If You Didn't like Overfishing, You Sure Won't Like Global Warming

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ABSTRACT

This contribution briefly recalls the declining status of global fisheries and marine ecosystems, with emphasis on the Central West Atlantic and the Caribbean. It then present a methodology for studying the potential effect of global warming on marine biodiversity and fisheries, whose results lead to the conclusion that fisheries catch potentials will shift toward higher latitudes, and lead to severe impacts in tropical waters, including the wider Caribbean. These finding highlight the need to rebuild fish population, particularly through marine protected areas, as high biomasses are needed both as basis for sustainable fisheries and to mitigate the effect of climate change.

KEY WORDS: Overfishing, global warming, Caribbean

Si a Usted no le Gustó la Sobrepesca, Seguro que no le Gustará el Calentamiento global

Esta contribución recuerda brevemente el estado en descenso de las pesquerías a nivel mundial y de los ecosistemas marinos, con énfasis en el Atlántico del Oeste Central y el Caribe. Entonces presenta una metodología para estudiar el efecto potencial del calentamiento global en la biodiversidad marina y en las pesquerías, estos resultados conducen a la conclusión que las capturas potenciales de las pesquerías se cambiaran hacia latitudes más altas, y esto conduce a unos impactos severos en aguas tropicales, incluyendo todo el Caribe. Éstos resultados resaltan la necesidad de reconstruir las poblaciones de peces, particularmente atreves de con áreas marinas protegidas, como altas biomasas se necesitan tanto como una base para pesquerías sostenibles y para atenuar el efecto del cambio climático.

PALABRAS CLAVES: Calentamiento global, sobrepesca, AMP

Si Vous n'avez pas Aimé la Surpêche, Vous allez Détester le Réchauffement Planétaire

Cette contribution rappelle brièvement le déclin de la pêche mondiale et de les écosystèmes marins, en mettant l'accent sur l'Atlantique Centre-Ouest et dans les Caraïbes. Il présente ensuite une méthodologie pour l'étude de l'effet potentiel du réchauffement climatique sur la biodiversité marine et la pêche, dont les résultats conduisent à la conclusion que la pêche de capture potentiels se déplacera vers des latitudes plus élevées, et conduire à de graves conséquences dans les eaux tropicales, compris la région des Caraïbes. Ces conclusions soulignent la nécessité de reconstruire les populations de poissons, notamment à travers les aires marines protégées, comme des biomasses élevées sont nécessaires à la fois comme base pour une pêche durable et d'atténuer les effets du changement climatique.

MOTS-CLÉS: Réchauffement climatique , surpêche, AMP

INTRODUCTION

The three decades following World War II were, globally, a period of rapidly increasing fishing effort and landings, but also of spectacular fisheries collapses, notably by small pelagic fish stocks. This is also the period where a toxic triad of catch underreporting, ignoring scientific advice, and blaming the environment emerged as standard response to ongoing fisheries collapses, which (thus) became increasingly more frequent, finally engulfing major North Atlantic fisheries.

In the Caribbean, this period was characterized by an emphasis on 'development', as newly independent states sought to turn their fisheries, initially stunted by colonialism, into engine of growth. This emphasis resulted at first in ill-documented catch increases (Pauly 1998, Mohammed 2003), which went along, however, with an enormous impact on habitats (see, e.g., Gardner *et al*. 2003) and ecosystems, including the occurrence of the phenomenon known as 'fishing down marine food webs (Pauly *et al*. 1998).

Indeed, fishing down affect the entire Central West Atlantic, although this was at first masked by spatial over-aggregation (see Figure 1, and Pauly and Palomares 2005). A pronounced fishing down effect is also visible for the Caribbean Sea Large Marine Ecosystem (Heileman and Mahon 2008; see also www.seaaroundus.org).

THE EXPANSIONS OF FISHERIES

The response to the depletion of traditional fishing grounds was an expansion of North Atlantic (and generally of Northern Hemisphere) fisheries along three dimensions: southward, into deeper waters and into new taxa, i.e., catching and marketing species of fish and invertebrates previously spurned, and usually lower in the food web. This expansion provided many opportunities for mischief, as illustrated by the European Union's negotiated 'agreements' for access to the fish resources of Northwest Africa (Kaczynski and Fluharty 2001), China's agreement-fee exploitation of the same, and Japan blaming the resulting resource declines on the whales (see Gerber et al. 2009). Also, this expansion provided new opportunities for mislabeling seafood unfamiliar to North Americans and Europeans, and misleading consumers, thus reducing the impact of seafood guides and similar effort toward sustainability.

