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Climate change in tropical fresh waters (comment on the paper 'Plankton dynamics under different climatic conditions in space and time' by de Senerpont Domis *et al.*, 2013)

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SUMMARY

1. de Senerpont Domis *et al.* (2013, *Freshwater Biology*, **58**, 463–482) forecasted changes in plankton dynamics in temperate, polar and tropical regions resulting from climate change. For tropical regions, they predicted an increase in precipitation intensity that would increase nutrient loading, increasing phytoplankton biomass and select for plankton adapted to flushing.
2. We do not agree with these predictions, as regional projections from the IPCC did not forecast a major increase in precipitation in tropical regions. The only regions where a slight increase in precipitation was projected were eastern Africa and South-East Asia. In eastern Africa, the major freshwater bodies are large, deep lakes that have very long residence times and are unlikely to be affected by flushing. Moreover, nutrient inputs from their catchment represent a small fraction of their total nutrient loading.
3. Several independent studies carried out in this region have provided evidence of a decrease in primary productivity in some of these large tropical lakes due to climate change. The major process providing nutrients to the euphotic layer is internal loading, which has been reduced as warming of the surface waters has increased the temperature gradient and the water column stability. Moreover, reduced velocity of trade winds during the dry season has affected the mixed layer depth and decreased internal nutrient fluxes. Therefore, the trend for large tropical lakes in a warming climate is oligotrophication, not eutrophication.
4. In tropical South America, the rainfall increase is not the dominant scenario; thus, the predicted changes in plankton dynamics do not stand.
5. Therefore, we believe that the predictions presented in the paper for tropical systems under a changing climate are invalid for most tropical systems.

Keywords: climate change, phytoplankton, Plankton Ecology Group model, tropical limnology, zooplankton

In their paper, de Senerpont Domis *et al.* (2013) discussed possible changes in plankton dynamics in temperate, polar and tropical regions resulting from climate change. According to the authors, this paper is an extension of the model designed by the Plankton Ecology Group (Sommer *et al.*, 1986), initially developed in temperate regions, to other latitudes, polar and tropical.

Most of the argumentation regarding the effect of climate change is based on changes in temperature and precipitation. Changes in temperature are not questionable, as the IPCC projections point towards a general temperature increase in all latitudes. However, the forecast for precipitation in tropical regions is not as straightforward as it may appear from this paper due to the fact that local or regional features might be stronger constraints than global climate to biological activity. Regional projections from the IPCC (Meehl *et al.*, 2007) for tropical regions (between 23ºN and 23ºS) did not

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forecast major changes in precipitation, as it might seem in fig. 2 in the paper by de Senerpont Domis *et al.*

The expected changes in precipitation in tropical regions are practically insignificant compared with higher latitudes and restricted to some specific areas. In the tropics, the only regions where precipitation is projected to increase are eastern Africa, South-East Asia (Table 1) and possibly the extreme north-west of South America, in the coast of Peru and Ecuador (Marengo *et al*., 2010). Regional climate models for South America predict that rather than higher precipitation, most areas will experience higher frequency of extreme rainfall (storm) events but also longer periods of drought (Marengo *et al*., 2010). These changes would decrease even more the predictability of seasonal rainfall and associated processes, when relevant (e.g. floodplain cosystems), and thus, the ecological consequences should be studied in shorter-scale approaches (Roland *et al*., 2012).

Table 1 Regional averages of precipitation projections from a set of 21 global models in the MMD for the A1B scenario, adapted from the 2007 IPCC Report (Meehl *et al*., 2007)

		Precipitation Response (%)				
	Months	Min	25	50	75	Max
West Africa	DJF	−16	−2	6	13	23
12S,20W to 22N,18E	MAM	−11	−7	−3	5	11
	JJA	−18	−2	2	7	16
	SON	−12	0	1	10	15
	Annual	−9	−2	2	7	13
East Africa	DJF	−3	6	13	16	33
12S,22E to 18N,52E	MAM	−9	2	6	9	20
	JJA	−18	−2	4	7	16
	SON	−10	3	7	13	38
	Annual	−3	2	7*	11	25
South-East Asia	DJF	−4	3	6	10	12
11S,95E to 20N,115E	MAM	−4	2	7	9	17
	JJA	−3	3	7	9	17
	SON	−2	2	6	10	21
	Annual	−2	3	7*	8	15
Central America	DJF	−57	−18	−14	−9	0
10N,116W to 30N,83W	MAM	−46	−25	−16	−10	15
	JJA	−44	−25	−9	−4	12
	SON	−45	−10	−4	7	24
	Annual	−48	−16	−9*	−5	9
Amazon	DJF	−13	0	4	11	17
20S,82W to 12N,34W	MAM	−13	−1	1	4	14
	JJA	−38	−10	−3	2	13
	SON	−35	−12	−2	8	21
	Annual	−21	−3	0	6	14

