Gascuel D., Christensen V., Pauly D. 2007. EcoTroph: modelling marine ecosystem functioning and impact of fishing. Abstract, 6th European Conference on Ecological Modelling - ECEM'07. Trieste, Italy, November 27-30, 2007, p. 179.

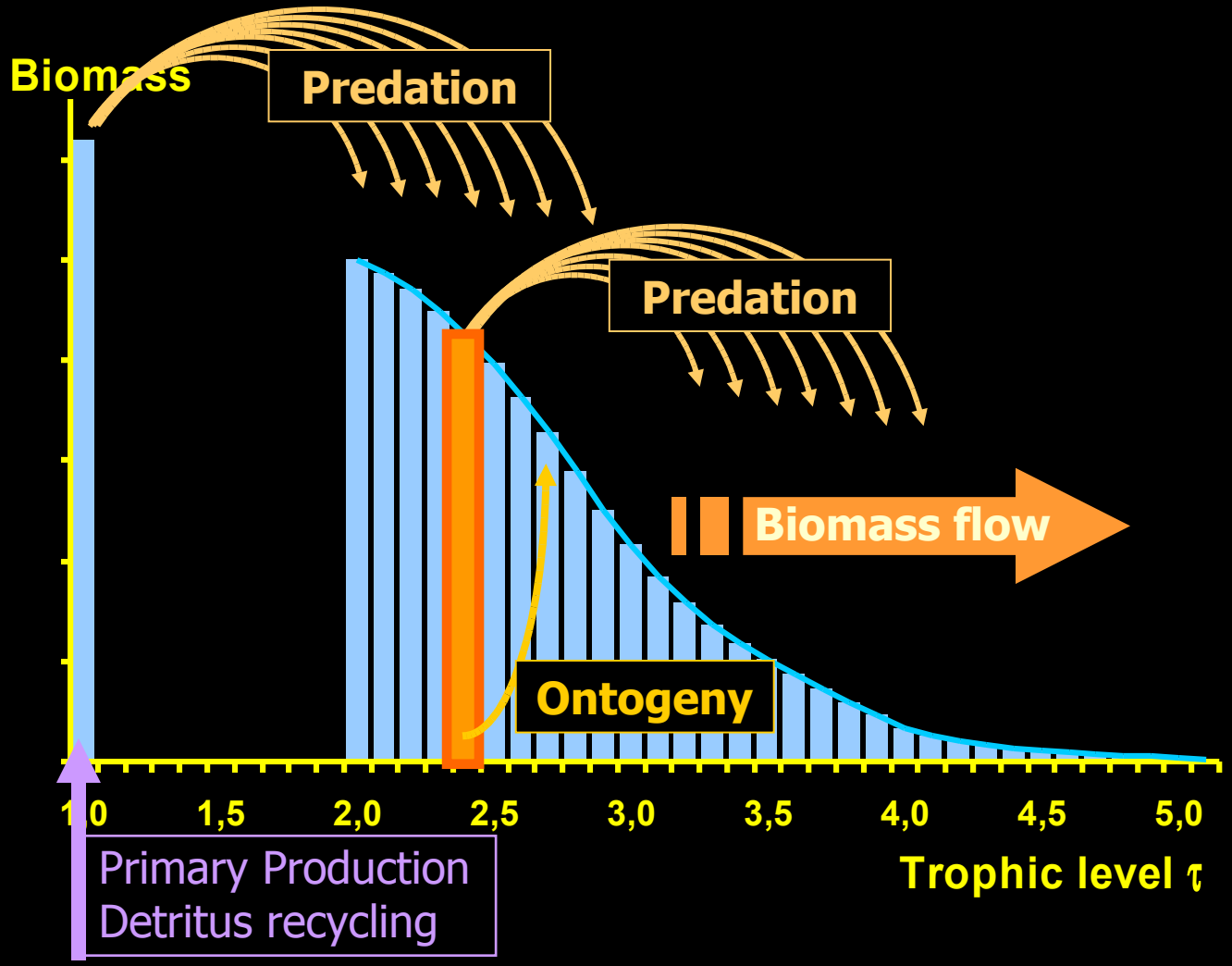
EcoTroph: modeling marine ecosystem functioning and impact of fishing

Didier Gascuel [1,2], Villy Christensen [2], Daniel Pauly [2]

1. Fisheries and Aquatic Sciences Center, Agrocampus Rennes, France
2. Fisheries Centre, University of British Columbia, Canada

ECEM07, November 2007

1 - EcoTroph: principles and basis equations



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

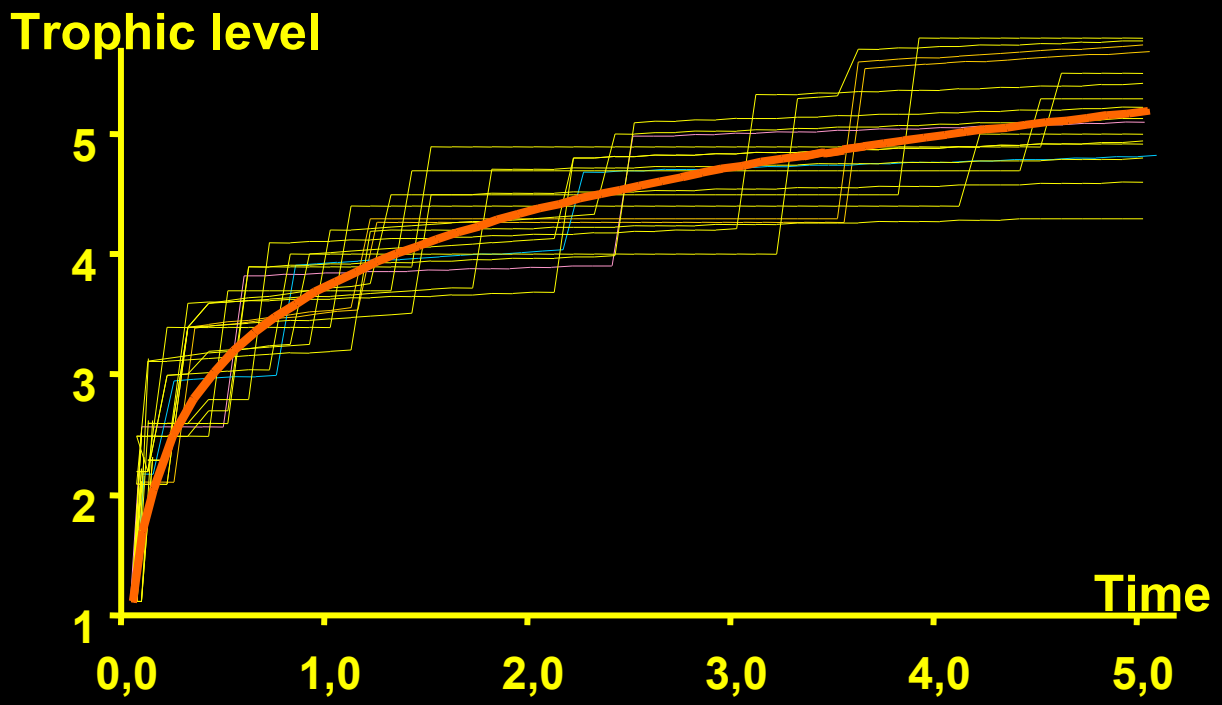
-> the Biomass Trophic spectrum

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

Don't confuse: the biomass $\mathbf{B\tau}$ present in the trophic class $[\tau, \tau+\Delta\tau[$

the biomass flow $\mathbf{\Phi\tau}$, 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)

