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OPINION

Plankton dynamics under different climate conditions in tropical freshwater systems (a reply to the comment by Sarmento, Amado & Descy, 2013)

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SUMMARY

1. In our recent contribution to the special issue on plankton dynamics in a fast-changing world, we outlined some general predictions of plankton dynamics in different climate regions now and in future, building on the Plankton Ecology Group (PEG) model (de Senerpont Domis *et al*., 2013).
2. We proposed a stylised version of plankton dynamics in Fig. 3 of our article and stated that these patterns need to be further elaborated. Our figure displays annual plankton dynamics now and in future in oligotrophic, mesotrophic and eutrophic lakes in arctic, temperate and tropical climate zones.
3. We fully agree with Sarmento, Amado & Descy (2013) that more data on tropical regions are needed, and we are looking forward to the emergence of published data from tropical regions to extend our still-limited understanding of plankton dynamics in these regions.
4. Sarmento *et al*. (2013) did not agree with our predictions on plankton dynamics for hydrology-driven water systems in the tropics. Unfortunately, however, Sarmento *et al*. (2013) did not substantiate their statements with the much-needed data on plankton dynamics in the tropics. Moreover, they merely provide an overview of precipitation patterns in the tropics, not an alternative hypothesis for our predictions.

Keywords: climate change, PEG model, phytoplankton, tropical limnology, zooplankton

In our recent contribution to the special issue on plankton dynamics in a fast-changing world, we postulated that in tropical systems temporal variability in precipitation can be an important driver of the seasonal dynamics of

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plankton communities (de Senerpont Domis *et al.*, 2013). Furthermore, we stated that the projected intensification of precipitation will have stronger consequences for hydrology-driven systems, characteristic of some tropical areas. We put forward that in these hydrology-driven systems, increased incidence of flooding events will lead to increased washout. Furthermore, we stated that the consequences of changes in climate are to a large extent system-specific, and depend on, for example trophic state. This was interpreted by Sarmento *et al.* (2013) as if we assume *'a major increase in precipitation in tropical regions'*. However, this was not claimed in our manuscript. Although Sarmento *et al.* (2013) provided more details on precipitation patterns, their overview (stemming from the same reference that we quoted in our article) agrees with our general statement on precipitation in tropical regions, that is, that the intensity of precipitation will increase. The intensity of precipitation events will grow also in areas that are expected to experience a decrease in mean precipitation and where the interval between subsequent rainfall events will be longer (Meehl *et al.*, 2007). To clarify, if precipitation intensity increases in areas experiencing a decrease in mean precipitation, this will result in higher incidence of extreme weather events, with prolonged drought spells alternating with intense precipitation (Marengo *et al.*, 2009).

Sarmento *et al.* (2013) concluded that because 'rainfall increase is not the dominant scenario in South America the predicted changes in plankton dynamics do not stand' and extrapolated that our predictions are invalid for most tropical systems. By far, the most prominent climate types in the tropics are A_f (tropical rainforest climate), A_m (tropical monsoon climate) and A_w (tropical savannah climate) in which rainfall plays an important role (Peel, Finlayson & McMahon, 2007). It is these patterns of rainfall that govern the plankton dynamics in most tropical inland waters, with the most dramatic effects in temporary waters. A rain-induced increase in water volume (dilution) or washout will lead to a drop in standing biomass, which we displayed in a stylised way in our Fig. 3.

Sarmento *et al.* (2013) suggest that the predicted pattern of hydrology-driven plankton dynamics might be valid only in floodplain lakes near large tropical rivers. Indeed, plankton dynamics similar to those depicted in our Fig. 3 can be found in the vicinity of the Amazon River [e.g. (Huszar & Reynolds, 1997; Ibanez, 1998), in the Araguaia River (Tocantins state, central Brazil; Nabout, Nogueira & Oliveira, 2006) and in the northern Pantanal (Fantin-Cruz *et al.*, 2011)].

However, our generalised pattern is based on more observations than floodplain lakes. In the state of Rio Grande do Norte (north-eastern Brazil), a survey of 44 reservoirs yielded a significant negative correlation between phytoplankton biomass and precipitation (Brasil, 2011). Similarly, in Pampulha Reservoir (Belo Horizonte, Minas Gerais, Brazil), phytoplankton biomass decreased significantly with rainfall (Figueredo & Giani, 2001). A complete washout was observed by Soares *et al.* (2008) in the Funil Reservoir, while in another oligotrophic reservoir (Lajes, both in Rio de Janeiro State, Brazil), phytoplankton biomass was highest in the dry period (Soares *et al.*, 2008).

Also in other tropical regions outside South America, plankton dynamics are postulated to be driven by hydrological (water input and output) or hydrographic features (water column stratification and mixing) (Melack, 1979), both of which are also related to climate (Talling, 1986). In Lake Guiers (north-west part of Senegal), flooding led to the lowest phytoplankton biomass (Ka *et al.*, 2011). In the tropical semi-arid region of Tigray (northern Ethiopia), clear differences in plankton communities exist during dry and wet seasons (Dejenie *et al.*, 2008, 2012). By and large, there are ample data on the effect of dry–wet season and rainfall on plankton dynamics and biomass. The general pattern emerging from these studies is that biomass drops after the rainfall. Without doubt there are exceptions to this generalisation. For example, no seasonality can be found in Lake Barva, Costa Rica (Umana-Villalobos, 2010) and the Monte Alegre Reservoir, south-east Brazil (Huszar *et al.*, 1998), where nutrient inflow stimulates phytoplankton growth at first (Kebede & Belay, 1994; Kim *et al.*, 2000), or where phytoplankton biomass is higher in the wet season than in the dry season, such as in two of the eight Ethiopian rift valley lakes studied by Zinabu (2002). Even in the oligotrophic large East African Lake Tanganyika hydrology-driven seasonality in plankton dynamics can be found, where the dry season south-east winds cause deeper vertical mixing and an upwelling at the southern end of the lake stimulating phytoplankton growth, and therefore, the pattern in dynamics is not completely different from the one depicted in our Fig. 3, although a climate change-induced overall stronger stratification may counteract this effect leading to oligotrophication in the deep East African lakes as described by Sarmento *et al.* (2013).

In conclusion, although we fully agree with Sarmento *et al.* (2013) that more data are needed to fully understand plankton dynamics in the tropics, our stylised representation of plankton dynamics in the tropics being governed by hydrology is backed by numerous (but not all) case studies. As the *intensity* of precipitation is projected to increase (Meehl *et al.*, 2007), resulting in more extreme weather events, increased incidence of flooding events will lead to increased washout. Unfortunately, Sarmento *et al.* (2013) did not substantiate their statements with the much-needed data on plankton dynamics in the tropics. Sarmento *et al.* (2013) merely provided an overview of precipitation patterns in the tropics and not really an alternative hypothesis for our predictions. We encourage scientists working on tropical regions to use their data and conduct follow-up studies to provide more details to this first attempt to visualise plankton dynamics in the tropics now and in future.

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