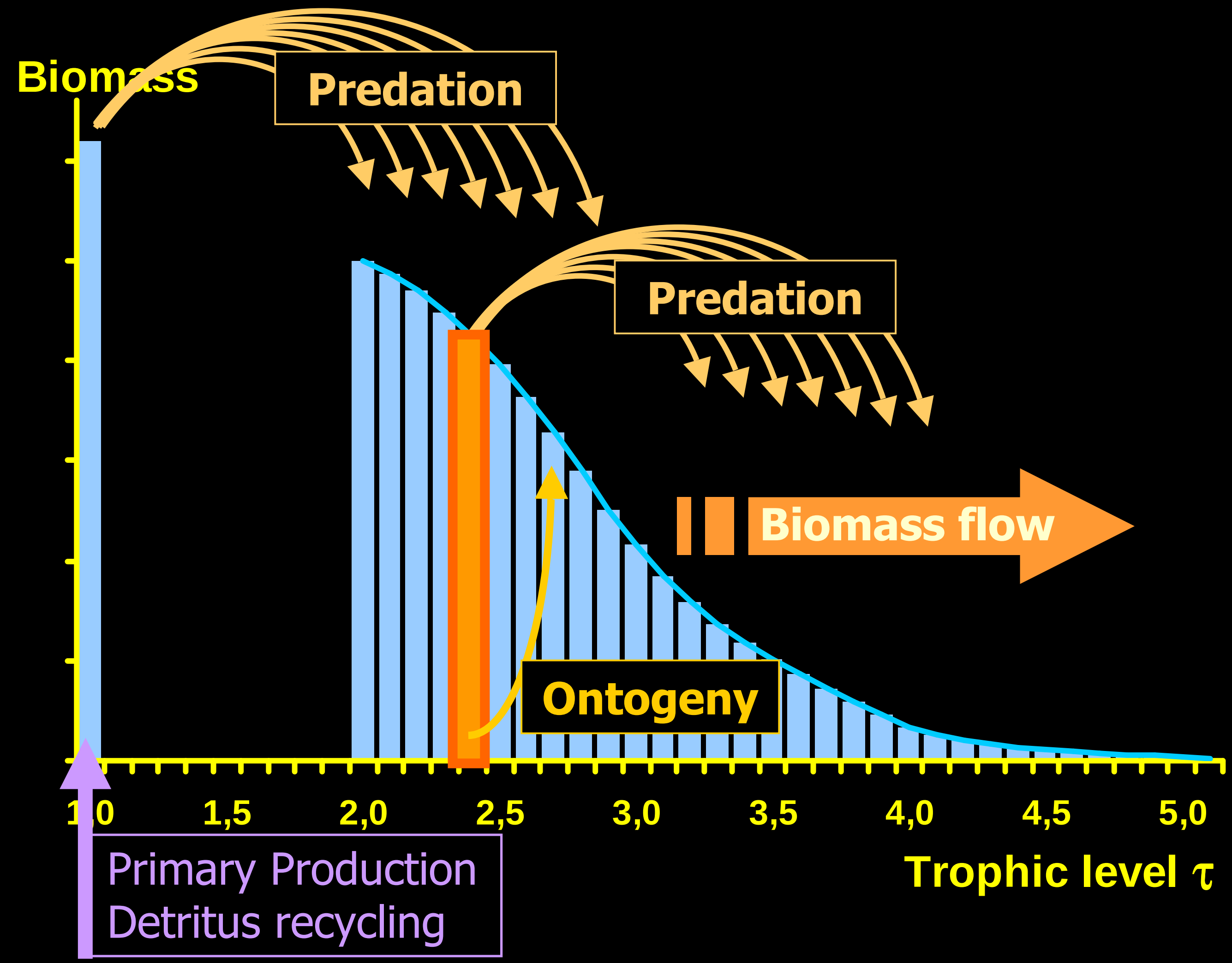
the Ecopath model

-> a practical (data driven) tool



Ouvéa lagoon (NC) – Bozec et al, 2004

1 - EcoTroph: principles and basis equations



- A continuous representation of the biomass distribution, according to trophic level τ

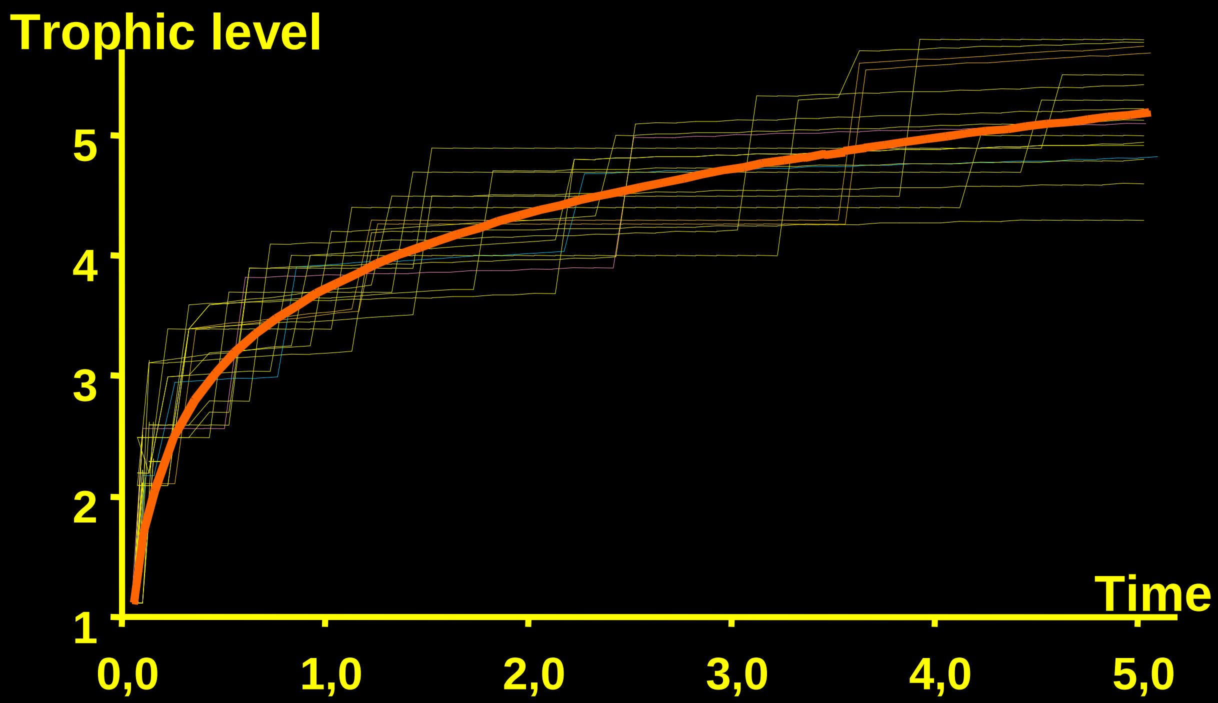
-> the Biomass Trophic spectrum

- The ecosystem functioning: a flow of biomass trough trophic levels

Don't confuse: the biomass **B**τ present in the trophic class [τ, τ+Δτ[

the biomass flow Φτ, passing trough the trophic class

➢ The dynamic of the trophic flow



- A discrete process at the particles level …
- … and a continuous model that expresses the mean process