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

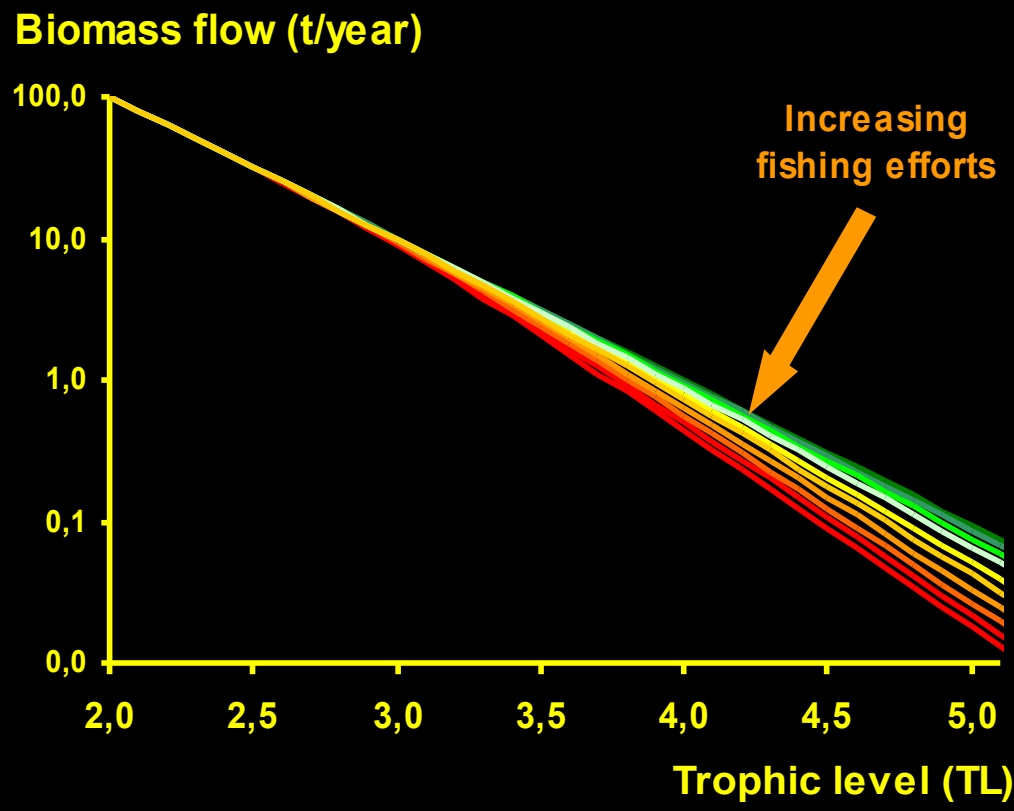
$$B\tau = \frac{\bar{\Phi}\tau}{\Delta\tau/\Delta t} \cdot \Delta\tau$$

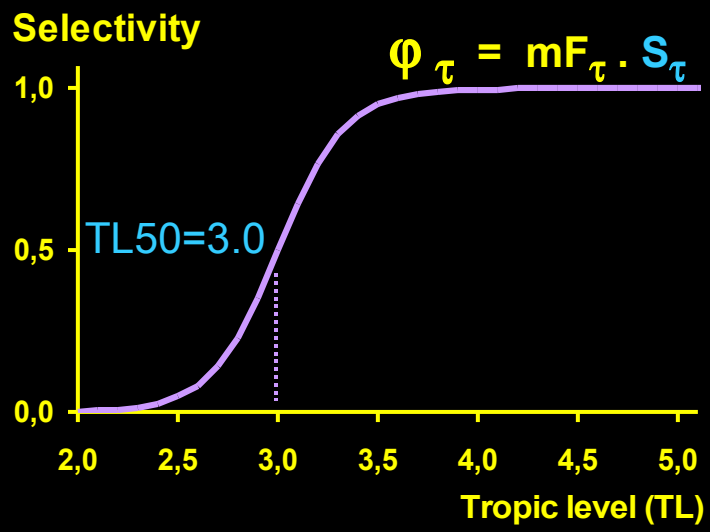
The biomass flow model: $\Phi(\tau + \Delta\tau) = \Phi(\tau) \cdot e^{-(\mu_\tau + \varphi_\tau) \cdot \Delta\tau}$

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

Fishing loss
. Exploitation

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





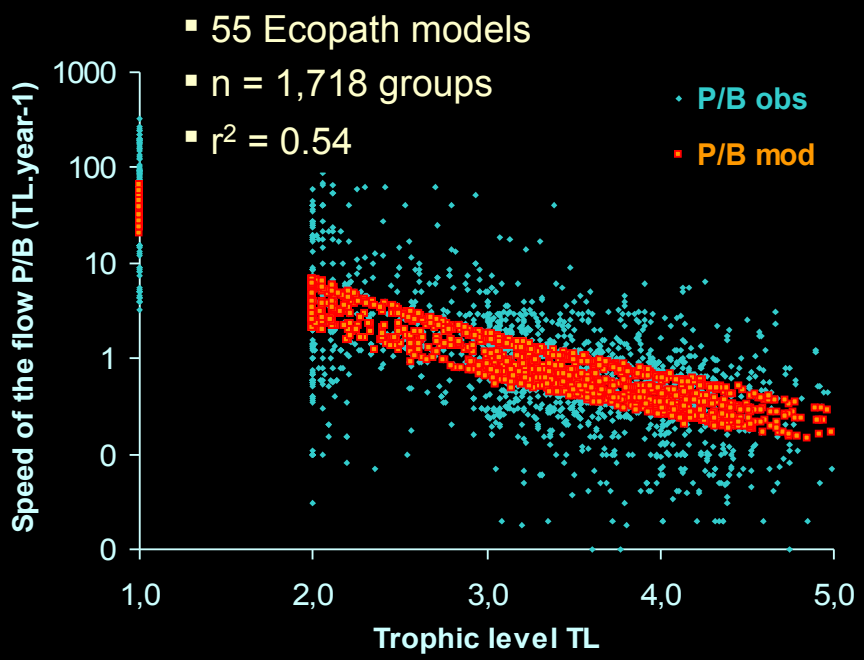
➢ The speed of the flow model

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)



