Nereus Annual Meeting
UBC, Vancouver, 01st June 2016

Impacts of fishing and climate change on the world's ocean biomass from 1950 to 2010

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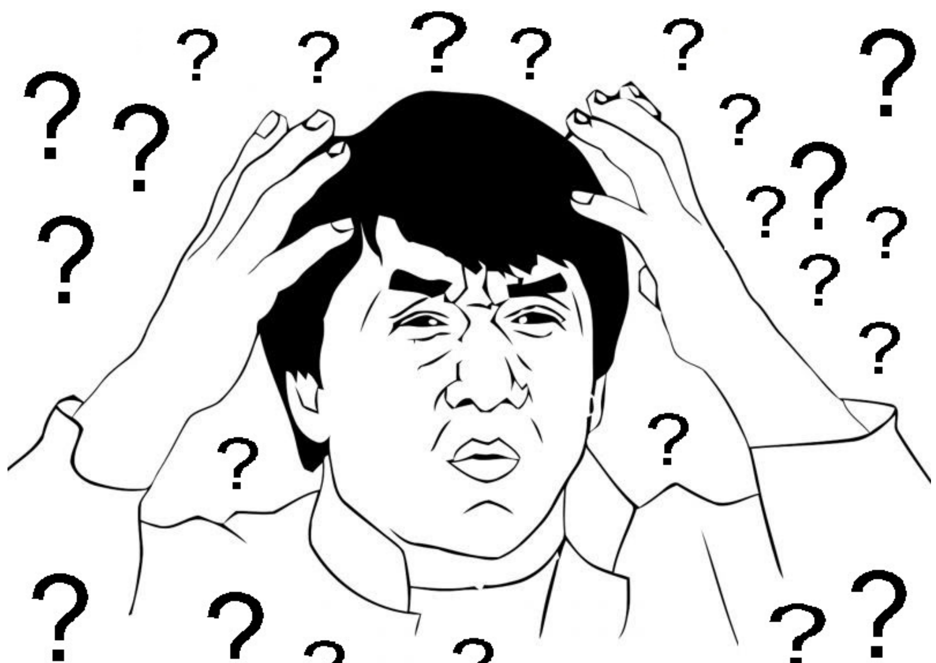
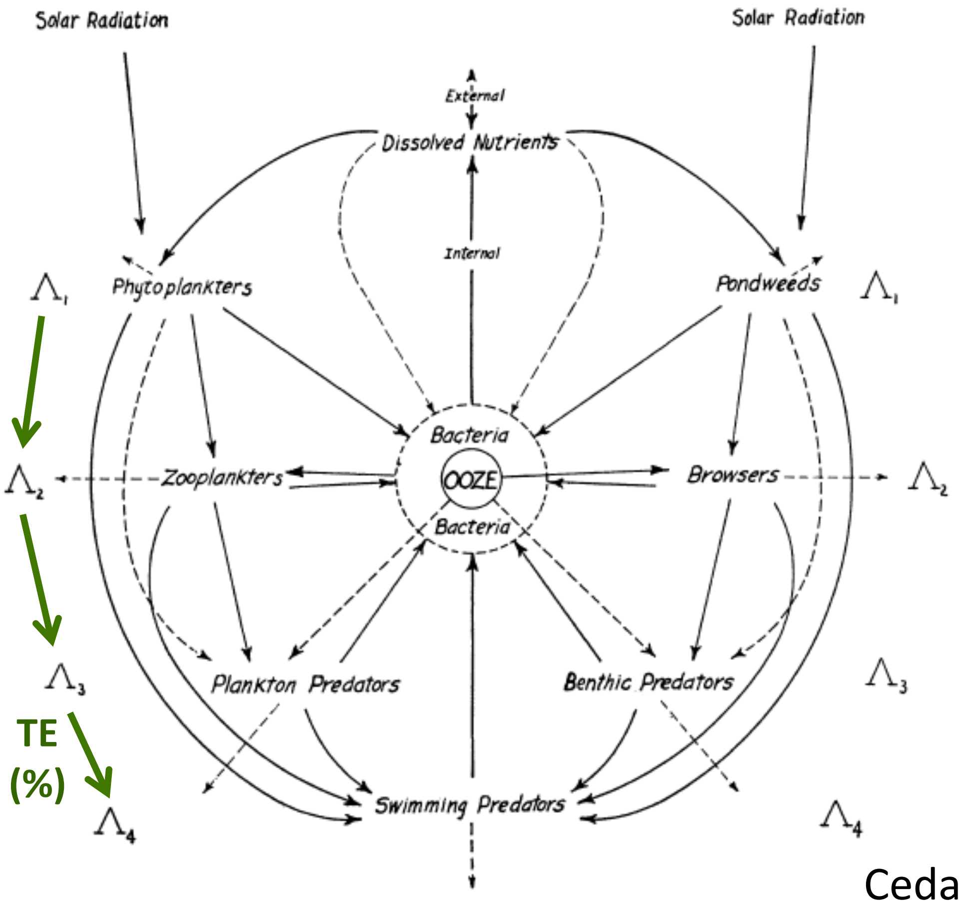
Impacts of fishing and climate change on the world's ocean biomass from 1950 to 2010

From current problems to future success



How to model an aquatic ecosystem?

→ Study of trophic networks: the trophic level (TL)



Cedar Bog Lake trophic network (Lindeman 1942)

- TL: characterizes the position of an organism within the trophic network
- Analysis of trophic dynamics and associated processes
- Trophic functioning key parameters: transfer efficiency (TE)
- Fractional trophic levels (Odum et Heald 1975)

Derived analyses

Photosynthesis and Fish Production in the Sea

The production of organic matter and its conversion to higher forms of life vary throughout the world ocean.