- The trophic flow is characterized by:
  - the biomass flow $\Phi\tau$ (in t/year),
  - the speed of trophic flow $\Delta\tau/\Delta t$ (in TL/year)

$$\text{Biomass}_\tau = \frac{\text{Flow}_\tau}{\text{Speed}_\tau}$$

$$\mathbf{B}\tau = \frac{\Phi\tau}{\Delta\tau/\Delta t} \cdot \Delta\tau$$

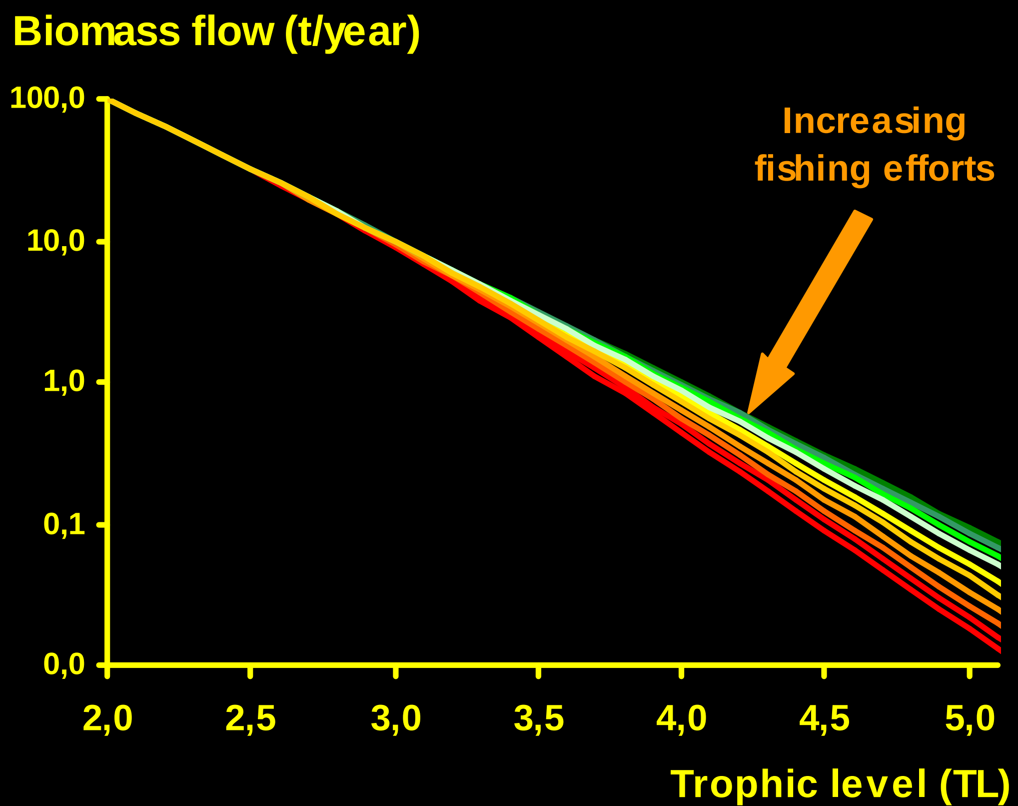
1 - EcoTroph: principles and basis equations

- **The biomass flow model:** $\Phi(\tau + \Delta\tau) = \Phi(\tau) \cdot e^{-(\mu_\tau + \varphi_\tau) \cdot \Delta\tau}$

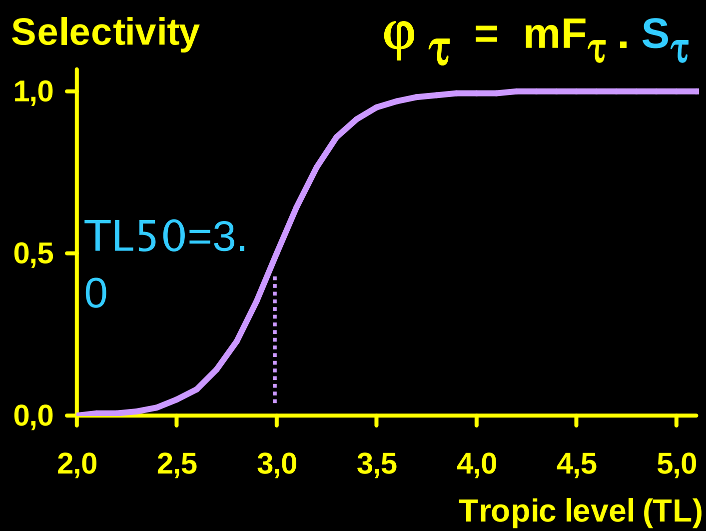
Natural loss
. Excretion,
. Non pred.mort.
. Respiration

$e^{-\mu}$ = Trophic efficiency

Fishing loss
. Exploitation



$\varphi_\tau = mF_\tau \cdot S_\tau$



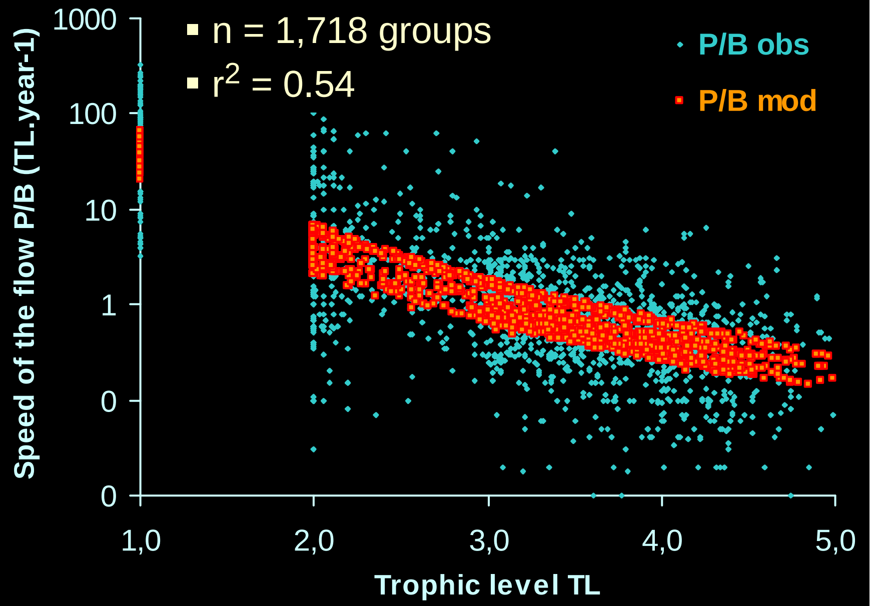
➢ The speed of the flow model

1. Reference state (current or virgin)
   - For case studies: field estimates
   - For theoretical purposes: an empirical generic model

$$(\Delta\tau / \Delta t)_{ref} = a \times \tau^{-b}$$
$$= 20.2 \times e^{0.041\,\theta} \times \tau^{-3.26}$$

(Gascuel et al., sub. Ecol.Mod)

- 55 Ecopath models
- n = 1,718 groups
- $r^2 = 0.54$



2. The Top-down equation:

$$(\Delta t / \Delta\tau)_\tau = (1-\alpha) \, . \, Mref_\tau + \alpha \, . \, Mref_\tau \, . \left[\frac{B(\tau+1)}{Bref(\tau+1)}\right]^\gamma + F_\tau$$