2. The Top-down equation:

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

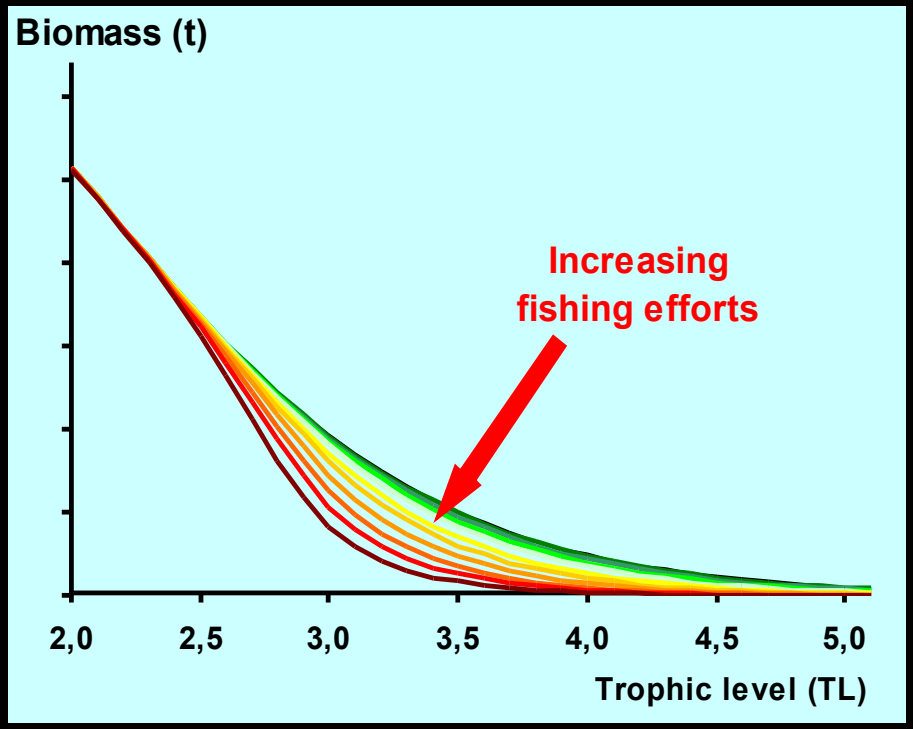
The speed of the flow depends on predators abundance

- $\alpha = 0$: 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**

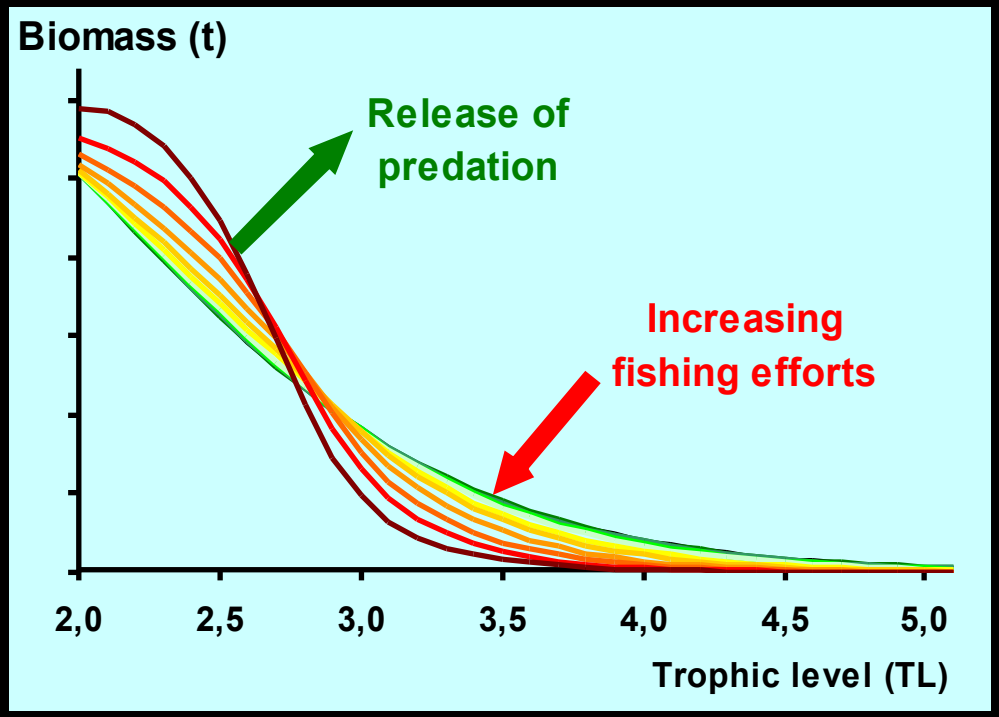


Bottom-up ecosystem

- direct impact of fishing
- indirect impact of the decrease in the preys abundance

2 - EcoTroph: simulating virtual ecosystems

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



Top-down ecosystem

- the decrease of predators induces an increase in preys abundance

2 - EcoTroph: simulating virtual ecosystems

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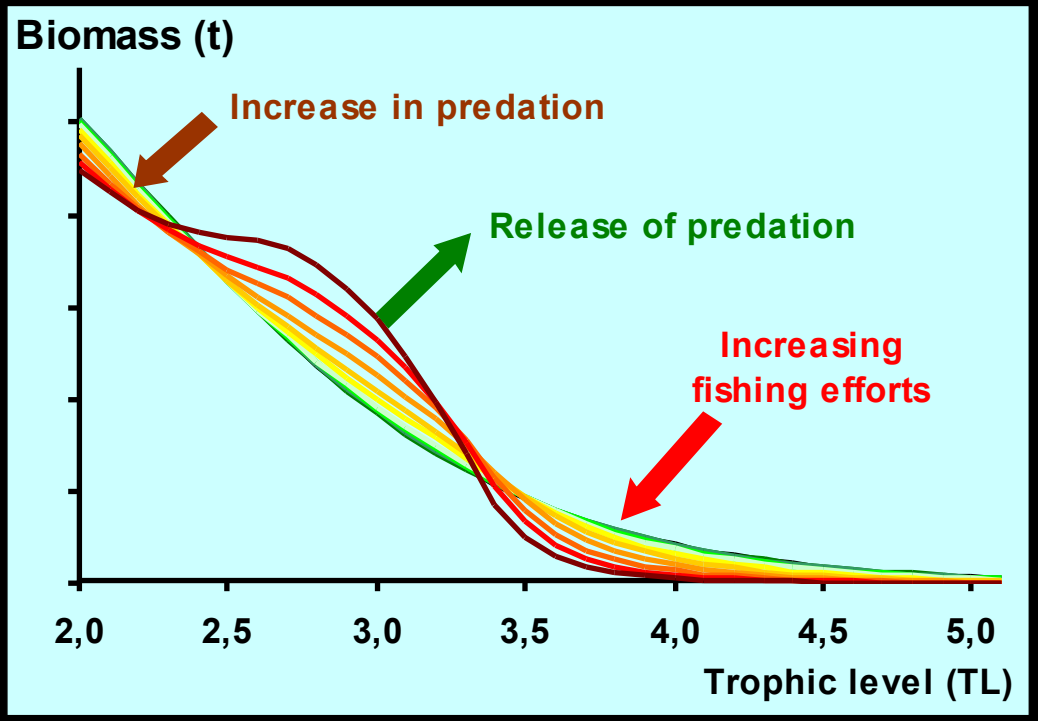
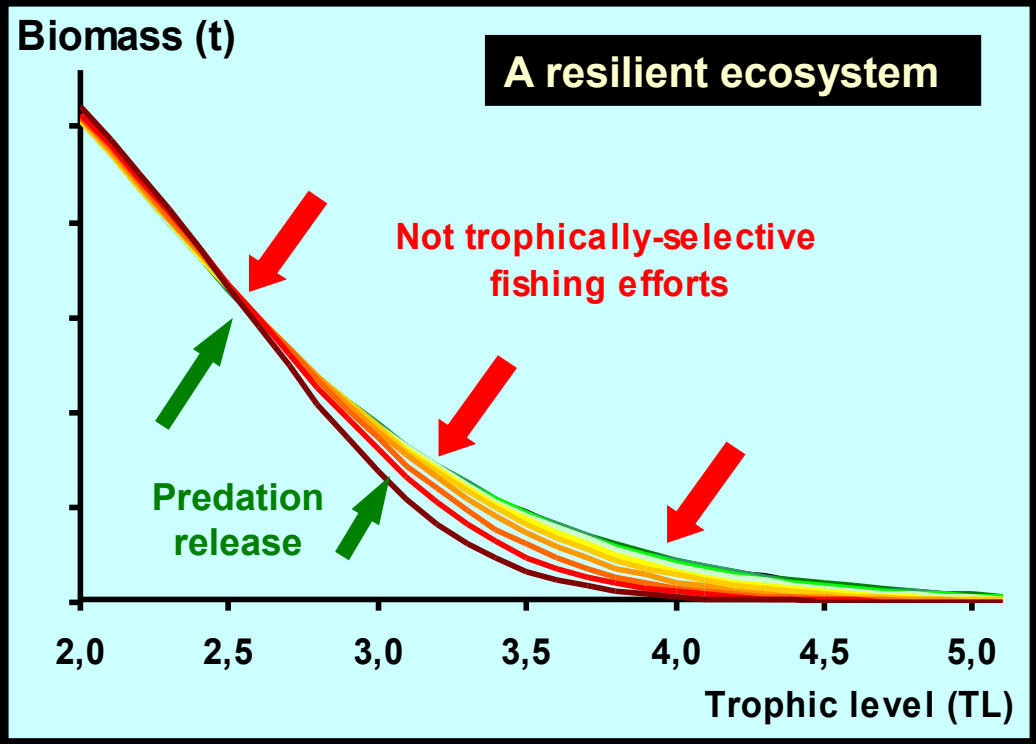