John H. Ryther

Numerous attempts have been made to estimate the production in the sea of fish and other organisms of existing or potential food value to man (*1–4*). These exercises, for the most part, are based on estimates of primary (photosynthetic) organic production rates in the ocean (*5*) and various assumed trophic-dynamic relationships between the photosynthetic producers and the organisms of interest to man. Included in the latter are the number of steps or links in the food chains and the mine the trophic dynamics of marine food chains also vary widely and in direct relationship to the absolute level of primary organic production. As is shown below, the two sets of variables—primary production and the associated food chain dynamics—may act additively to produce differences in fish production which are far more pronounced and dramatic than the observed variability of the individual causative factors.

gional studies of productivity in many parts of the world. Most of these have been brought together by a group of Soviet scientists to provide up-to-date world coverage consisting of over 7000 productivity observations (*7*). The result has been modification of the estimate of primary production in the world ocean from 1.2 to 1.5×10^{10} tons of carbon fixed per year (*5*) to a new figure, 1.5 to 1.8×10^{10} tons.

Attempts have also been made by Steemann Nielsen and Jensen (*5*), Ryther (*8*), and Koblentz-Mishke *et al.* (*7*) to assign specific levels or ranges of

Primary production required to sustain global fisheries

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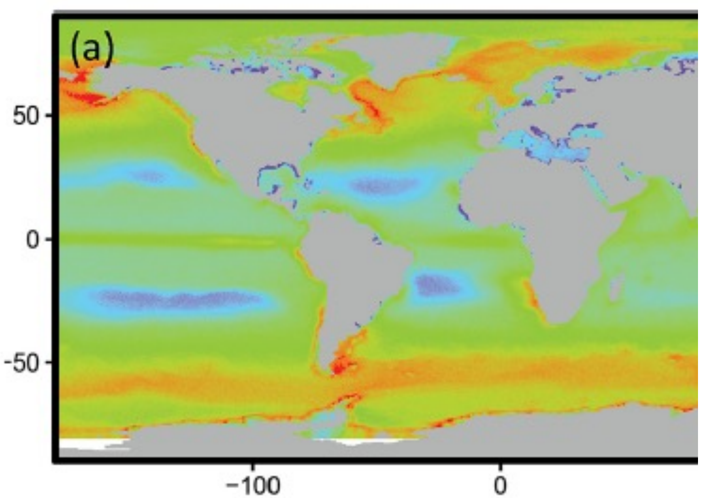
The mean of reported annual world fisheries catches for 1988–1991 (94.3 million t) was split into 39 species groups, to which fractional trophic levels, ranging from 1.0 (edible algae) to 4.2 (tunas), were assigned, based on 48 published trophic models, providing a global coverage of six major aquatic ecosystem types. The primary production required to sustain each group of species was then computed based on a mean energy transfer efficiency between trophic levels of 10%, a value that was re-estimated rather than assumed. The primary production required to sustain the reported catches,

resources therefore seems insufficient by itself to alter on a large scale any but the target populations and those of other species interacting closely with target species'[1].

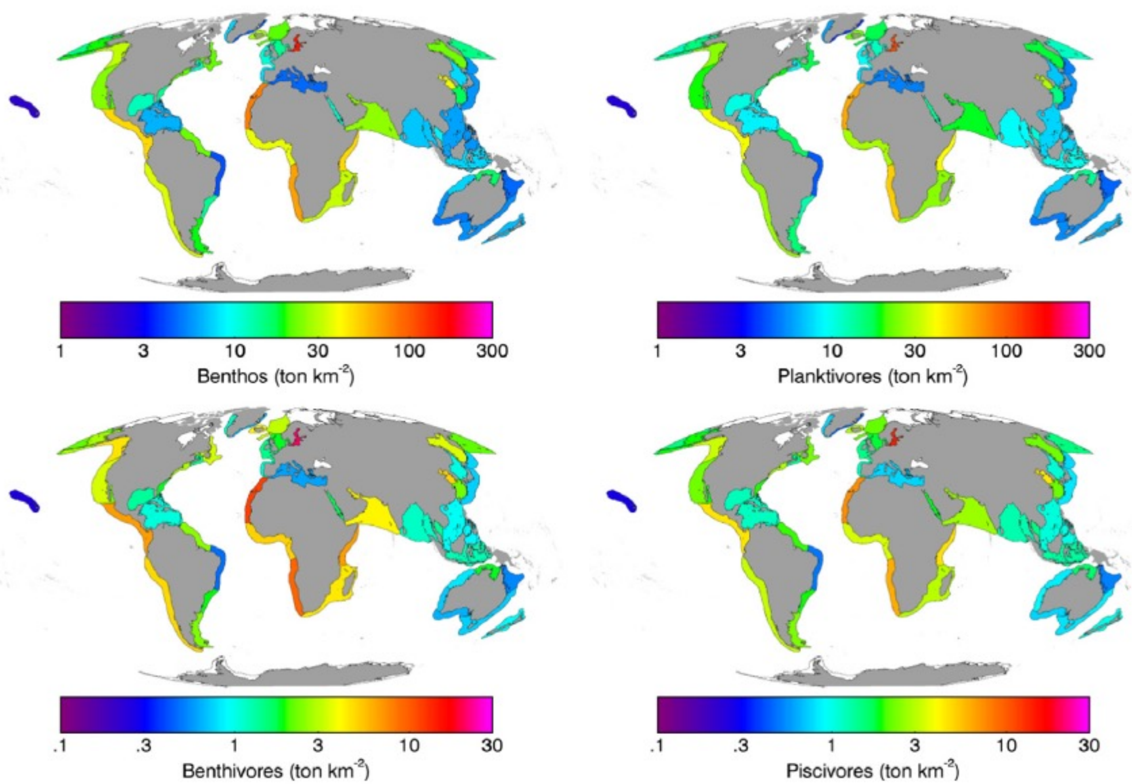
This work is an attempt to obtain a more accurate estimate of the PPR to sustain the world fisheries catches (including discarded 'bycatch'), based on the same approach as used above to estimate terrestrial PPR, wherein independent estimates are obtained on a commodity group and system basis, then added up to yield a robust estimate of the total.