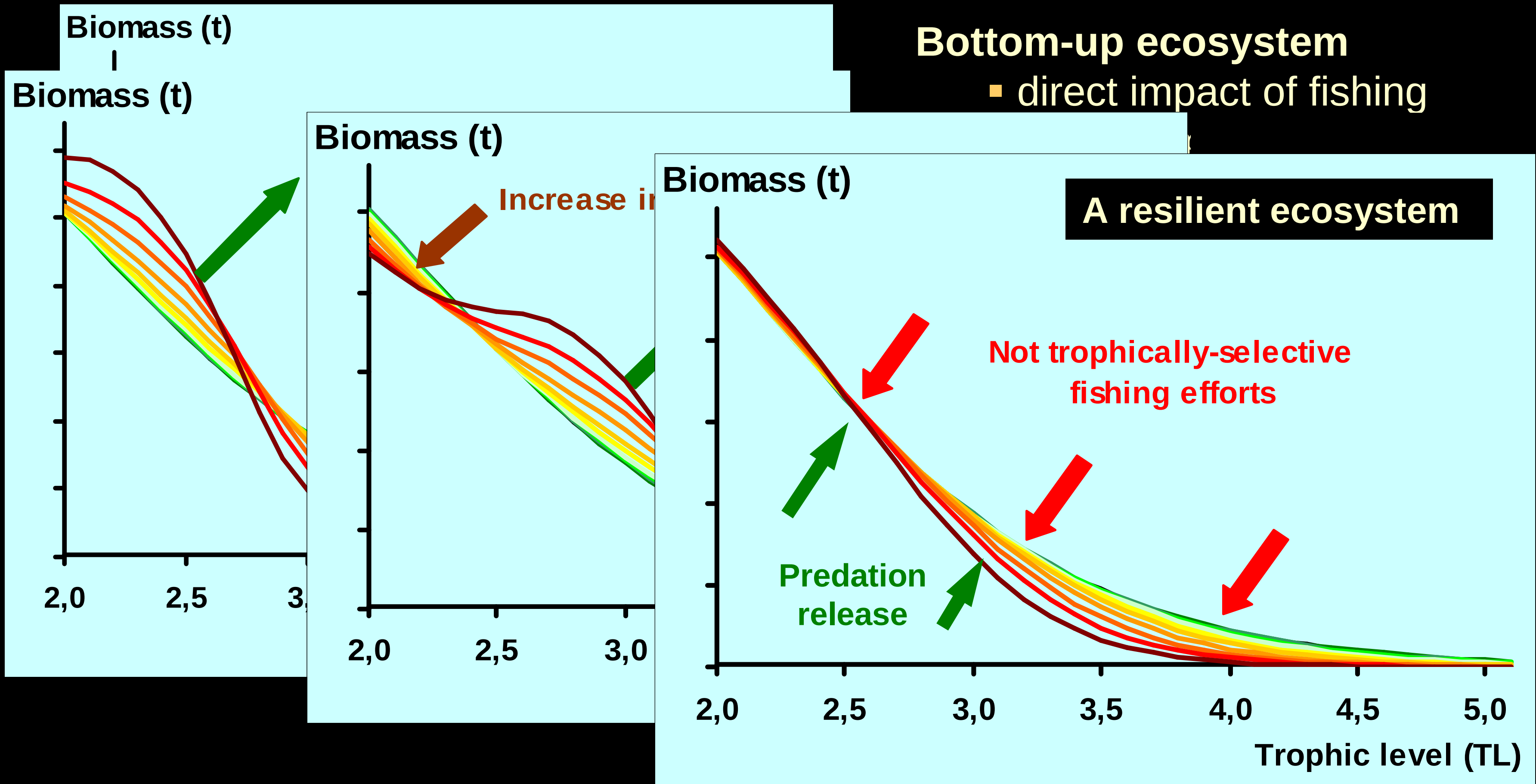
The speed of the flow depends on predators abundance

- $\alpha = 0$: Bottom-up
- $0<\alpha<1$: Top-down

Higher the catch, lower the life expectancy, higher the speed of transfer.

2 - EcoTroph: simulating virtual ecosystems

- **Theoretical analysis of functioning -> generic relationships between parameters**



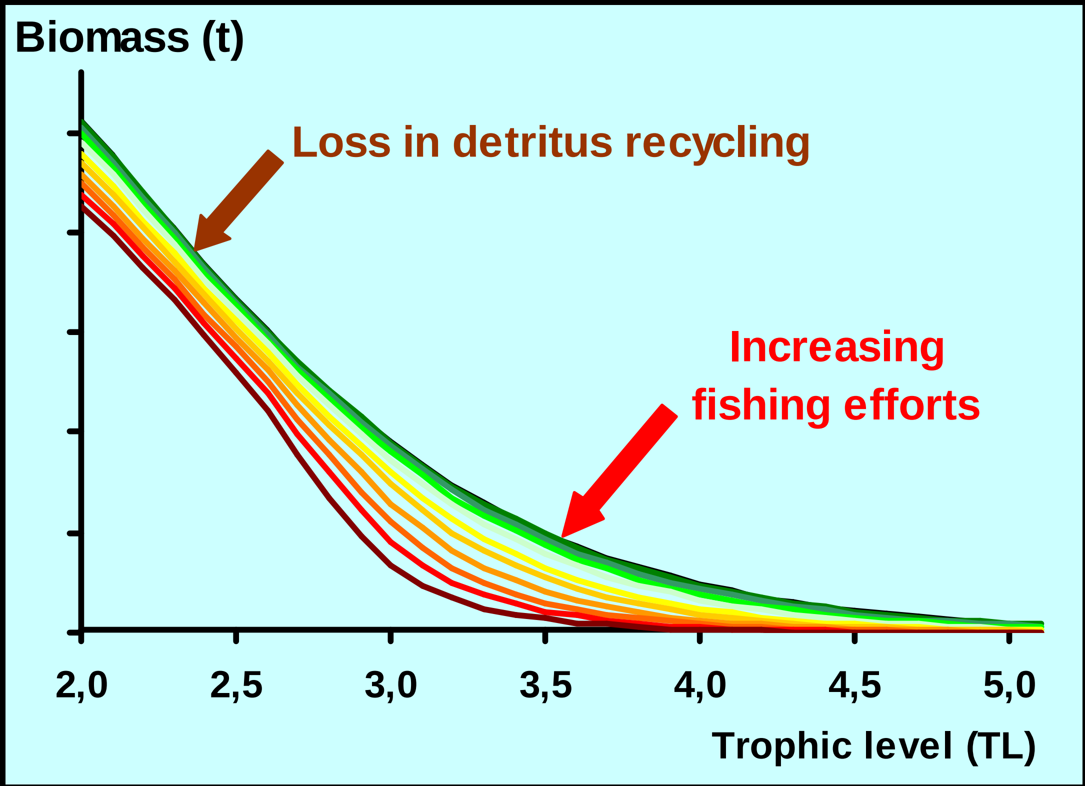
Bottom-up ecosystem

- direct impact of fishing

2 - EcoTroph: simulating virtual ecosystems

Biomass input control: $\Phi(1) = (1-\beta) \cdot \Phi v(1) + \beta \cdot \Phi v(1) \cdot \frac{B\ tot}{Bv\ tot}$

Hypothesis = the primary production partly depends on detritus recycling



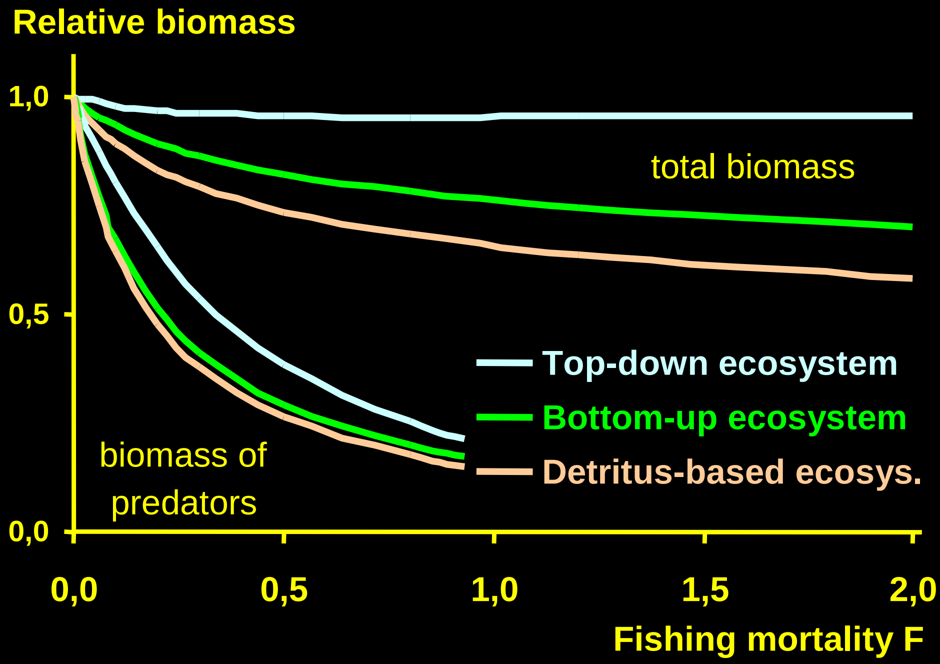
Detritus-based ecosystems are more sensitive,