The mean precipitation responses are first averaged for each model over all available realisations of the 1980–1999 period from the 20th Century Climate in Coupled Models (20C3M) simulations and the 2080–2099 period of A1B. Computing the difference between these two periods, the table shows the minimum, maximum, median (50%) and 25 and 75% quartile values among the 21 models, for precipitation (%) change. A value of 5% indicates no change, as this is the nominal value for the control period by construction (significant median annual values are marked with an asterisk).

The generalised seasonal development of current and future phytoplankton and zooplankton biomass presented in fig. 3 in the paper by de Senerpont Domis *et al.* does not reflect a general pattern for tropical lakes, but may only be valid for lowland, shallow, floodplain lakes usually observed in large tropical river basins. None of the 21 models of the IPCC predict an increase in precipitation in the Amazon and very little in the Congo basin, where these lowland floodplain lakes are most common. Thus, the prediction of phytoplankton dynamics changes as a result of higher rainfall may be incorrect.

In eastern Africa, which is the only region where precipitation would actually increase according to the IPCC (Table 1), most lakes are large and deep. Given their size, long retention time and small catchments, these large lakes will not be affected by flushing, as suggested by de Senerpont Domis *et al.* (2013). On the contrary, it has been well accepted for decades that internal loading is the major process affecting nutrient availability in large tropical lakes (Kilham & Kilham, 1990). The major effect of global and regional warming on these lakes has been an increase in temperature-driven density gradients due to warmer surface temperature with a subsequent increase in water column stability. At the same time, reduced wind speed has decreased vertical mixing and nutrient fluxes from internal loading (affecting mainly P inputs), resulting in reduced primary production. This has been evidenced in several studies on Lake Tanganyika, East Africa, based on recent data (Verburg, Hecky & Kling, 2003, 2006; Stenuite *et al*., 2007) as well as palaeolimnological records (e.g. O'Reilly *et al*., 2003; O'Reilly, Dettman & Cohen, 2005; Cohen *et al*., 2006; Tierney *et al*., 2010). Thus, despite the slight increase in precipitation that might occur, the effect of climate change alone on eastern African great lakes is oligotrophication, rather than an increase in planktonic productivity. However, this reasoning holds for large, deep lakes with a permanent hypolimnion, whereas shallower lakes may respond to climate change in a different way. It is also obvious that other anthropogenic impacts may override the effects of climate change and totally invalidate predictions based solely on climate. For instance, eutrophication of Lake Victoria resulted from multiple stresses including population growth, increased land use, exotic species introduction and meteorological variability (Hecky *et al*., 2010).

In South America, there are three distinct climate change scenarios, with respect to precipitation patterns, that could affect ecosystem functioning (Roland *et al.*, 2012): zone 1, western Amazon and sub-tropical region with a slight increase in precipitation; zone 2, east Amazon and north-east (semi-arid region) with lower precipitation; and zone 3, south-east and coastline with similar precipitation amounts but increased frequency of storms. The aquatic ecosystems present in these three areas differ in several ways (e.g. with regard to frequency of connection of river to the ocean, to their humic content, and food-web structure), so that the interactions of the predicted changes with climate would be certainly different. The only zone that might follow the changes predicted by de Senerpont Domis *et al.* is zone 1 (i.e. western Amazon) which is dominated by rivers and oxbow lakes. Thus, lake type and regional characteristics should be taken into account for more precise predictions of changes in ecosystem function as a consequence of climate change.

Overall, the discussion throughout the paper concerning the tropical regions might be biased. The authors did not take into account the specificity of tropical systems, and some of the studies extensively cited by de Senerpont Domis *et al.* (e.g. studies comparing subtropical versus temperate systems, or long-term warming experiments in mesocosms conducted in northern Europe) are not the most relevant to describe and even less to predict plankton dynamics in tropical regions. We believe that more studies in tropical lakes, both large and small, in different regions, are still necessary to infer the impact of climate change on these ecosystems.

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