Freshwater Biology

Freshwater Biology (2014) **59,** 2656–2658 doi:10.1111/fwb.12455

OPINION

Macrophyte effects on algal turbidity in subtropical versus temperate lakes: a comment on Wang *et al.* (2014)

ANDREW M. DOLMAN

Department of Freshwater Conservation, Brandenburg University of Technology Cottbus – Senftenberg, Bad Saarow, Germany

SUMMARY

1. A recent analysis of 30 lakes in the Yangtze basin found no effect of benthic macrophyte coverage on the relationship between chlorophyll *a* concentrations and total phosphorus (TP).
2. While several recent studies have found the effects of macrophyte coverage to be weaker in subtropical versus temperate shallow lakes, in this case, the finding was due to a statistical error meaning that the comparison was effectively made for lakes with very low TP concentrations of just 1 μg L^{-1}.
3. Centring the data so that the comparison is made at a TP concentration where both vegetated and non-vegetated lakes are found confirms a strong effect of macrophytes on the chlorophyll *a* to TP relationship.
4. Thus, macrophyte effects for these subtropical lakes in the Yangtze basin are in fact similar to those found in temperate lakes.

Keywords: benthic vegetation, chlorophyll *a*, macrophytes, phosphorus, subtropical lakes

In a recent analysis of 30 lakes in the mid-lower Yangtze basin, Wang *et al.* (2014) tested whether total phosphorus (TP) thresholds for regime shifts differ between subtropical and temperate shallow lakes, as well as between lakes of different depths. They found that while TP thresholds did vary with lake depth, thresholds for tropical and subtropical lakes of similar depths were almost equal.

Although these overall conclusions appear sound, they also concluded that, for these subtropical lakes, the presence of macrophytes was not associated with lower algal turbidity, measured as chlorophyll *a* concentration (Chl *a*). They noted that this conflicts with previous findings for temperate lakes where, for a given TP concentration, macrophyte coverage has been shown to be associated with lower chlorophyll *a* concentrations (e.g. Jeppesen *et al.*, 1990; Scheffer, 1998), and this led them to speculate as to why the effect of macrophytes in Yangtze lakes, or subtropical lakes in general, may differ from that in temperate lakes.

Prior studies have in fact found the influence of macrophytes on Chl *a* to be weaker in subtropical lakes (Bachmann *et al.*, 2002; Kosten *et al.*, 2009). However, the lack of effect inferred by Wang *et al.* (2014) was due entirely to a small mistake made early in their analysis when they examined the effect of macrophytes on the relationship between $\log_{10}$(Chl *a*) and $\log_{10}$(TP). Here, I show, using their data, that there is in fact a clear difference between the $\log_{10}$(Chl *a*) and $\log_{10}$(TP) relationship in vegetated and non-vegetated lakes.

The data comprise TP concentrations, chlorophyll *a* concentrations and macrophyte coverage for 30 unique lakes, for some of which there are data from multiple years, giving a total of 76 lake-years of data. The data were provided on request, and complete details of the data set are found in Wang *et al.* (2014). The original analysis was performed using STATISTICA (StatSoft's, Tulsa, OK, USA) 8.5; the analyses presented here were performed using R version 3.0.2 (R Core Team, 2013).

Wang *et al.* (2014) fitted a linear regression model between $\log_{10}$(Chl *a*) and $\log_{10}$(TP), with separate intercept and slope parameters for lakes without and with macrophyte coverage. They found no significant difference in intercept ($P > 0.5$) or slope parameters ($P > 0.1$) and from this concluded that there was no difference

Correspondence: Andrew M. Dolman, Department of Freshwater Conservation, Brandenburg University of Technology Cottbus – Senftenberg, Seestrasse 45, 15526 Bad Saarow, Germany. E-mail: andrew.dolman@tu-cottbus.de

between these regression lines (blue and red lines in Fig. 1). However, a likelihood ratio test between a model with the same slope and intercept, and one with slopes and intercepts that differ, gives a P-value < 0.0001, showing a highly significant effect of macrophyte presence on the relationship of $\log_{10}$(Chl *a*) to $\log_{10}$(TP).

The error lies in their testing for a difference in the heights of the lines (intercepts) at the point where $\log_{10}$(TP) = 0 (i.e. TP = 1 μg L^{-1}). This point is far to the left of the range of TP values in these lakes (marked on Fig. 1 with a black circle), and if data were present, they would be for ultra-oligotrophic lakes. It would be more appropriate to test for a difference in the height of the lines at some TP concentration where both vegetated and non-vegetated lakes are found, for example the mid-point of their overlap, where TP = 74 μg L^{-1} (marked with a black vertical arrow on Fig. 1). This can be easily achieved by subtracting $\log_{10}(74)$ from the $\log_{10}$(TP) concentrations and refitting the model using this new, centred, $\log_{10}$(TP) scale. These new intercepts have back-transformed values of 5.8 and 22 μg chlorophyll *a* L^{-1}, for lakes with and without macrophytes, respectively; these are their expected chlorophyll *a* concentrations when TP = 74 μg L^{-1}. This difference is highly significant (P < 0.00001), with a 95% confidence interval corresponding to 53–84% lower chlorophyll *a* concentrations in lakes with macrophytes.