A cascade effect

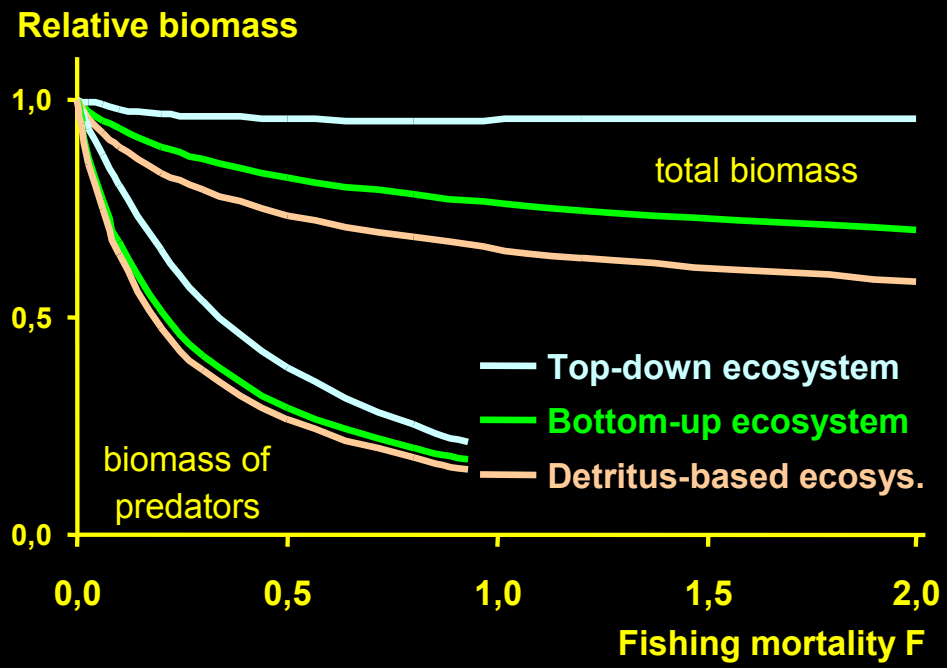
2 - EcoTroph: simulating virtual ecosystems

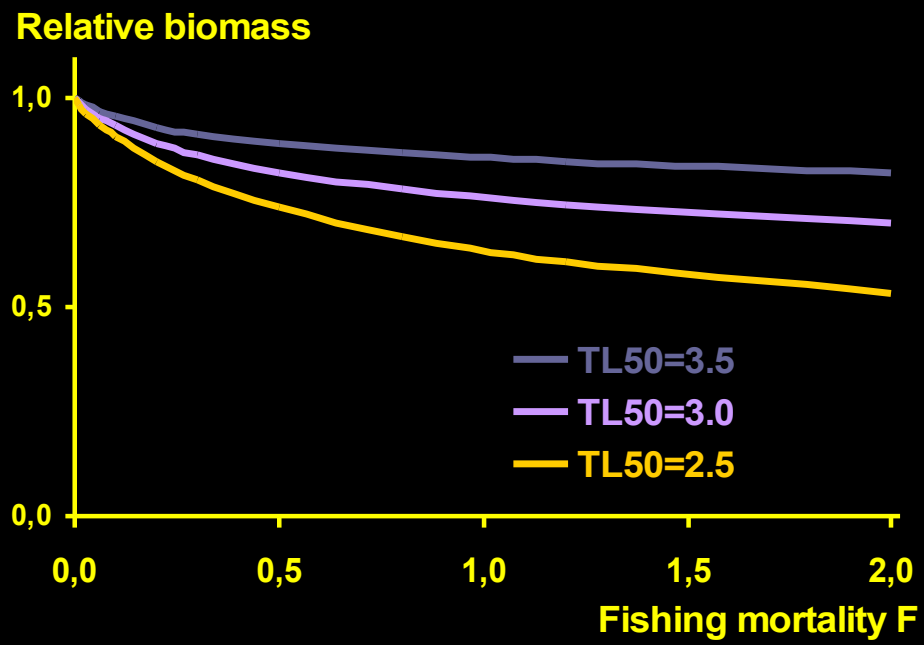
- Theoretical analysis of functioning -> generic relationships between parameters



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

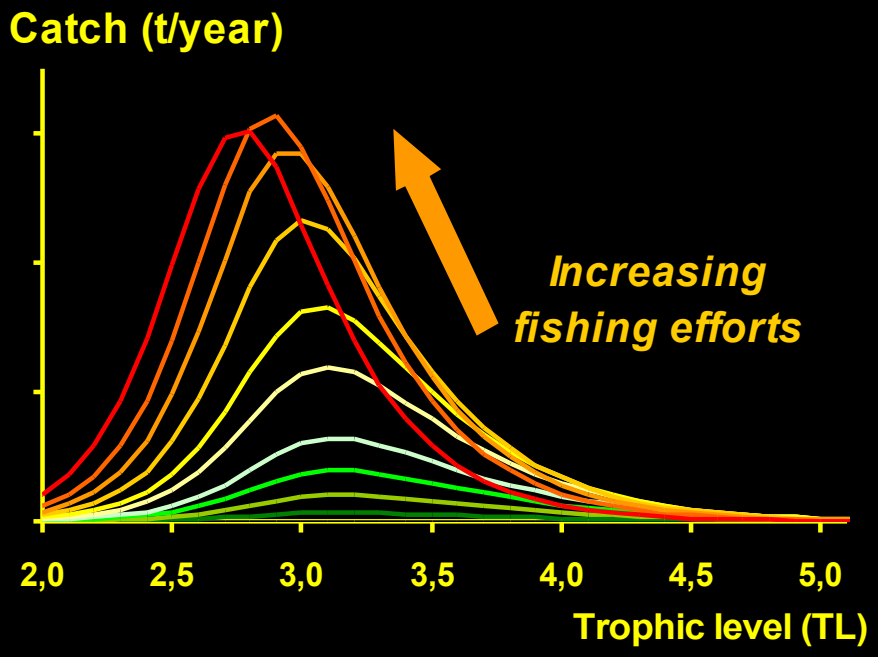




- Impact of fishing on ecosystem biomass increases when the trophic level of first catch TL50 decreases