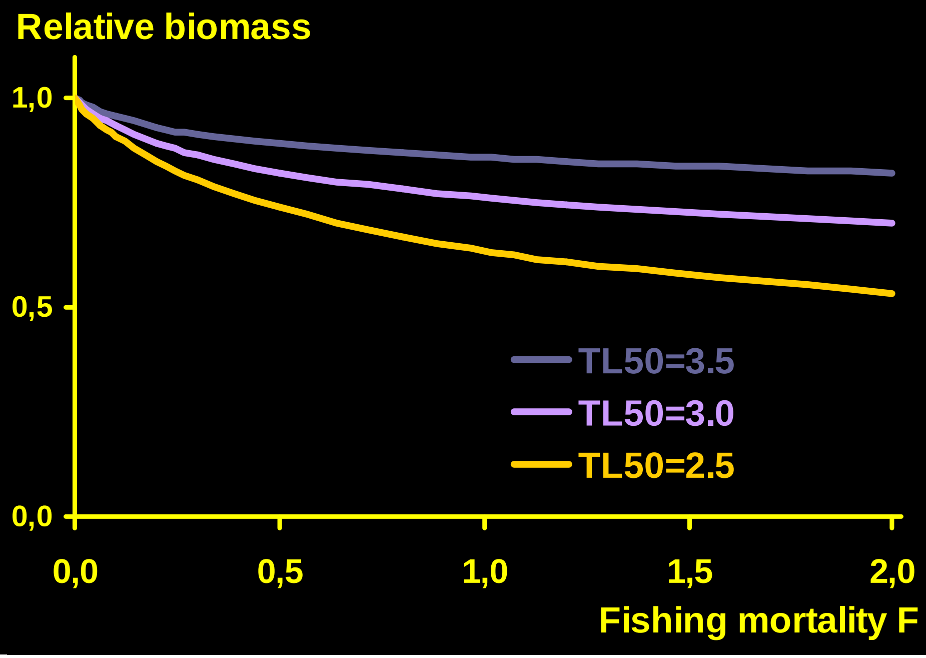
…

(without top-down control)

2 - EcoTroph: simulating virtual ecosystems

- Ecosystem biomass decreases with exploitation
- Top-down ecosystems are more resilient
- Detritus-based ecosystems are less
- Predators are severely affected

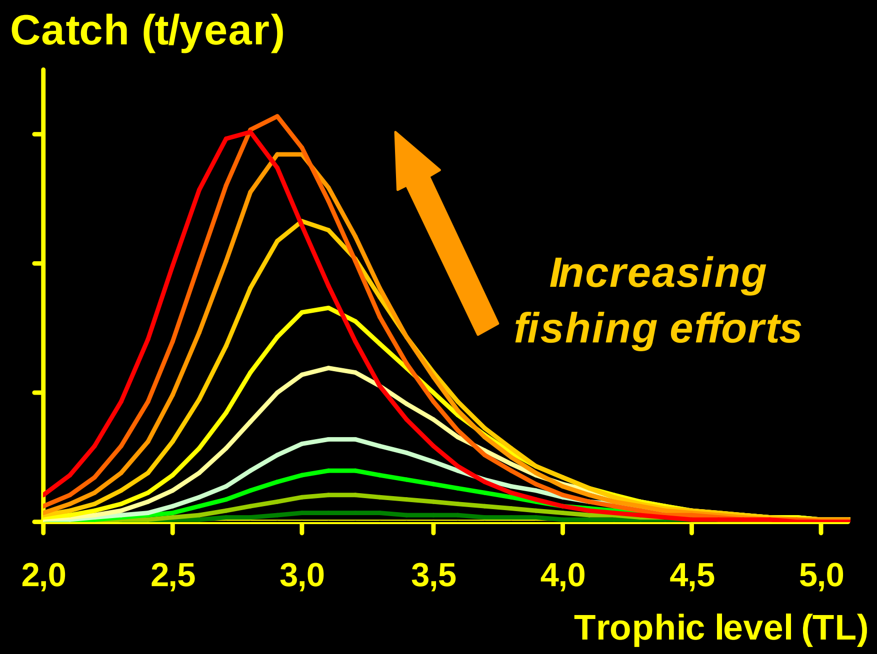




- Impact of fishing on ecosystem biomass increases when the trophic level of first catch TL50 decreases

2 - EcoTroph: simulating virtual ecosystems

Catch: $Y_\tau = \varphi^*_\tau \,.\, \Phi^*_\tau \,.\, \Delta\tau$

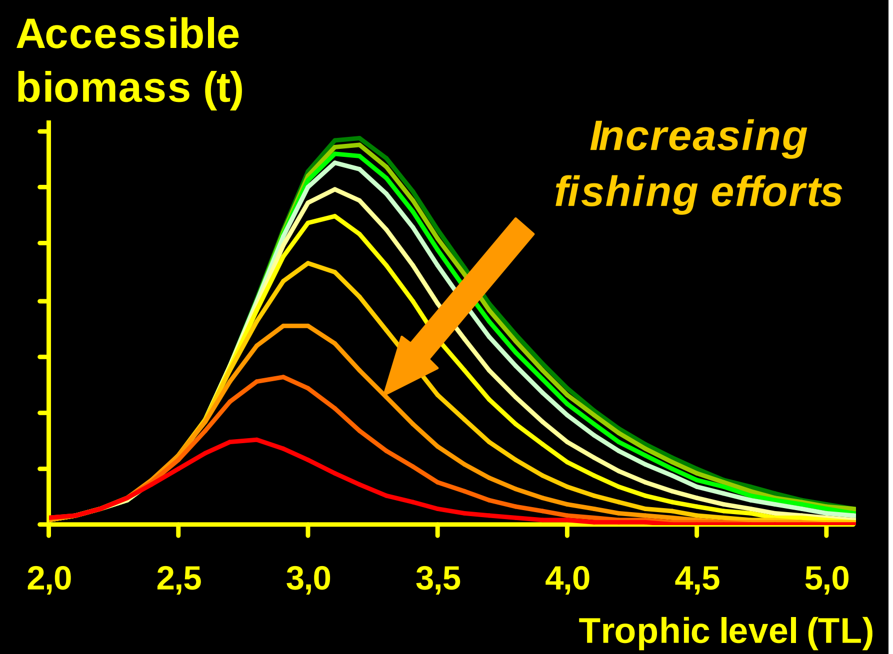


- Wide potential catches on low trophic levels
- Over fishing of high trophic levels
- Fishing down the marine food web

Accessible flow:

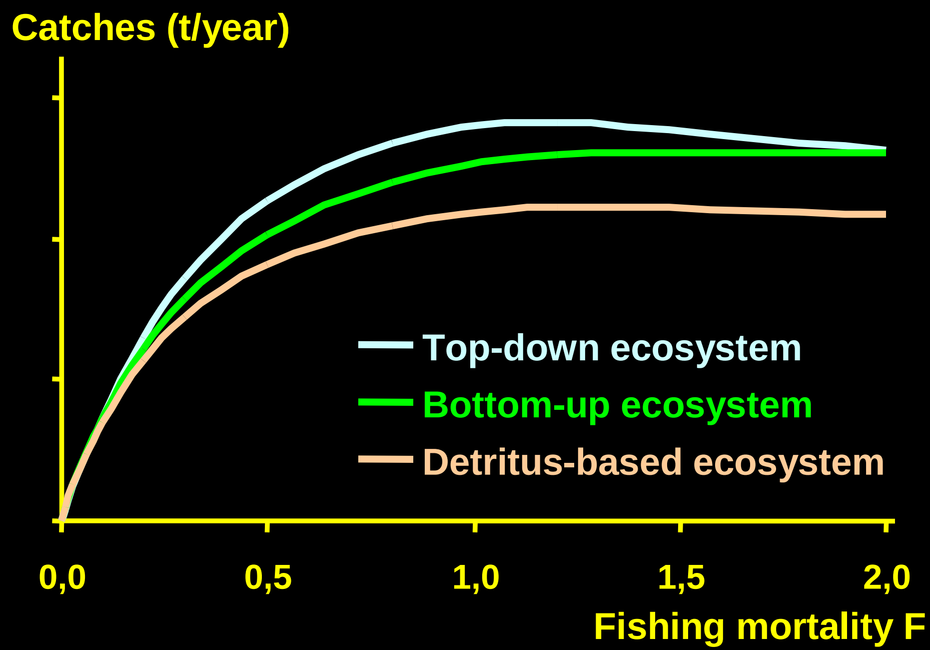
$$\Phi^*(\tau+\Delta\tau) = \Phi^*(\tau) \,.\, e^{-(\mu^*_\tau + \varphi^*_\tau).\Delta\tau}$$

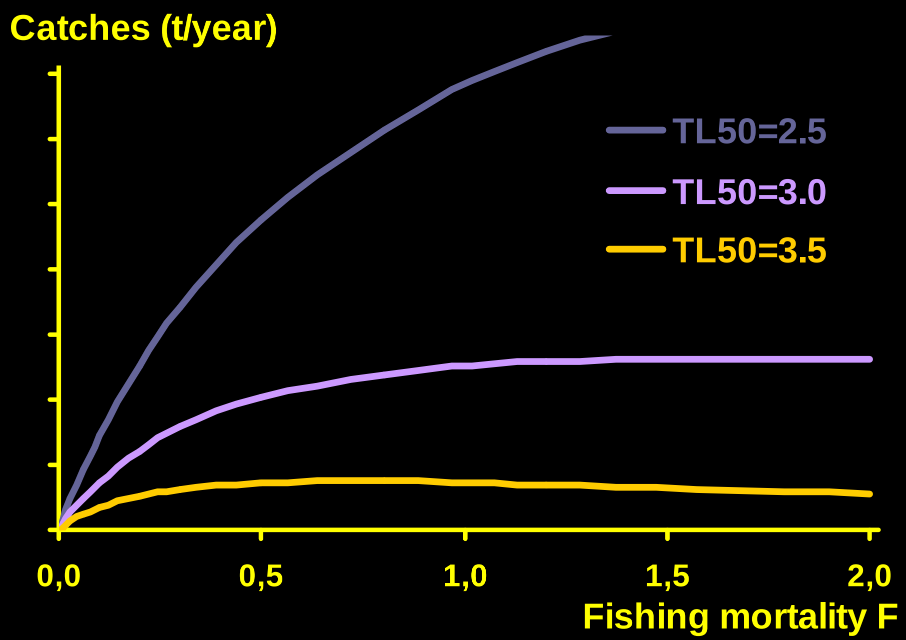
With μ^*_τ : rate of flow loss + flow gain (from inaccessible biomass)



2 - EcoTroph: simulating virtual ecosystems

- Top-down ecosystems are more productive
- Detritus-based are less
- Ecosystem over-fishing occurs for highest fishing mortalities



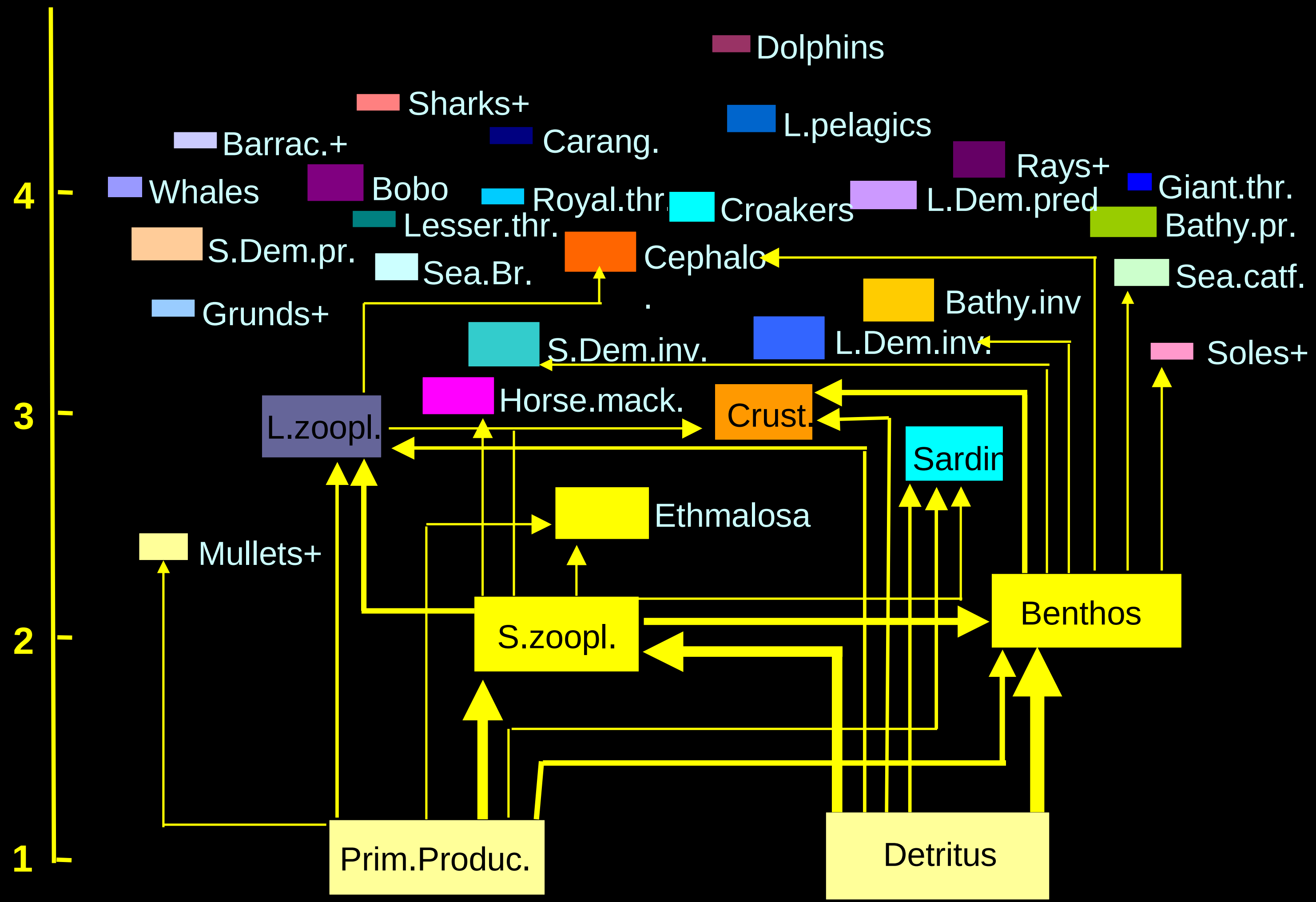


- Exploiting low trophic levels leads to higher catches and higher ecosystem FMSY
- …but it induces strong biomass depletion and severe over-fishing for top predators