Our approach, illustrated in Fig. 1, uses only flows of matter (catches and food consumption of fishes and their prey) and does not require estimation of biomasses, which have proved hard to estimate reliably on a global basis[2].

Recent world fisheries statistics, covering a short period (1988-1991) without major changes in catch composition and reported by the UN Food and Agriculture Organization (FAO)[3], were split into 39 commodity groups, by ecosystem types. The PPR was then estimated by group, and ecosystem type, based on an estimate of 10% mean transfer efficiency between trophic levels (Fig. 2), and the mean trophic levels of



Jennings et al. (2015)



Fogarty et al. (2016)

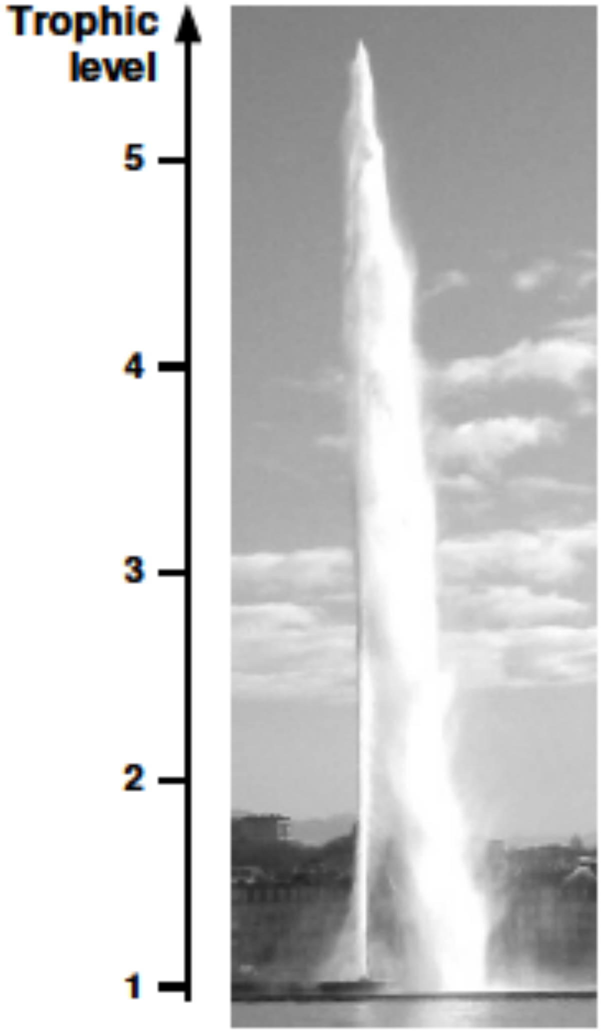
2. Methods

EcoTroph (ET)

Trophic flows ecosystem model

-> based on fluid dynamic equations

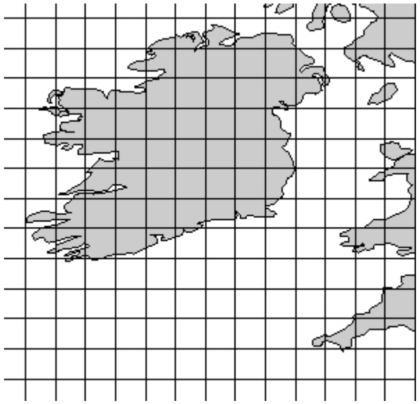
$$B_\tau = \frac{\Phi_\tau}{K_\tau} \times \Delta\tau$$