2 - EcoTroph: simulating virtual ecosystems

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

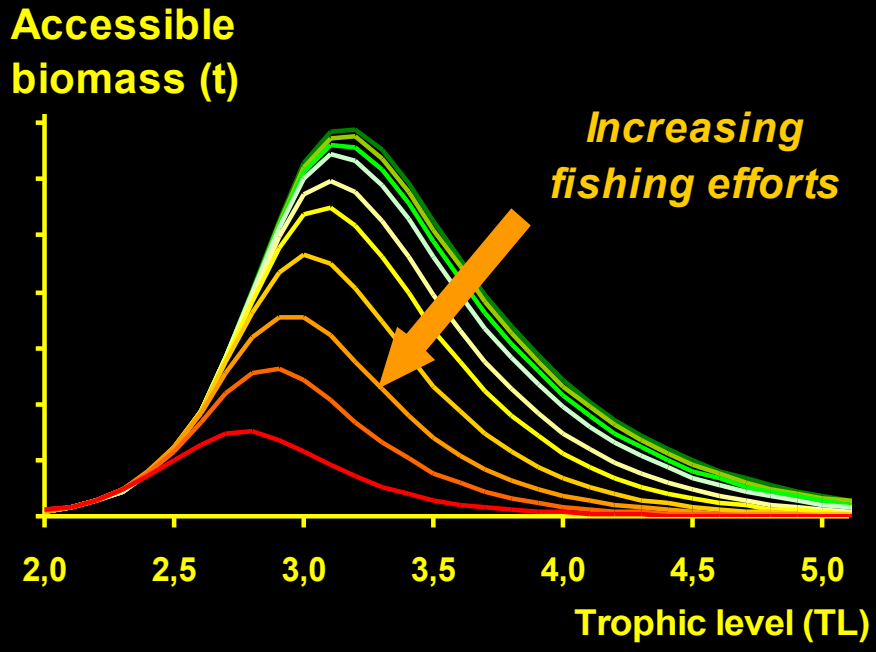


- Wide potential catches on low trophic levels
- Over fishing of high trophic levels
- Fishing down the marine food web

Accessible flow:

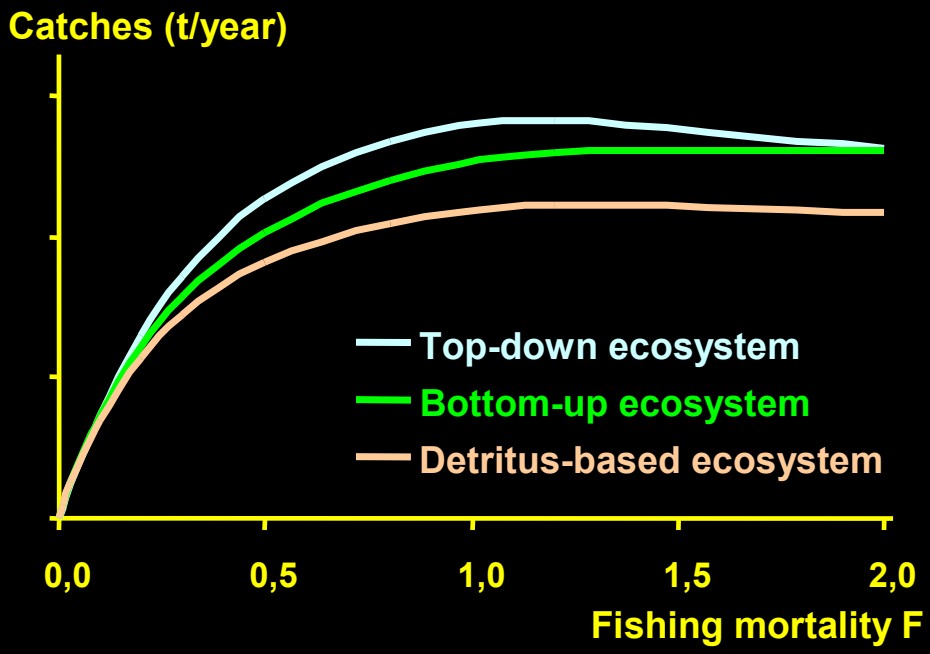
$$\Phi^*(\tau+\Delta\tau) = \Phi^*(\tau) \,.\, e^{-(\mu^*_\tau + \varphi^*_\tau).\Delta\tau}$$

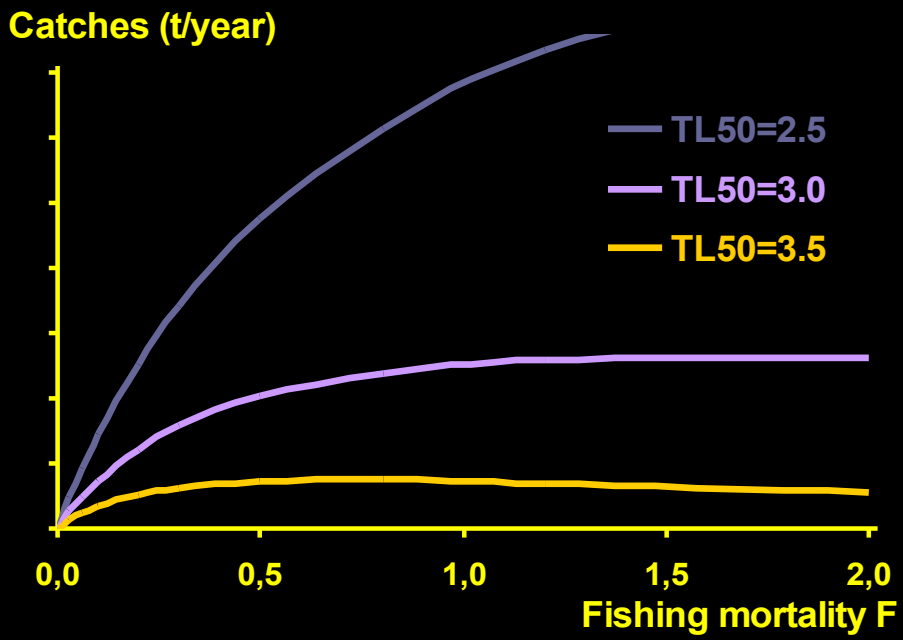
With μ^*_τ: rate of flow loss + flow gain (from inaccessible biomass)