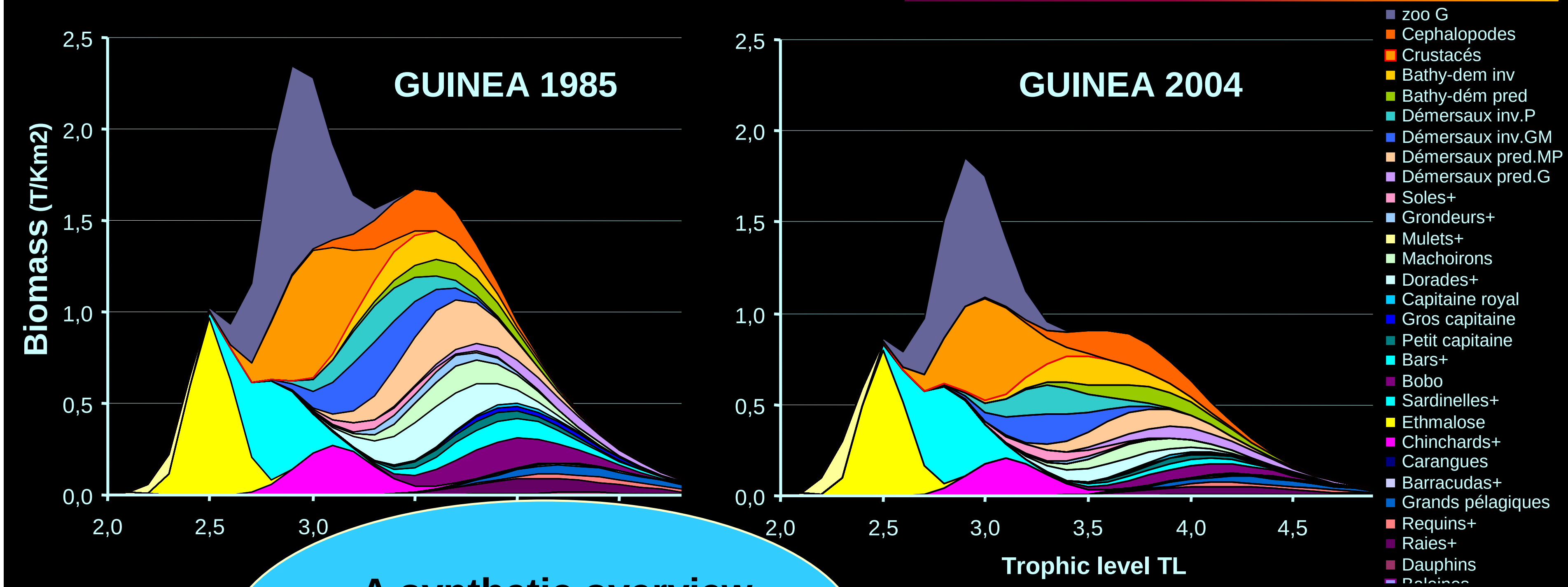
3 - EcoTroph: application to a case study

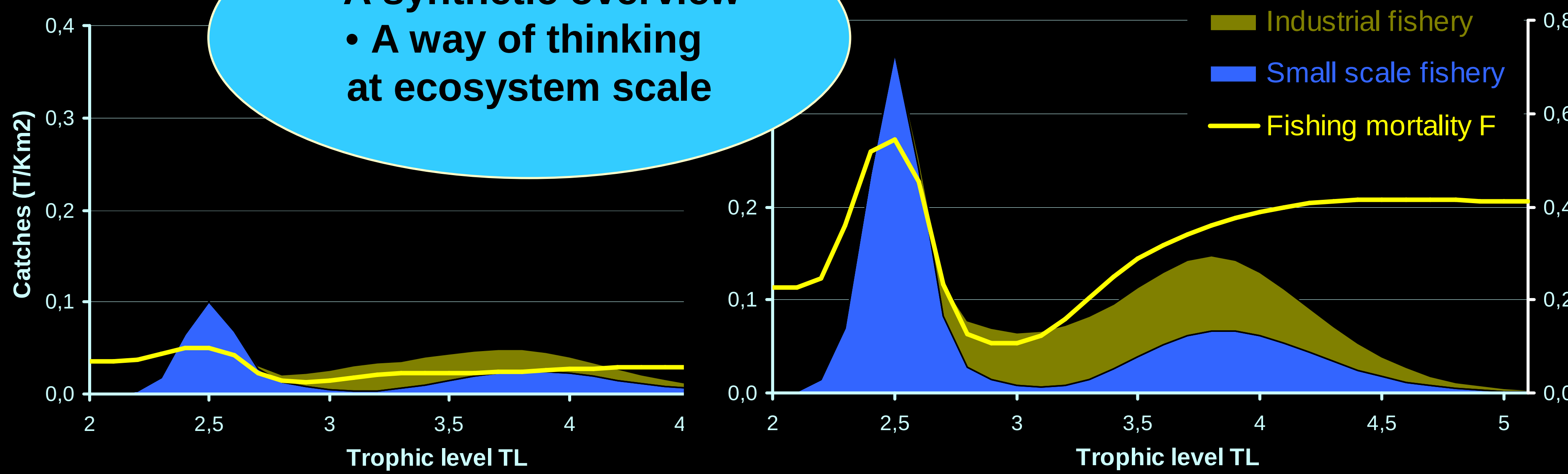
Application to the Guinean ecosystem (1985 and 2004)

- Here (but it's not a requirement of EcoTroph), the Ecopath model (35 boxes) is used for estimating the EcoTroph input parameters (B, P/B, and TL)



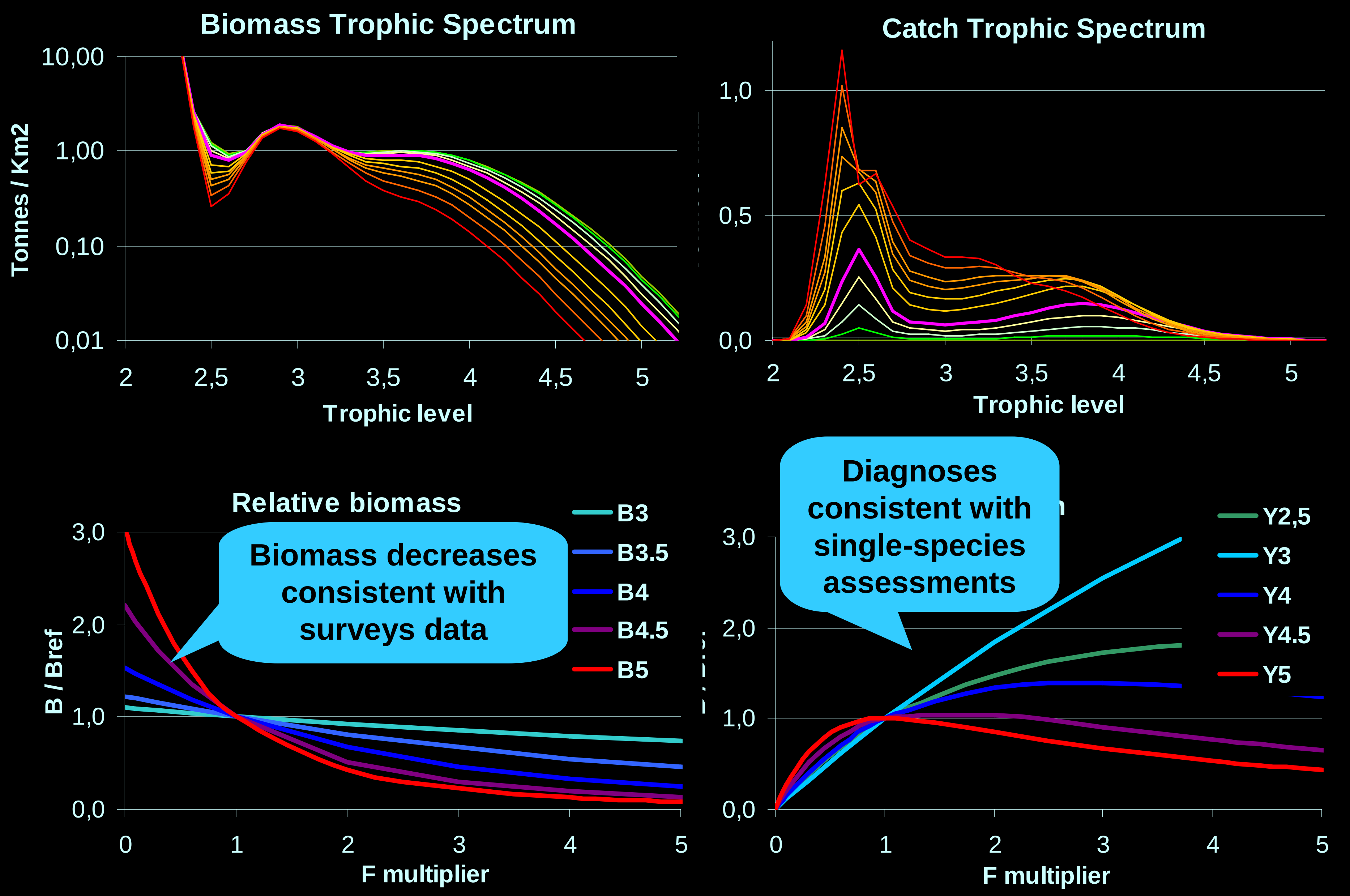
3 - EcoTroph: application to the Guinean ecosystem