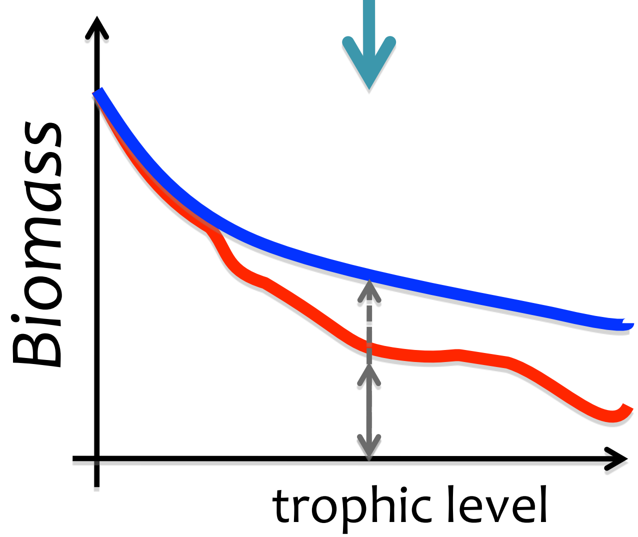


Biomass mapping with ET

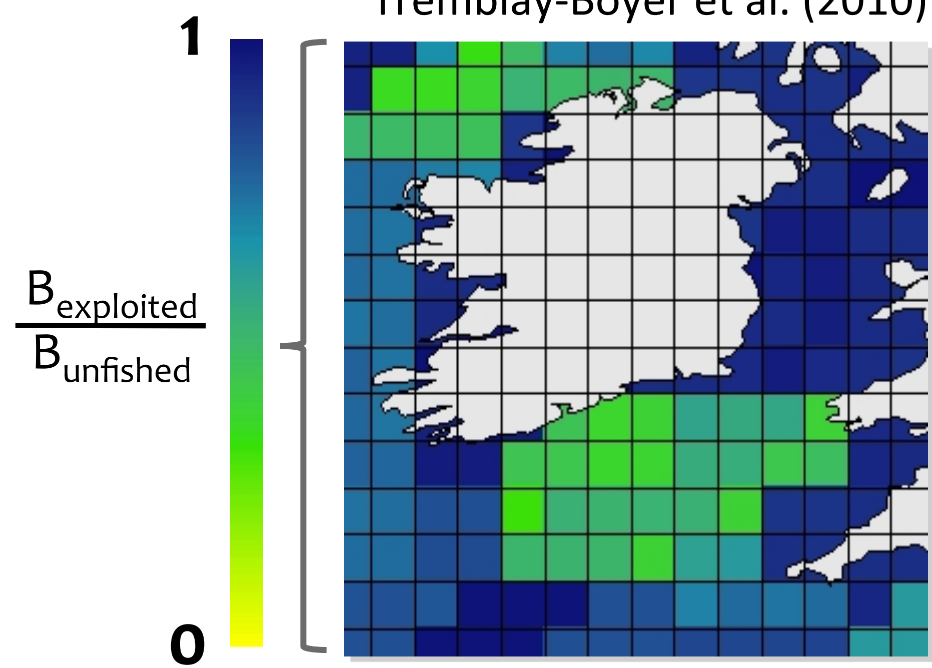
<u>For each cell:</u>
Ecotroph model
+ transfer efficiency
+ primary production
+ sea surface temperature
+ fisheries catch by trophic levels

Divide the world in
0.5 x 0.5 degree grid
(that's about <u>180,000 cells</u>)





Tremblay-Boyer et al. (2010)



ET equations

- For τ in [2,5], with TL intervals $\Delta\tau=0.1$:

  - Calculation of unexploited biomass:

1. $P_{\tau+\Delta\tau,unexpl} = P_{\tau,unexpl} * \exp(-\mu_\tau \Delta\tau)$, with P_1=PP and $\mu_\tau=-\log(TE/100)$
2. $K_{\tau,unexpl} = 20.19 * \tau^{-3.26} * \exp(0.041*SST)$, from Gascuel et al. (2008)
3. $B_{\tau,unexpl} = P_{\tau,unexpl} / K_{\tau,unexpl}$

  - Calculation of fished biomass:

4. $P_{\tau+\Delta\tau} = P_\tau * \exp(-\mu_\tau \Delta\tau) – Y\tau * \exp(-\mu_\tau \Delta\tau/2)$
5. $\varphi_\tau = (1/\Delta\tau) * \log(P_\tau / P_{\tau+\Delta\tau}) – \mu_\tau$
6. $K_\tau = K_{\tau,unexpl} / (1 - \varphi_\tau)$
7. $B_\tau = P_\tau / K_\tau$
8. Repeat steps 4-7 for all years between 1950 and 2100

Sensitivity analyses

Parameter	Values
Kinetic (K)	Gascuel et al. (2007) / Meta-analysis from EcoBase
Primary production (PP)	SeaWIFS for 1998 / GFDL RCP2.6 / GFDL RCP8.5
Sea surface temp (SST)	NOAA World Atlas for 2001 / GFDL RCP2.6 / GFDL RCP8.5
Catch data	FAO data / Sea Around Us catch data (v40)
Resolution	0.5*0.5° grid / 1*1° grid / LMEs-FAO areas
Transfer efficiency (TE)	5% (Kolding et al. 2015) / 10% / Meta-analysis from EcoBase