2 - EcoTroph: simulating virtual ecosystems

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



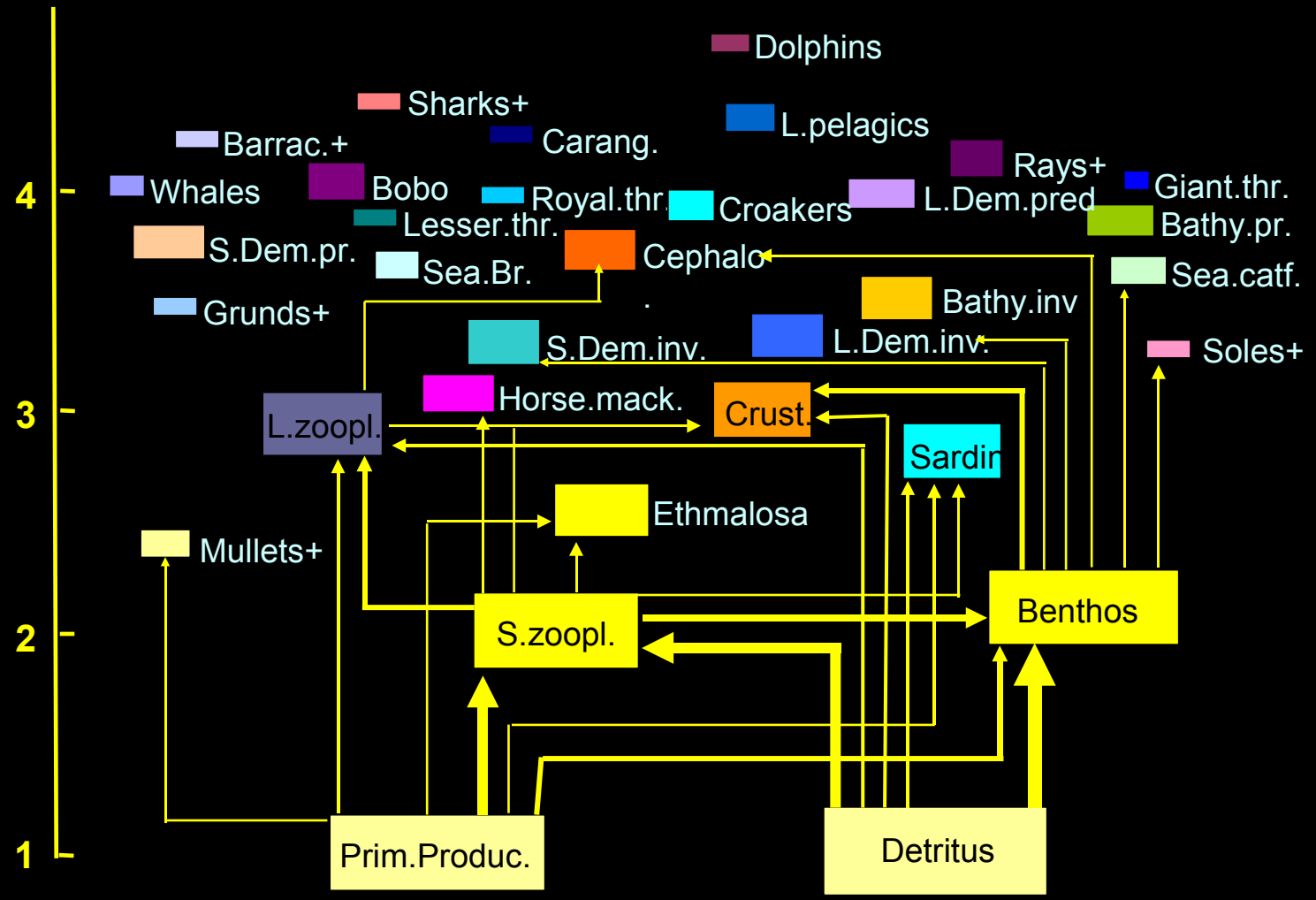


- Exploiting low trophic levels leads to higher catches and higher ecosystem FMSY
- …but it induces strong biomass depletion and severe over-fishing for top predators

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)



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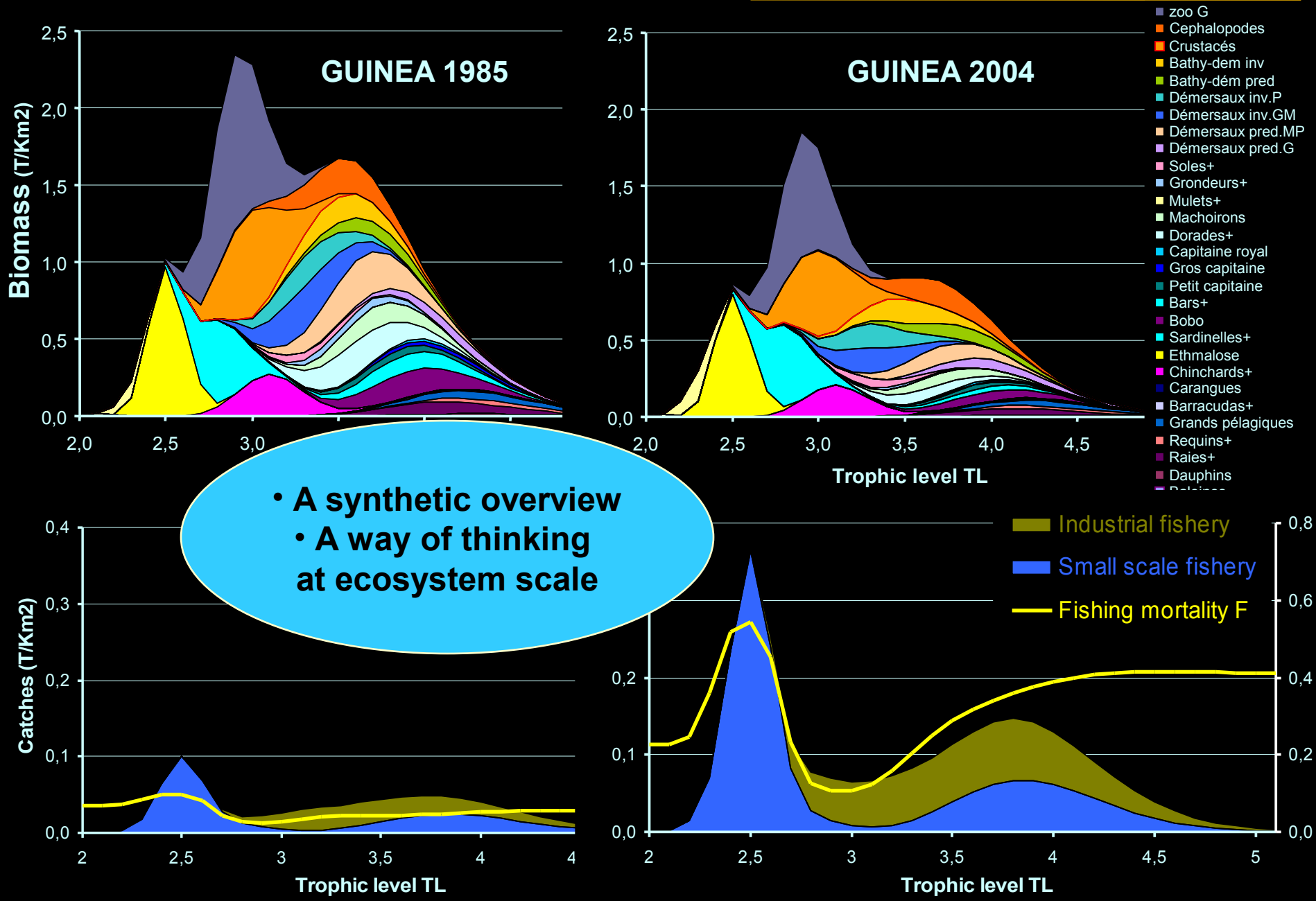