In the Caribbean, this implies an increase of exports (notably penaeid shrimps, lobster and conchs, and high quality fish, such as snappers), along with an inability, particularly for small island states, of partaking in the fisheries for large pelagics in adjacent waters, which are overwhelmingly exploited by distant-water fleet.

With fisheries catches declining, aquaculture - despite all public relation efforts - not being able to pick up the slack, and rapidly increasing fuel prices, structural changes are to be expected in both the fishing industry and the scientific disciplines that study it, and influence its governance. Notably, fisheries biology, now predominantly concerned with the welfare of an ever-expanding fishing industry, will have to be converted into fisheries conservation science, whose goal will be to resolve the problems that has created, and thus help maintain the marine biodiversity and ecosystems that provide existential services to fisheries (Pauly *et al*. 2002). Similarly, fisheries economists will have to get past their obsession with privatizing fisheries resources, as their stated goal of providing the proper incentives to fishers can be achieved without giving away what are, after all, public resources.

Overall, the crisis that fisheries now go through can be seen as an opportunity to renew both their structure – away from fuel-intensive large-scale fisheries – and their governance, and to renew the disciplines which study fisheries, creating a fisheries conservation science in the process. Its greatest achievement will be the creation of an urgently-needed global network of Marine Protected Areas (Wood *et al*. 2008). Here, the Caribbean will have a positive role to play, as it is, with the Philippines, the region of the world where MPAs are most widely accepted (see below).

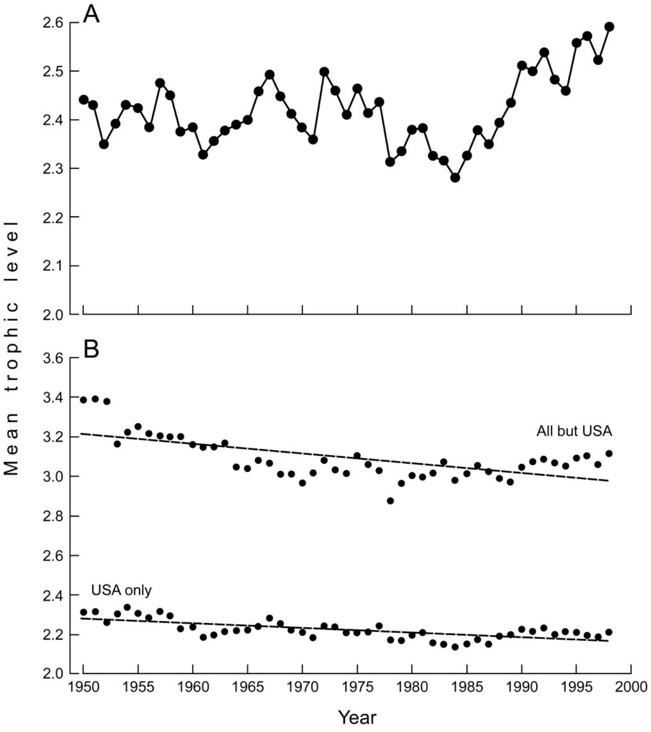

Figure 1. Illustrating 'fishing down marine food webs' in an area (the Western Central Atlantic, FAO Area 31) which at first sight did not show such effect. (A): Trendless time series of mean trophic levels, based on FAO landing data from the whole of FAO area 31. (B): The same data, after separation into two subsets, i.e., the Northern Gulf of Mexico (USA) and the area ranging from Mexico to Venezuela. This reveals two trends lines previously masked by aliasing (see text).

GLOBAL WARMING[1]

There are various ways that scientists of various disciplines can contribute to the debate on global warming. The first, obviously, was to establish the reality of the greenhouse effect, and this was achieved well over one hundred years ago, through the work of Svante Arrhenius (1896). However, it is only in the last three decades that the work of Charles Keeling, James Hansen and others, systematized in successive IPCC assessments, established empirically that human not only could change the climate, but were indeed engaged in doing so, with potentially catastrophic outcomes.