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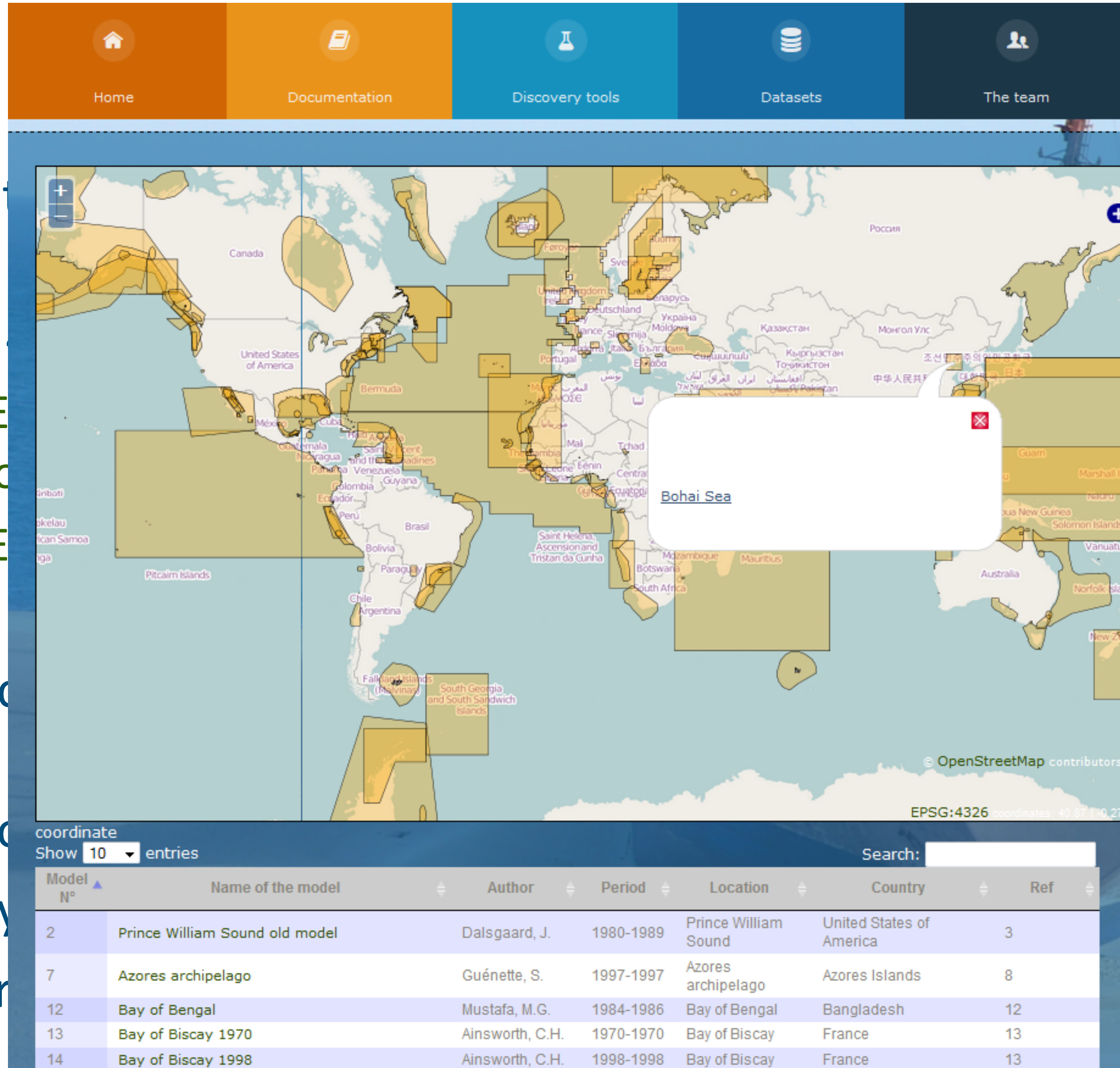
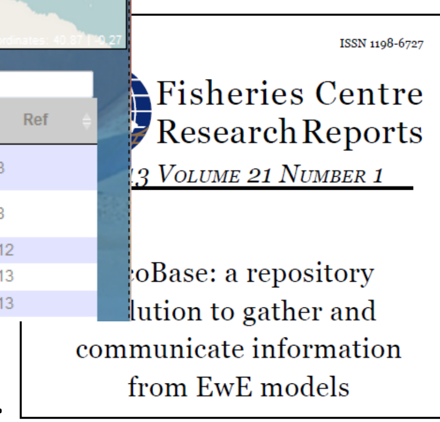
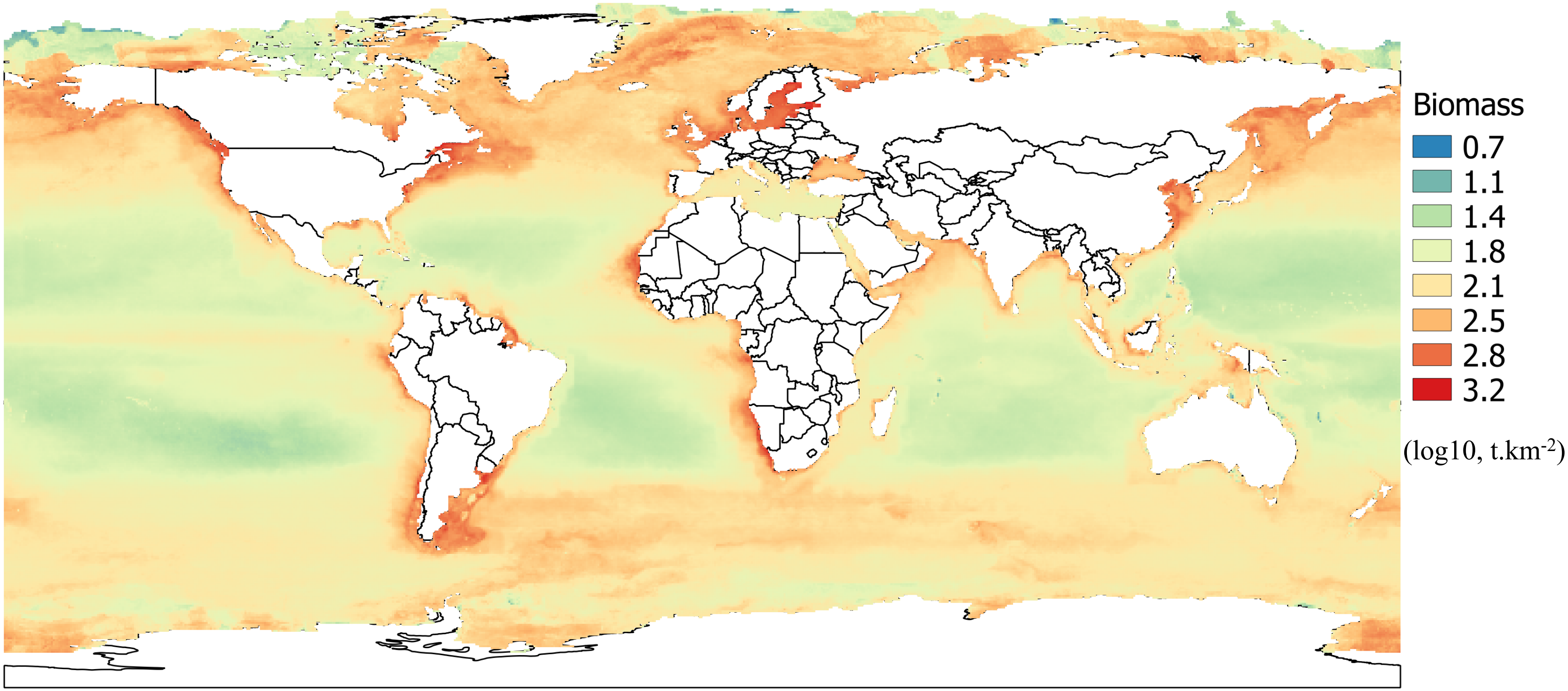




Colléter et al. (2013) Fisheries Centre Research Report 21(1), 60p.

