A GLOBAL MAP OF THE RELATIVE IMPACT OF FISHING ON THE BIOMASS OF MARINE ECOSYSTEMS FROM 1950 TO 2004[1]

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Marine ecosystems are affected by fisheries globally and it is essential to understand their historical and current impact at this scale. We present here an index to quantify the impact of fishing on the top predators and total biomass of the ecosystems of the world's oceans since the 1950s. The index is based on an ecosystem model called EcoTroph, whose representation of energy fluxes in ecosystems is equivalent to that of Ecopath models but is focused on trophic levels instead of species/species group (Gascuel *et al.*, 2009). The EcoTroph model is available as a plug-in to the Ecopath with Ecosim software version 6.

The world's oceans were divided into a grid of half degree squares. For each cell, the model uses as input parameters primary production, annual catches (available from 1950 to 2004 from the *Sea Around Us* Project's global catch database), a theoretical value for the ecosystem transfer efficiency and a relationship between the speed of biomass flow through trophic levels (TL) and temperature (Gascuel *et al.*, 2008). An algorithm based on EcoTroph and virtual population analysis, called 'Catch Trophic Spectrum Analysis' (CTSA), is used to estimate biomass by trophic levels under both the historical patterns of catches and under a hypothetical unfished state of the ecosystem ('pristine'). The index of relative impact of fishing on the ecosystem is calculated for each decade from the 1950s as the ratio of exploited to pristine biomass.

Our analysis confirms the higher impact of fisheries on predators (TL>3.5), with the decline in predator biomass occurring faster than that of total biomass (TL 2-5) (Figure 1-1). It highlights the temporal spread of fisheries from the coasts to the High Seas (Figure 1-2) and from northern to southern waters (Figure 1-3). These trends are captured in the current worldwide distribution of predator biomass (Figure 2), with a strong spatial heterogeneity and a pronounced depletion along the coasts, especially in northern countries.

Even though we use a simple approach to the modelling of ecosystems, based on trophic levels instead of species, EcoTroph and CTSA allow capturing the main impacts of fishing on ecosystems, as well as account for ecological and environmental factors such as primary production, temperature and top-down effects. We note that results show little sensitivity to the parameters of transfer efficiency, but that accounting for top-down effects can alter the effects of fishing in heavily exploited ecosystems. The global maps presented here give a first synthetic vision of the global impact of fisheries and confirm trends in ecosystem biomass that were previously inferred through proxies (Morato *et al.*, 2006; Pauly & Watson, 2005) but never directly demonstrated.

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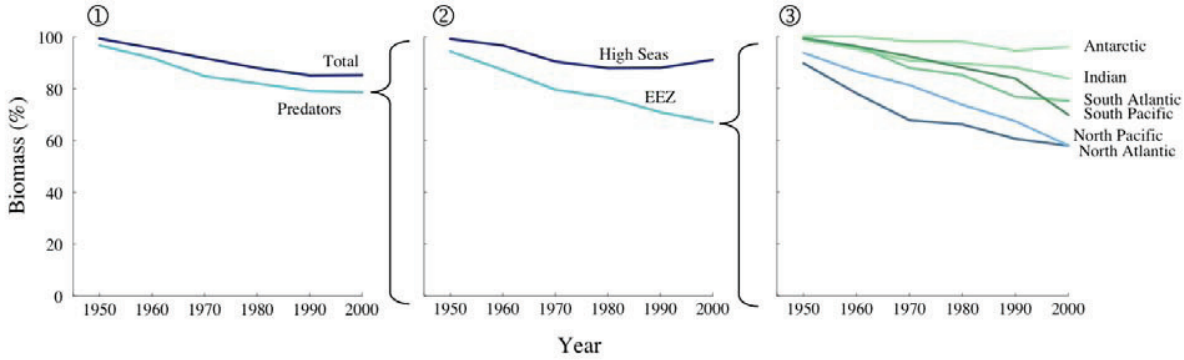

Figure 1. Global trends in biomass remaining compared to pre-1950 levels for (1) total (TL 2-5) vs. predators (TL > 3.5); (2) predators in High Seas and Economic Exclusive Zones (EEZs); (3) predators in EEZ by oceans, from South to North.

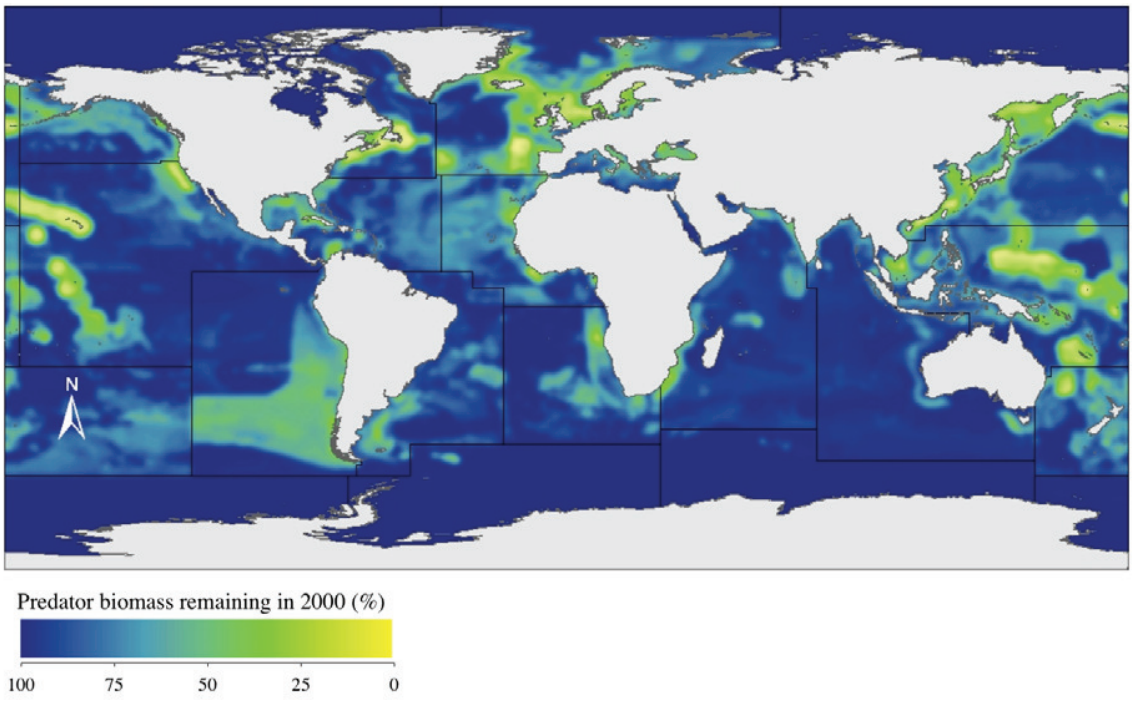

Figure 2. Predator biomass remaining compared to pre-1950 levels.

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