The mechanisms at work are mainly physical and chemical, and notwithstanding numerous exceptions (see e.g., Wilson *et al.* 2009) and feedback loops, this mainly means that systems biologists study are at the receiving end of climate change. In other words, we must study how ecosystems and the species therein are going to respond to physical forcing. Terrestrial ecologists have taken a lead

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[1] This section is adapted from Pauly and Cheung (2009).

on this, not least because they could build on spatial information on natural (forests, savannas, etc.) and agricultural systems, for which numerous global databases exist.

This is different for marine biologists and fisheries scientists, two disciplines whose practitioners are accustomed to working at a local level, on one, or a few species at a time, and to test narrow hypotheses (Peter 1991). Thus, their main response to the global warming challenge so far have been local studies, highlighting e.g., the poleward movement of selected species (see e.g., Perry *et al*. 2005), from which global inferences are then drawn. This approach is fraught with problems, especially considering the representativeness of the species and locales studied.

The *Sea Around Us* project has a global mandate, however, and this is the reason why we have mapped the growth and decline of global catches since 1950 (Pauly 2007, Watson *et al*. 2004), and the data and insights gathered in the course of this work enable us to tackle global climate change issues. The following account briefly discuss steps that we used to produce a number of papers on the impact of global warming on marine biodiversity and fisheries on the world's marine ecosystems, and to lay a strong foundation for future contributions. We proceeded in four steps.

Step 1 was the elaboration of a model for shifting the species distributions (generally poleward, and into deeper water) as temperature increased, building on the over thousand range maps we constructed, in the course of the *Sea Around Us* project, for mapping fisheries catches. (We have a map for all 'commercial species', these being defined as fish or invertebrate species for which at least one member country submits catch data to the FAO; Figure 2). From each of these maps, a temperature preference profile was derived (Figure 2, inserts), defined by the water preferentially inhabited by that species. (Note that we avoided circularity, because we never used temperature to define species range maps; see Close *et al.* 2006). Then, for each (half degree lat./long.) cell of a species distribution range map, a population dynamics model was set up, featuring the (bi)annual broadcasting eggs and larvae whose differential survival is determined largely by the water temperatures they encounter. Given increasing temperatures, this generates amoeboid poleward movement of the species in question, lasting as long as the initial temperature preference profile as not re-established (see contributions in Cheung *et al.* 2008). The projected temperature data we used for this originates from outputs of the Ocean-Atmosphere coupled general circulation model (GCM) CM 2.1 of NOAA's Geophysical Fluid Dynamics Laboratory and provided by our partners at Princeton University, led by Jorge Sarmiento. These output accounts not only for temperature changes, but also for changes in currents. We examined the effects of changes in ocean conditions under three greenhouse gas emission scenarios: 720 ppm, 550 ppm, 370 ppm CO_2 concentration by 2100, but we limited our projections to 2050.