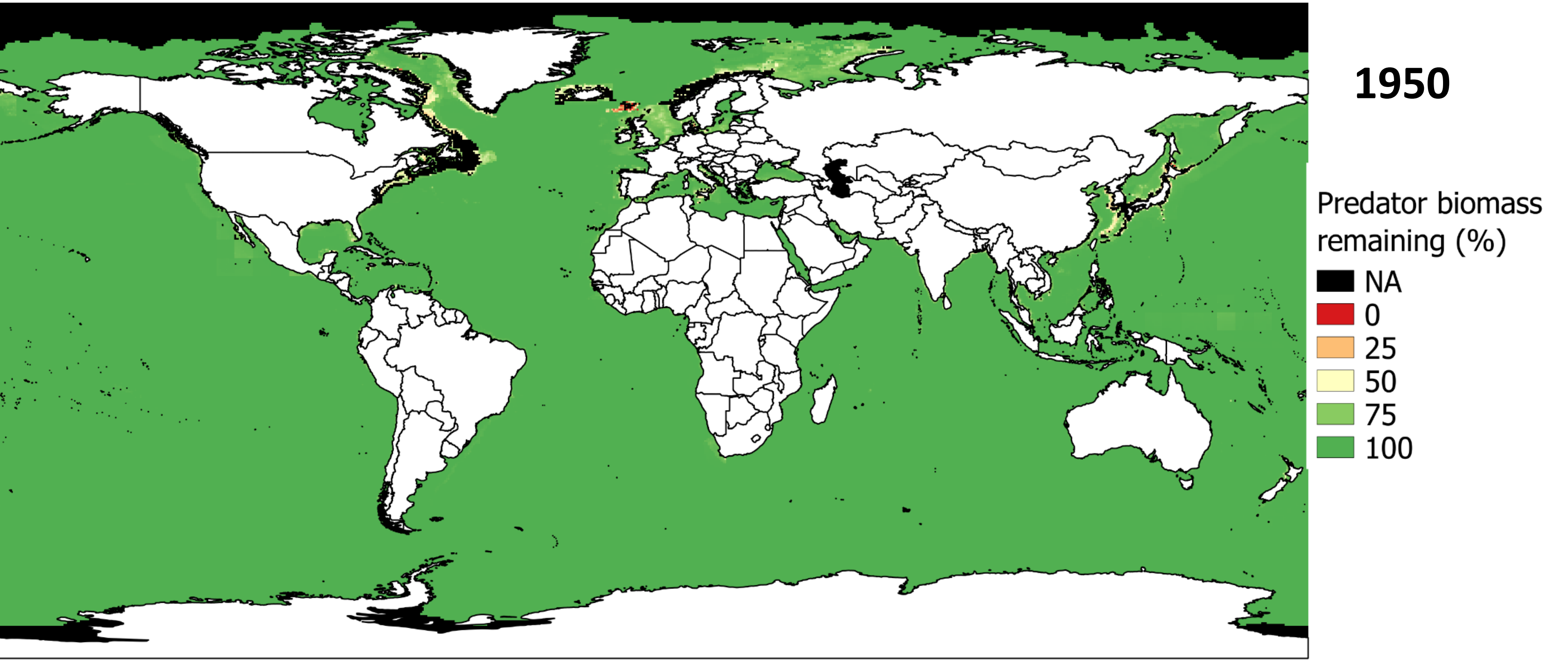
3. Preliminary results

Unexploited biomass



- Highest biomass in mid to high latitudes
- Total biomass estimations:
  - 2 ≤ TL ≤ 5: 40*10^9 tonnes
  - 3.5 ≤ TL ≤ 5: 2.1*10^9 tonnes