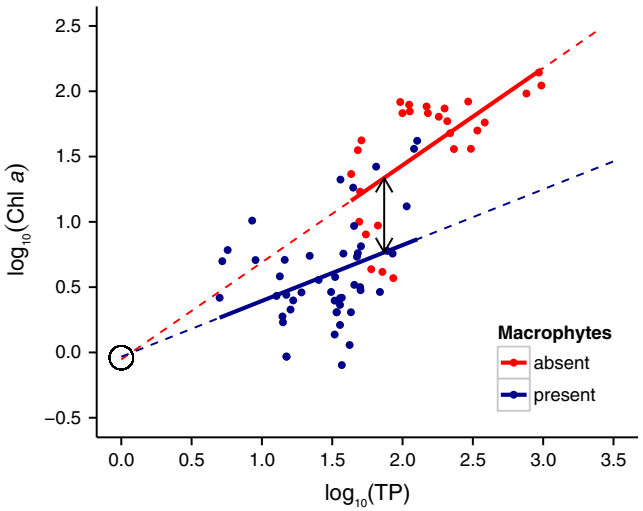

Fig. 1 The relationship between chlorophyll *a* (Chl *a*) and total phosphorus (TP) for lakes from the mid-lower Yangtze basin with (blue) and without (red) macrophyte coverage. Data are from Wang *et al.* (2014). Units are μg L^{-1}. The black circle on the left hand edge of the regression lines shows the position where Wang *et al.* (2014) tested for a difference in the height of the lines (at their intercepts). The vertical black arrow at $\log_{10}$(TP) = 1.9 (TP = 74 μg L^{-1}) is the mid-point of the overlap between the vegetated and non-vegetated lakes, and a more appropriate position to test for a difference between these two regression lines.

It is tempting to draw the conclusion that colonisation by macrophytes causes these lakes to have 53–84% lower chlorophyll *a*. However, causality here likely runs both ways: for example, colonisation by macrophytes may provide refuges for zooplankton thereby reducing chlorophyll *a* via top-down effects, but equally lakes with lower chlorophyll *a* for a given TP concentration (for whatever other reason: depth, flushing rate, temperature, etc.) will also be more favourable for macrophyte colonisation.

Recent studies have found weaker differences between vegetated and non-vegetated lakes in tropical versus temperate regions (Bachmann *et al.*, 2002; Kosten *et al.*, 2009), and this difference is thought to be due to greater top-down control of zooplankton in tropical lakes by a denser and more omnivorous fish community, with multiple reproductive events per year and a behavioural preference for feeding within submerged macrophyte beds (Jeppesen *et al.*, 2007; Meerhoff *et al.*, 2007; Teixeira-de Mello *et al.*, 2009). In these 30 subtropical lakes from the mid-lower Yangtze basin, macrophytes demonstrate an effect on the chlorophyll *a* to TP relationship that is similar in magnitude to that noted for the Netherlands and Denmark, as well as some lakes in subtropical Florida (Canfield *et al.*, 1984; Scheffer, 1998). Perhaps, the features of fish communities that can suppress macrophyte-associated zooplankton, while typical of subtropical fish communities in general, are somehow absent in these Yangtze basin lakes.

Acknowledgments

I would like to thank the original authors for providing their data and for a useful discussion about this reanalysis. I would also like to thank the anonymous reviewer who directed me to recent literature on this topic. Andrew Dolman is a member of the NITROLIMIT project funded by the BMBF with Grant Numbers 033L041A and 0033W015AN.

References

Bachmann R.W., Horsburgh C.A., Hoyer M.V., Mataraza L.K. & Canfield D.E. Jr (2002) Relations between trophic state indicators and plant biomass in Florida lakes. *Hydrobiologia*, **470**, 219–234.

Canfield D.E. Jr, Shireman J.V., Colle D.E., Haller W.T., Watkins C.E. II & Maceina M.J. (1984) Prediction of chlorophyll *a* concentrations in Florida lakes: importance of

aquatic macrophytes. *Canadian Journal of Fisheries and Aquatic Sciences*, **41**, 497–501.

Jeppesen E., Jensen J.P., Kristensen P., Søndergaard M., Mortensen E., Sortkjær O., *et al.* (1990) Fish manipulation as a lake restoration tool in shallow, eutrophic, temperate lakes 2: threshold levels, long-term stability and conclusions. *Hydrobiologia*, **200–201**, 219–227. Kluwer Academic Publishers, Belgium.

Jeppesen E., Søndergaard M., Meerhoff M., Lauridsen T.L. & Jensen J.P. (2007) Shallow lake restoration by nutrient loading reduction—some recent findings and challenges ahead. *Hydrobiologia*, **584**, 239–252.

Kosten S., Lacerot G., Jeppesen E., Motta Marques D., Nes E.H., Mazzeo N. *et al.* (2009) Effects of submerged vegetation on water clarity across climates. *Ecosystems*, **12**, 1117–1129.

Meerhoff M., Clemente J.M., de Mello F.T., Iglesias C., Pedersen A.R. & Jeppesen E. (2007) Can warm climate-related structure of littoral predator assemblies weaken the clear water state in shallow lakes? *Global Change Biology*, **13**, 1888–1897.

R Core Team (2013) *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Scheffer M. (1998) *Ecology of Shallow Lakes*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Teixeira-de Mello F., Meerhoff M., Pekcan-Hekim Z. & Jeppesen E. (2009) Substantial differences in littoral fish community structure and dynamics in subtropical and temperate shallow lakes. *Freshwater Biology*, **54**, 1202–1215.

Wang H.-J., Wang H.-Z., Liang X.-M. & Wu S.-K. (2014) Total phosphorus thresholds for regime shifts are nearly equal in subtropical and temperate shallow lakes with moderate depths and areas. *Freshwater Biology*, **59**, 1659–1671.

(Manuscript accepted 18 August 2014)