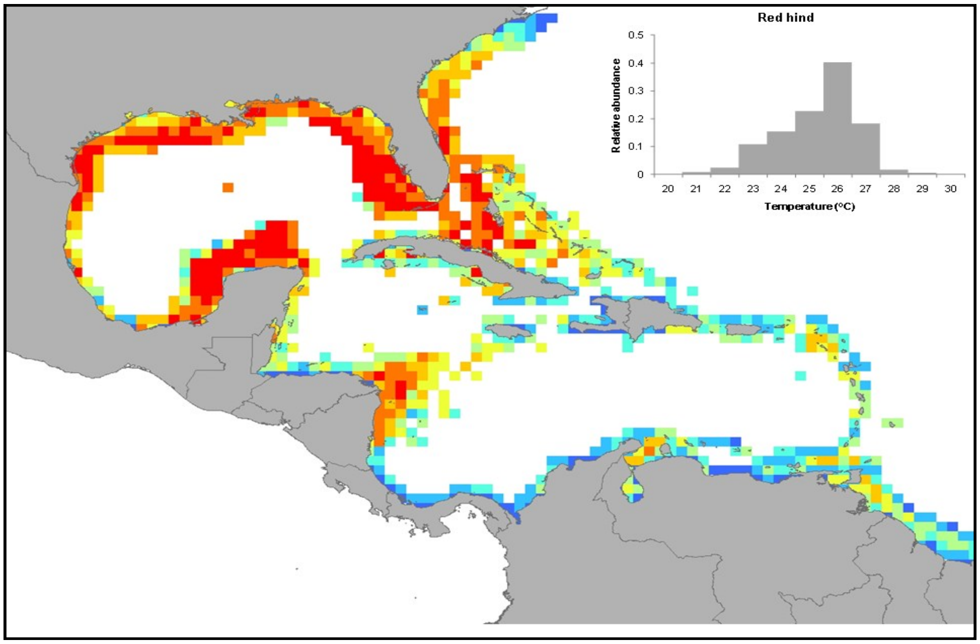

Figure 2. Example of distribution range maps: the Red hind *Epinephelus guttatus* and, as insert, the corresponding temperature preference profiles. Similar maps, pertaining to well over 1200 species and higher taxa may be found at www.seaaroundus.org.

Step 2 consisted of establishing a strong predictive relationship between the area of distribution of a species and its productivity, as required to reflect the changed distribution generated in Step one. Such a strong relationship is documented in Cheung *et al.* (2008) and has the form:

$$\log C_p = -2.881 + 0.826\cdot\log PP - 0.505\cdot\log A - 0.152\cdot\log\lambda + 1.887\cdot\log CT + 0.111\cdot\log HCT + \varepsilon$$

Where:

C_p is the potential catch (in t/year, estimated as the mean of several years with the highest catch);

PP is the annual primary production in the area of distribution (g·C);

A is the area of distribution (km^2); λ is the trophic level;

CT is number of years used from the computation of C_p;

HCT is the catch reported in the corresponding genus or family (to account for reporting in taxa other than species) and ε is the error term of the model, which explains 70% of the variability in a data set comprising 1066 species, covering animals as diverse as Antarctic krill *Euphausia superba* and yellowfin tuna *Euthunnus albacares*.

Step 3 consisted of applying the shift model in Step 1 to over one thousand species as defined above (over 700 species finfish and over 300 species of invertebrates). This led to global maps showing areas dominated by species extirpations (near both poles, and in the inter-tropical belt) and areas dominated by invasions (Arctic and Southern Ocean) and areas with high turnover (extirpation + invasions). They represent the first global maps of threats to marine biodiversity (see Cheung *et al.* 2009a). Moreover, because they were based on a large sample size and on species with a large biomass, we believe that pattern they identify representative and thus can guide future work about the impact of global warming on marine biodiversity.

Step 4, by combining the catch potential in Step 2 with the species shifts in Step 3 generated maps of change in catch potential for the entire world oceans (Figure 3). When these where overlaid with the outlines of countries' Exclusive Economic Zones, the main result was that a few high latitude countries (e.g., Norway, Iceland) might benefit from the large scale redistribution of fish species, i.e., see increases of their catch potential of up to 40%, while low latitude, tropical countries would suffer declines of 10-30 % in their catch potential (Cheung *at al.* 2009b), other things remaining equal. For the Caribbean Large Marine Ecosystem (Heileman and Mahon 2008, and www.seaaroundus.org), these changes are predicted to be in the order of 10 - 20 %. However, this again assumes that other things remain equal, and we know they won't (see below).

This work also allowed identification of limitations in our coverage of the world's biodiversity, as there are numerous countries which, in their reports to FAO, omit the catch of artisanal fisheries (i.e., coastal species), important as they might be (see contribution in Zeller and Pauly 2007). In the future, we will remedy this by insuring that every EEZ in the world is represented by at least five or six coastal species. However, the major limitation of our study probably is non-consideration of several important abiotic factors which we assess will be critical to future research. Thus, one important factor so far neglected is dissolved oxygen, which generally will be reduced in future oceans because stronger temperature gradients with regards to depth will reduce mixing. We will account for this potentially strong effect on fish productivity by explicitly taking account of the impact of oxygen on fish growth (Pauly 1981 In press).