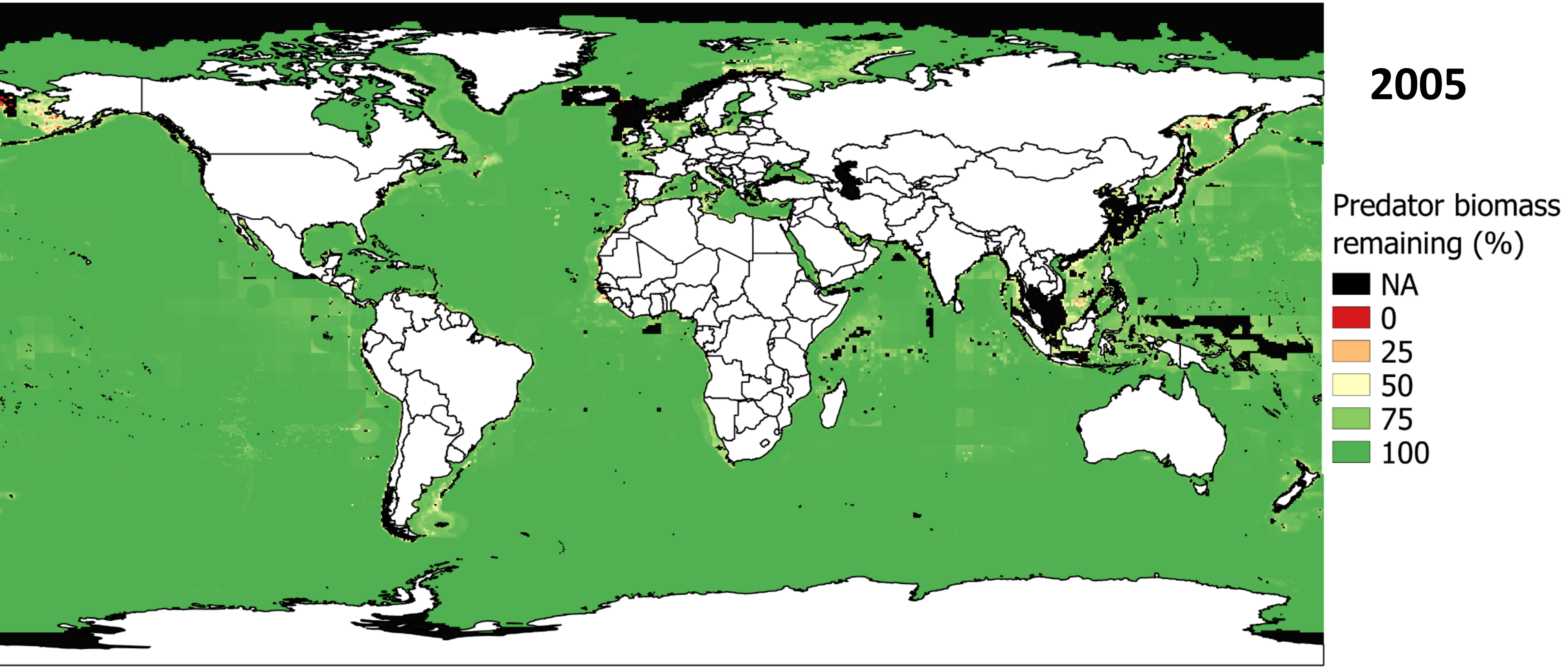
Exploited biomass



- Impacts concentrated on the North Atlantic

- Problems with NA values: not enough production to sustain catches

Exploited biomass



- Impacts extended to all latitudes and regions
- Problems extended to South East Asia and China Sea