- A synthetic overview
- A way of thinking at ecosystem scale

3 - EcoTroph: application to the Guinean ecosystem



The Catch Trophic Spectrum Analysis (CTSA): a method to estimate fishing rates and ecosystem biomass, from total catches by trophic level.

Input parameters

. yields per trophic level $Y\tau$

. kinetics of transfers a,b,c

. trophic efficiencies $e^{-\mu_\tau}$

. intensity of top-down control α (et β)

reverse forms of EcoTroph equations →

Estimates

. fishing flow loss $\varphi\tau$

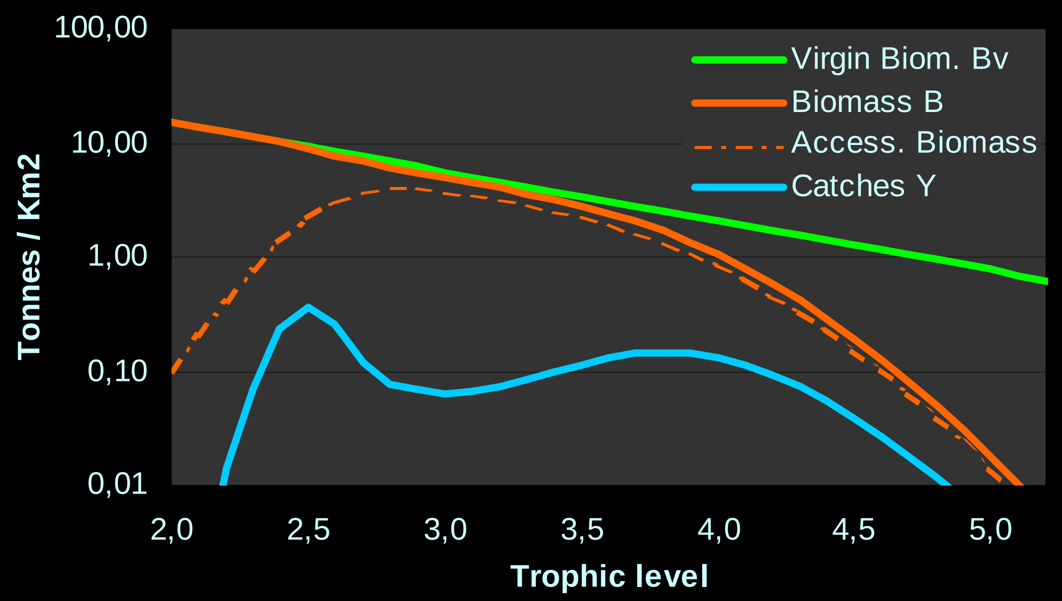
. fishing rates $E\tau = \varphi\tau/(\varphi\tau + \mu\tau)$

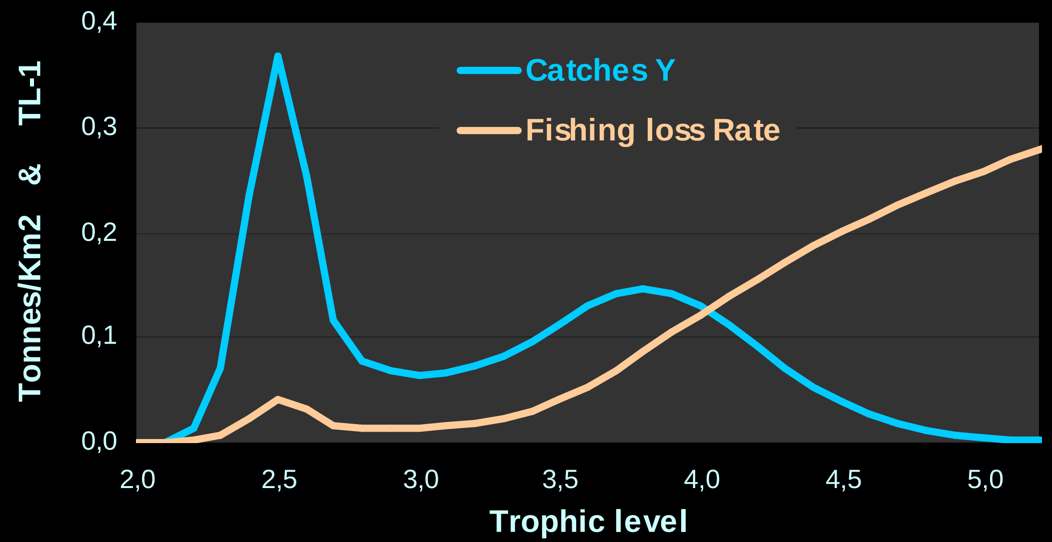
. Biomass flows $\Phi\tau$

. Biomasses $B\tau$

…like a VPA (backward or forward)

3 - EcoTroph: application to the Guinean ecosystem





ET – CTSA: a tool to estimate:

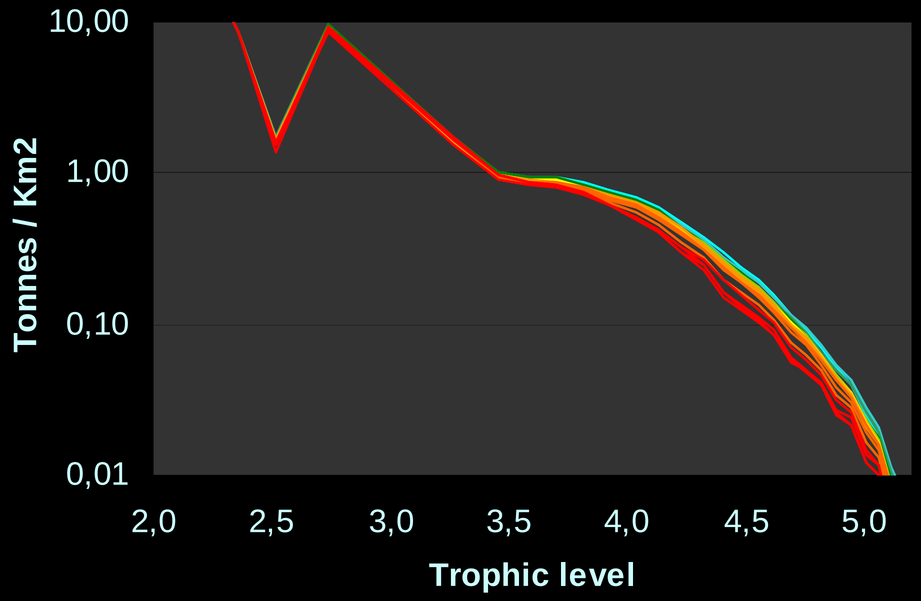
- **biomass**
- **fishing impact**
- **fishing strategies**
- **…**