A second important neglected factor is acidification. Lower pH is generally perceived as affecting only organisms with calcium carbonate shells, but in reality, it is likely to affect all water-breathing organisms, by reducing the gradient which allows them to get rid of high carbon dioxide into the water as they exhale. Empirical evidence exists that this reduces impact on the performance of water-breathers, and hence the productivity of fish (e.g., Munday *et al.* 2009).

A paper accounting for these and other factors is in progress and we expect that it will generate estimates of potential catch devoid of 'winners': the world fisheries will lose out, and the effect will be strongest in the tropics, including the Caribbean.

CONCLUSIONS

It is not nice to be the bearer of bad news, and the news concerning global warming effect on Caribbean fisheries are not good. In fact, global warming effect will increase the negative trends noted above for coral reefs.

One the other hand, the wider Caribbean is one of the few areas of the world where, thank to various initiatives (not least the persistence of the GCFI), the creation of new MPAs is widely seen as positive for biodiversity and fisheries. As it turns out, MPAs are also likely to be one of our best tools for mitigating the effects of global warming on marine biodiversity and fisheries, as large biomasses, such as those enabled by MPAs, allow for a wide genetic diversity, including individuals more tolerant of the new conditions created by climate change. MPAs alone will not help (foremost we have to curb both fishing effort and greenhouse gas emission), but they are a step in the right direction.

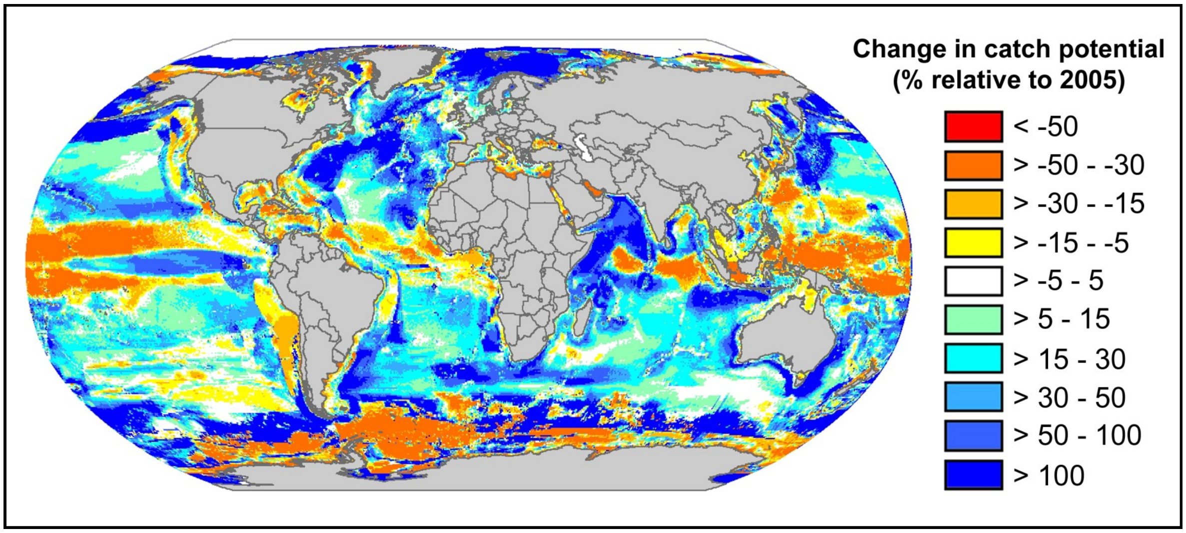

Figure 3. Predicted change in the potential of fisheries, given the distribution range shifts induced by global warming and a relationship linking distribution and potential catches. Insert show some countries predicted to gain, and to lose from such changes (from Cheung et al. 2009b). Note that these predictions do not account for change in oxygen distribution in, and acidification of the oceans, and hence represent an optimistic scenario (see text).

The Venezuelan ban on trawling, which abolished a fisheries whose epitaph was presented by Jeremy Mendoza at this meeting (Mendoza 2010), is another step in the right direction, particularly if policies are formulated and implemented for managing the small-scale fisheries that will emerge in its place. Here again, the wider Caribbean is ahead of the pack, and one can only hope that it stays there.

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