- Uncertainty in TE a
  biomass estimates

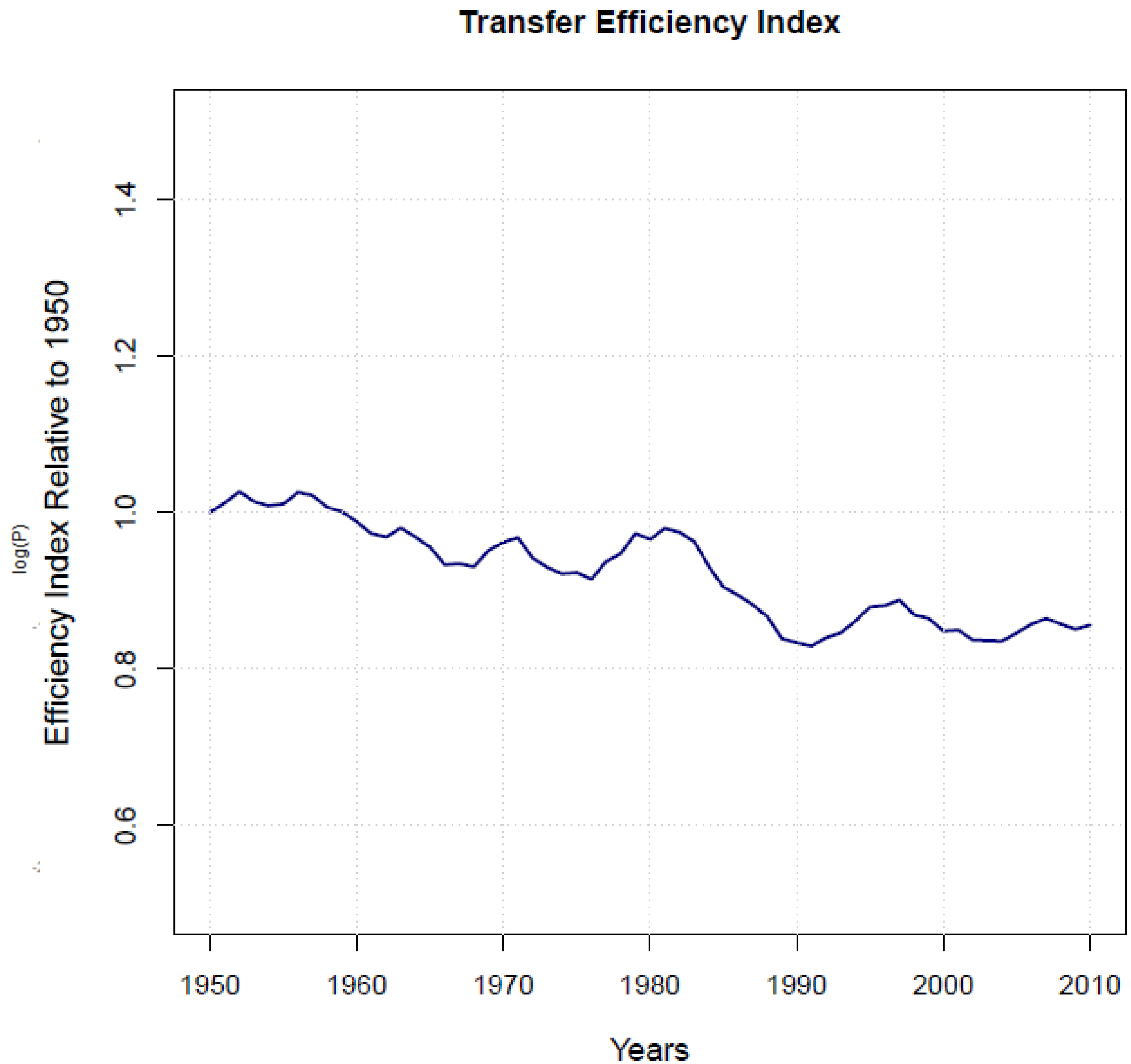
- Current research fo

  - As a function of t

  - Spatially

  - Temporally

  - And following th



Maureaud (unpublished)

4. Discussion/Conclusions

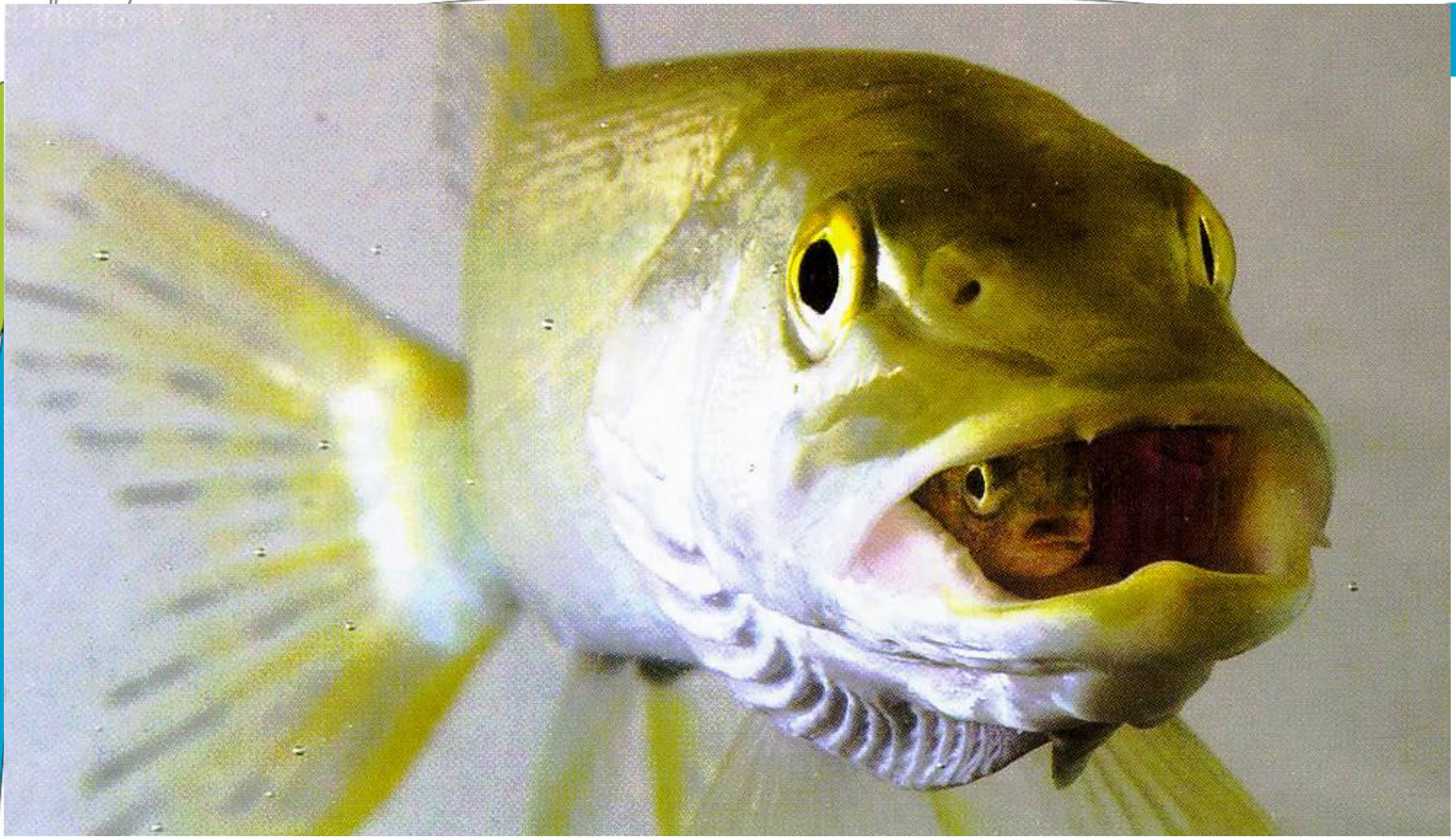
Discussion/Conclusions

- **Modelling climate change impacts:**
  - **Change in primary production values**
  - **Change in sea surface temperature (kinetic)**
  - **Change in the transfer efficiency**
    - ***Phytoplankton size composition***
    - ***Species assemblage***
    - ***Impacts of the changes in temperature***

Discussion/Conclusions

- Ecosystem model with few parameters based on established ecological principles -> comparison at a global scale
- Insights into the effects of parameter uncertainty on global biomass
- Help to highlight priorities for future research and data collection
  - Need to put more effort on the study of the Transfer Efficiency
- However, simple model structure and global processes lead to:
  - Several groups and processes of ecological and conservation interests not accounted for
  - Model less useful when dealing with biodiversity, resilience, social aspects, and impacts at smaller scales

Thanks for your attention!



Any questions?

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