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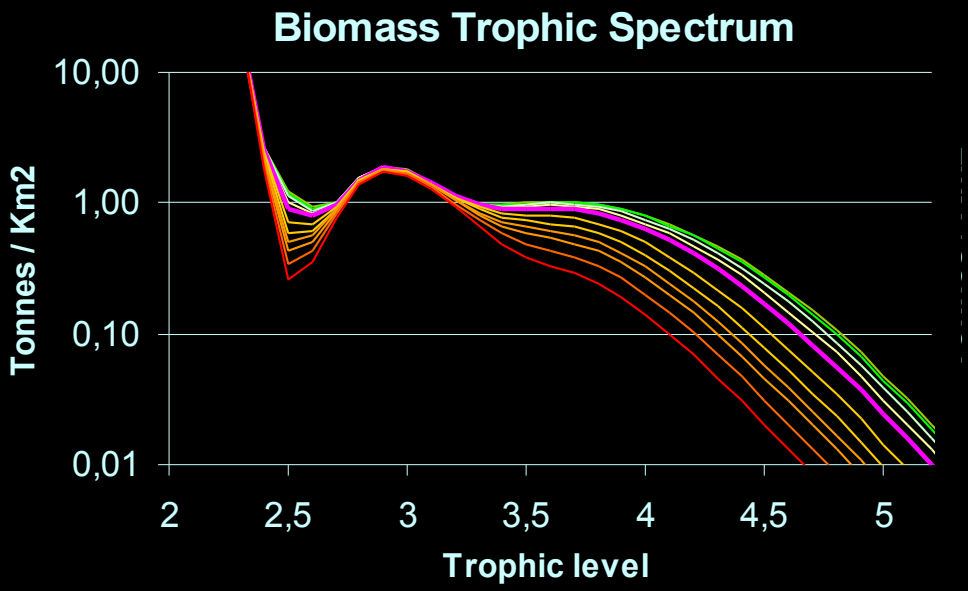