A model of the past …and a method to estimate input parameter of forecast

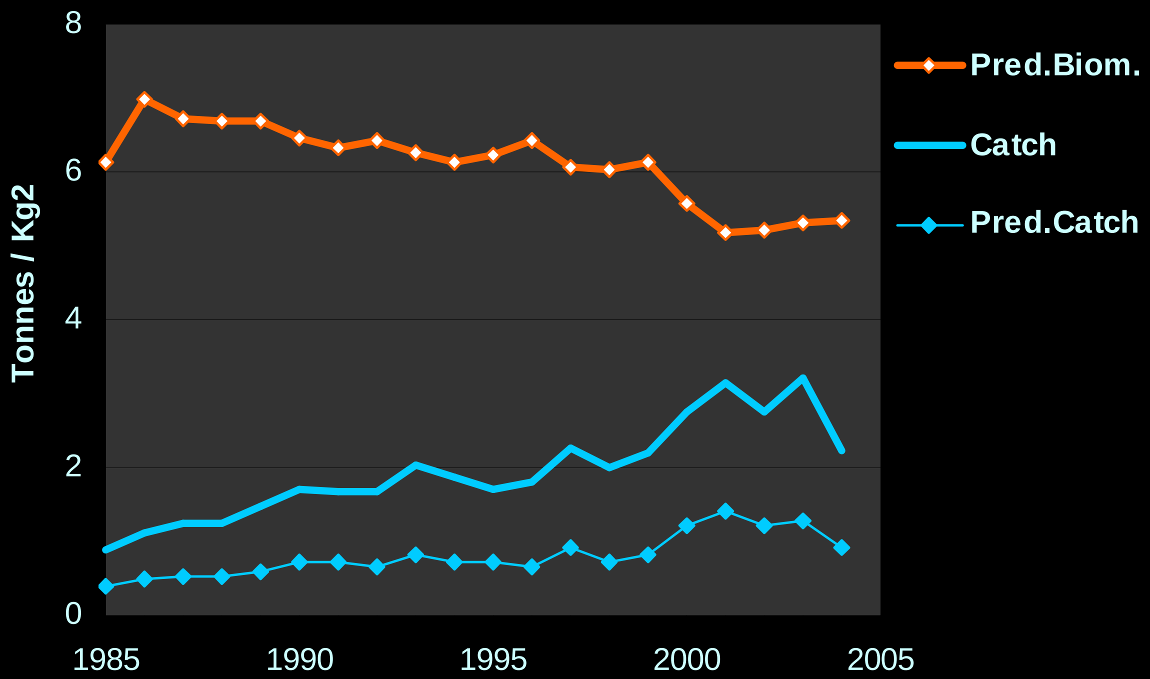
3 - EcoTroph: application to the Guinean ecosystem

A dynamic model, for fitting on time series

(Guinea, 1985-2004)



Biomass trophic spectra



First run …

change parameter (top-down, efficiency,…) …

Cf. Ecosim

Conclusion

1. Functioning of marine ecosystems can be conceptualize as a continuous trophic flow, from low to upper trophic levels

2. The EcoTroph model is based on simple assumptions:
   - The biomass flow decreases with trophic levels (according to the trophic efficiency)
   - The speed of the flow is faster in low trophic levels
   - Top-down control: flow kinetics depend on predators abundance
   - Secondary production partly comes from biomass recycling

3. EcoTroph input parameters are calculated as functions of TL (leading to a strong decrease in the number of parameters required)

4. The model leads to a consistent theoretical representation … of almost all we already know (yield, biomass, mean TL, cascades, resilience,…)

5. It is complementary to Ecopath for case study analyses (and should be proposed as an additional routine of EwE …in few months)

Thanks

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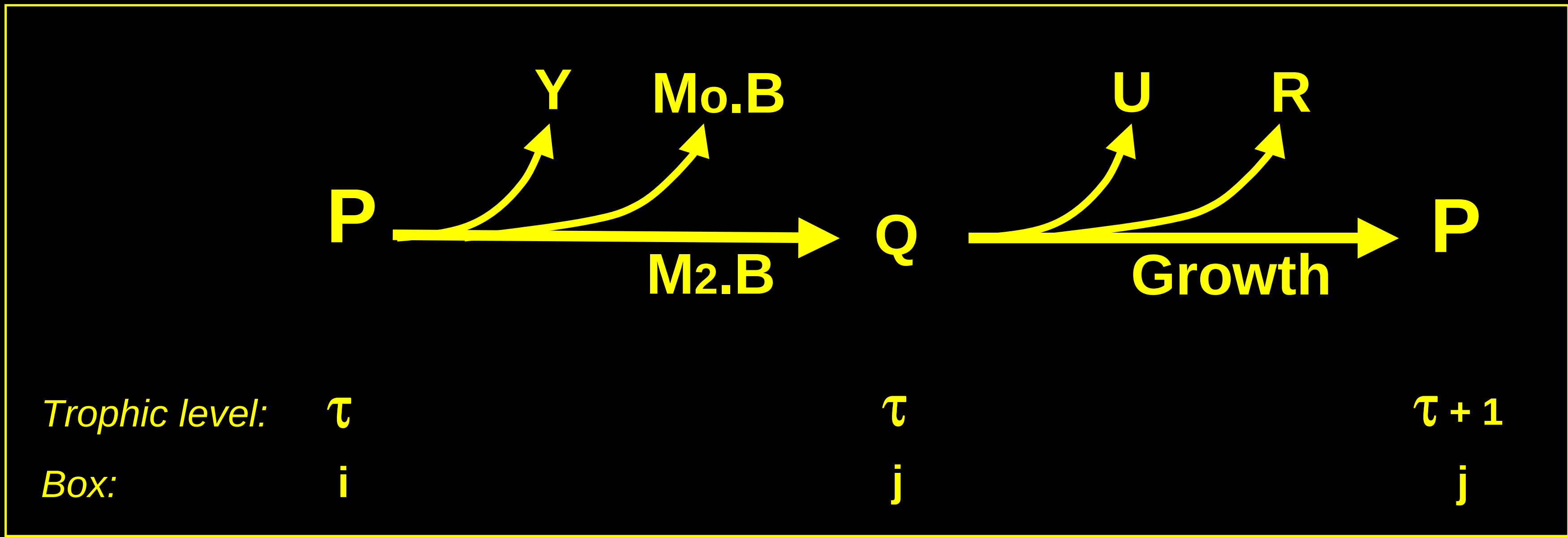
1 - EcoTroph: principles and basis equations

➢ EcoTroph versus Ecopath?



- Ecopath (and Ecosim) is also a model of biomass flow: $P\tau = \Phi\tau \cdot \Delta\tau$
- The speed of the flow is equal to the Production/Biomass ratio: $\Delta\tau/\Delta t = (P/B)\tau$
- Two processes are involved in trophic transfers: predation and growth
- In study state P/B = Z -> The speed of the flow depends on F, M_0, M_2

2 - Theoretical approach – EcoTroph versus Ecopath

	Ecopath	EcoTroph	link equation
Model structure	Aggregation of species into Boxes	Continuous distribution of the biomass	
Parameters	One value of each parameter per box	Parameters expressed as functions of TL	
Trophic parameters	$DC_{i,j}$, Q/B_i	TL_s	
	Production P	Biomass flow Φ	$P = \Phi . \Delta\tau$
	Productivity P/B	Speed of flow $\Delta\tau / \Delta t$	$P/B = \Delta\tau / \Delta t$
	Biomass Bi	Biomass $B\tau$	$B = P / (P/B)$
	Fishing mortality	Fishing flow loss	$F = \varphi . \Delta\tau / \Delta t$