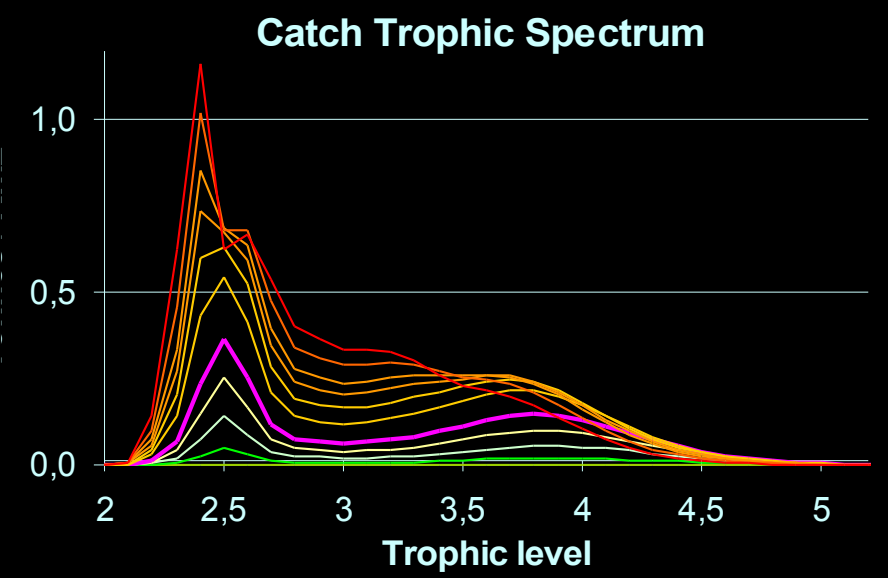

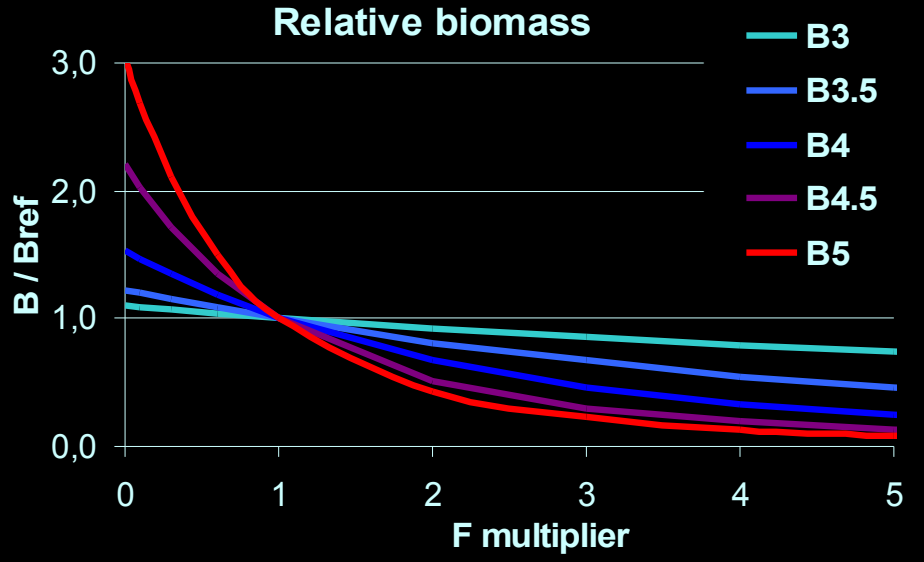

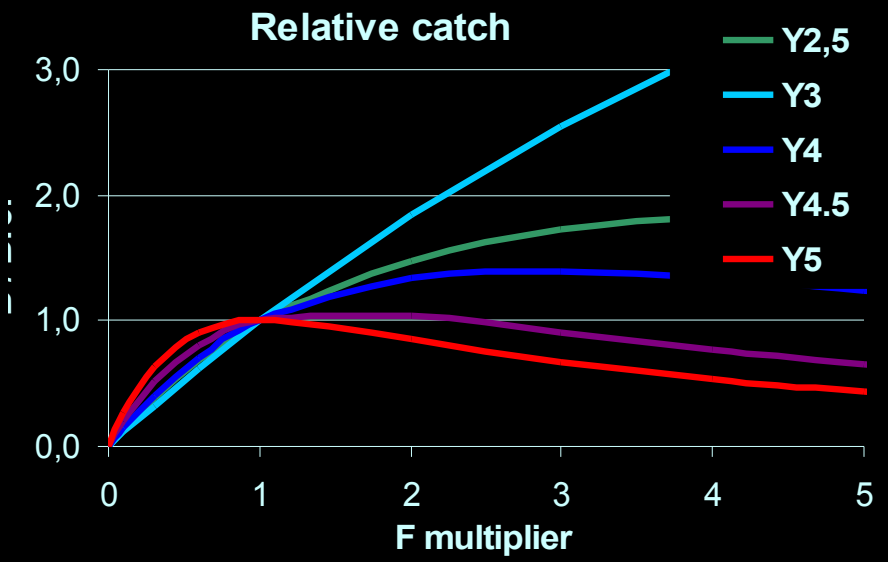

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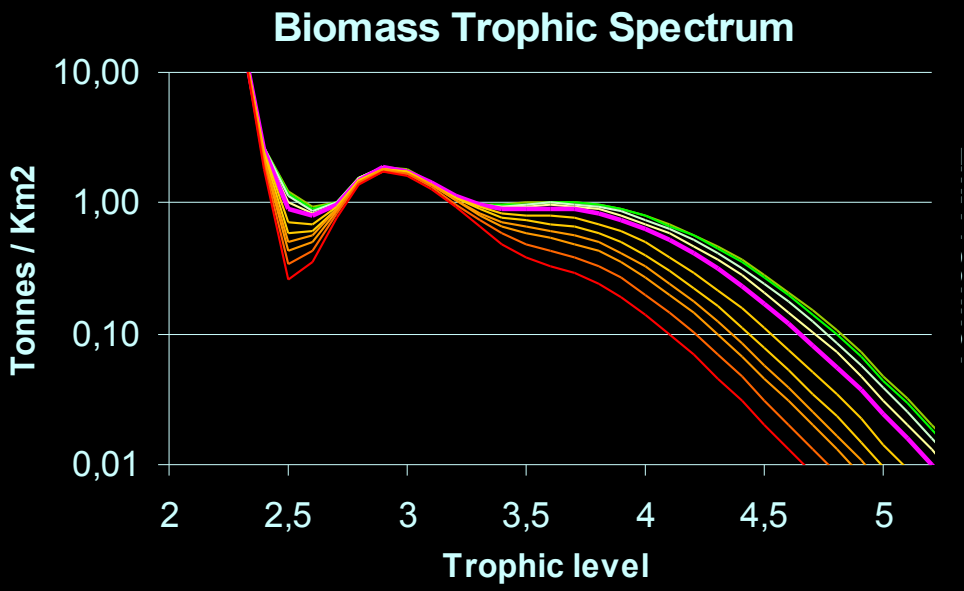

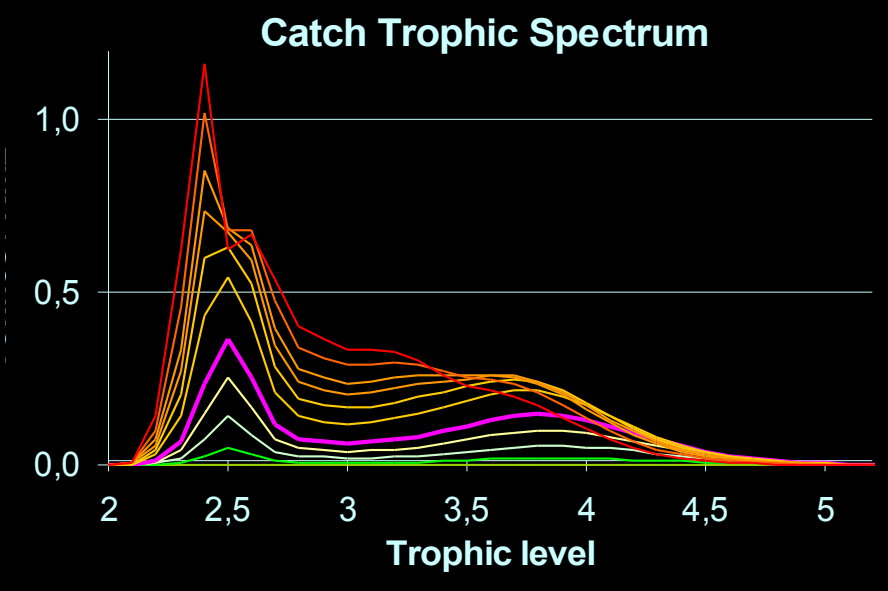

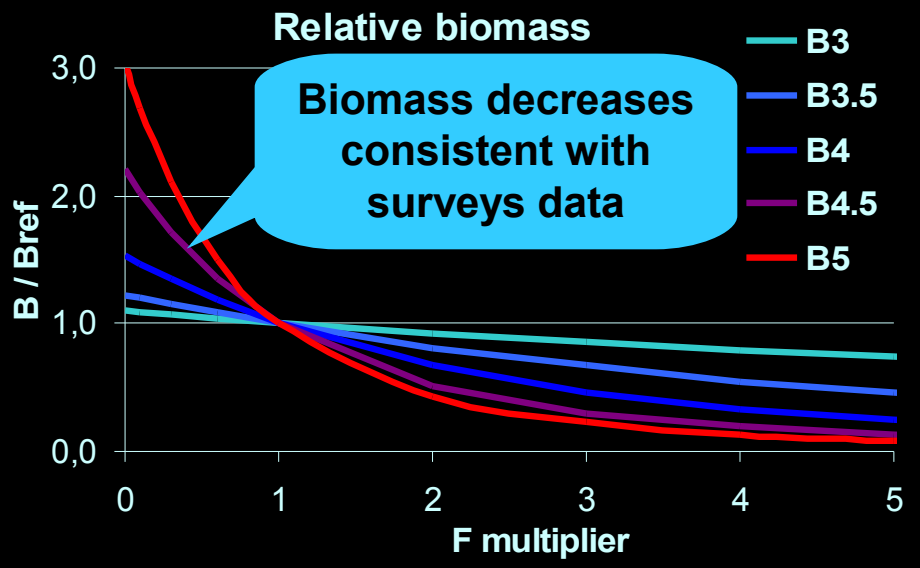

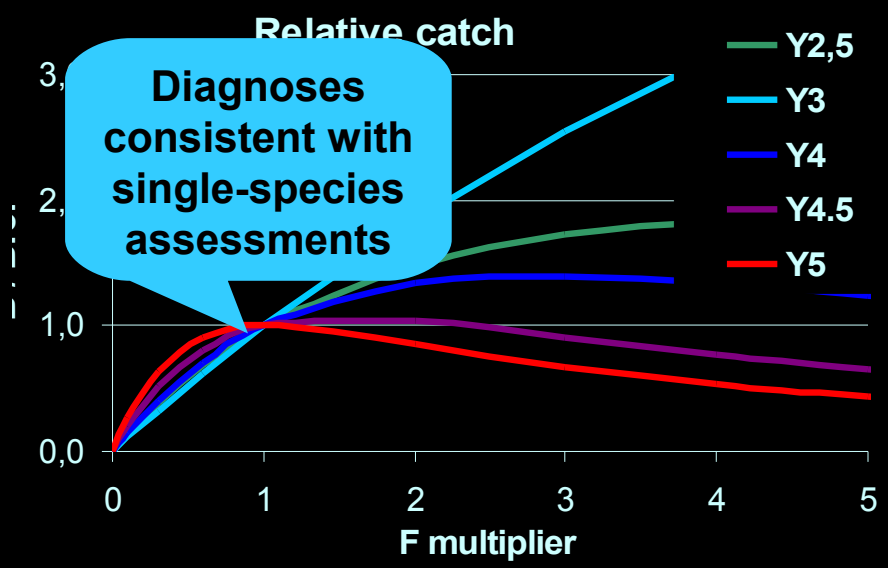

Conclusion

- 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)

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

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

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   to a strong decrease in the number of par

Grimm, 2007 (yesterday before !):
"The more patterns a model reproduces simultaneously, the more likely is has captured the key elements of the system organisation"

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

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Thanks

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