Climate change and eutrophication risk thresholds in English rivers

Changement climatique et seuil de risque d'eutrophisation dans les rivières anglaises

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RÉSUMÉ

Il y a de grandes chances que le changement climatique augmente à l'avenir le risque d'eutrophisation, en raison de la diminution du débit des rivières et de la hausse de la température de l'eau. La prolifération d'algues, une manifestation de l'eutrophisation, peut réduire la qualité de l'eau et modifier la structure et la fonction des écosystèmes aquatiques. En utilisant la chlorophylle comme indicateur de la biomasse algale et du risque d'eutrophisation dans les rivières de plaine en Angleterre, nous avons identifié cinq moyens de contrôle du risque liés au climat. Le temps de résidence de quatre jours était un seuil important pour la formation de la prolifération d'algues. Les quatre autres critères critiques étaient le débit de la rivière, la concentration de phosphore, la température de l'eau et la lumière du soleil. Nous avons élaboré des séries chronologiques pour ces critères, entre 1951 et 2099 en fonction des scénarios dérivés de l'UKCP09 pour déterminer le nombre moyen de jours dans une période de référence et une période à venir où les seuils établis seraient tous atteints. Le nombre annuel moyen de jours de risque augmente entre le niveau de référence (1961-1990) et les années 2050 (2040-2069) jusqu'à 40 % de plus. Les seuils de phosphore sont toujours dépassés (sauf sur un site). L'interaction entre la variabilité du flux, la température et la lumière du soleil détermine le risque. L'exposition à la lumière du soleil peut être le facteur le plus important dans la prévention de la prolifération des algues. Ceci présente des opportunités possibles de gestion dans les endroits où il n'est pas facile de réduire les concentrations de P à des niveaux suffisamment bas pour freiner le développement des efflorescences algales.

ABSTRACT

Climate change is expected to increase the risk of eutrophication in the future due to decreased river flow and higher water temperature. Algal blooms, one manifestation of eutrophication, can reduce water quality and alter the structure and function of aquatic ecosystems. Using chlorophyll as an indicator of algal biomass and of eutrophication risk in lowland rivers in England, we identified five climate-related controls on risk. Residence times of four days were an important threshold for algal bloom formation. The other four critical controls were river flow, phosphorus concentration, water temperature and sunlight. We developed time series for these from 1951 to 2099 based on UKCP09-derived scenarios to determine the average days in a baseline period and a future period when established thresholds were all met. The average number of 'risk' days per year increases between baseline (1961-1990) and the 2050s (2040-2069) by up to 40%. Phosphorus thresholds are always exceeded (except at one site). The interaction between flow variability, temperature and sunlight determines risk. Exposure to sunlight may be the most important factor in preventing algal blooms. This offers the potential for management options in those places where it is not easy to achieve reductions in P concentrations to levels low enough to curb development of algal blooms.

KEYWORDS

Climate change, eutrophication, management, rivers, thresholds.

1 INTRODUCTION

Climate change is expected to increase the risk of eutrophication in the future; primarily through changes in river flow, nutrient concentrations and water temperature. Algal blooms, one manifestation of eutrophication, can reduce water quality and alter the structure and function of aquatic ecosystems (Bowes et al., 2016) but where and when this may happen is uncertain, requiring an assessment of risk to guide management solutions and protect the environment. Here we assess projected response in algal biomass (chlorophyll blooms), to changes in climate-related drivers (residence time, phosphorus concentration, river flow, water temperature and sunlight exposure).

2 METHODS

We used 115 sites from the UK's Future Flows and Groundwater Levels project (Prudhomme et al., 2012). We defined residence time as the time water takes to travel from an upstream distance to a site; and identified a sub-set of 26 sites for analysis for which it is above a predefined threshold thought sufficient to facilitate algal blooms (four days at low flow). . Site specific thresholds in the remaining controlling variables were identified from plots of variables of water quality against chlorophyll concentration (to indicate chlorophyll bloom risk) from observed water quality data. Daily time series were acquired or developed for the period 1951 – 2099, using the following:

- Future Flows Hydrology (Prudhomme et al., 2012) provided 11 scenarios of future daily river flow.
- A load apportionment model was used to determine current relationships between flow and phosphorus concentration to estimate future concentrations under current waste water treatment conditions and under an improved waste water treatment scenario for the 11 flow scenarios (Charlton et al., 2017).
- Future Flows Climatology estimates of future air temperature were used to estimate water temperature using regression equations based on observed air and water temperature records.
- Sunlight was estimated from an analysis of riparian shade and projected radiation data.

The average number of days per year that all thresholds were met in baseline (1961 – 1990) and future (2050s: 2040 – 2069) periods was determined.

3 RESULTS AND DISCUSSION

3.1 Thresholds

A chlorophyll threshold of 30 µg/l indicated the onset of an algal bloom for most rivers. A phosphorus threshold of 30 µg/l was selected for all sites, based on understanding developed through nutrient limitation experiments across a range of UK rivers in other studies. A sunlight threshold of 65 $W/m^2/day$ was chosen for all the sites based on a minimum of at least 3 hours of full sunshine per day over ~3 consecutive days (derived from earlier work). Flow and temperature thresholds were variable between sites, and based on available monitoring data.

3.2 Change in risk

Bloom risk days (days when the flow, temperature, sunshine and phosphorus concentration thresholds for algal growth were all met) increase between the baseline period (1961-1990) and the 2050s future period (2040-2069). The median increase is about 8 days across all sites from about 50 in the baseline period, although the maximum increase is up to 15 days (Figure 1).

Phosphorus thresholds are met most days of the year and phosphorus concentrations do not prevent bloom development except at one site. After phosphorus, river flow thresholds are most frequently met; sunlight and water temperature thresholds were least often met. The interaction between flow variability and temperature and sunlight would appear to be significant in both limiting the number of days all thresholds are met and also in controlling the timing of attainment of all thresholds. With the lowest number of threshold days at the greatest number of sites, exposure to sunlight may be the most important factor in preventing algal blooms. There is considerable uncertainty in the estimation of future water temperature and an improved way of estimating water temperature would really help model future water quality.

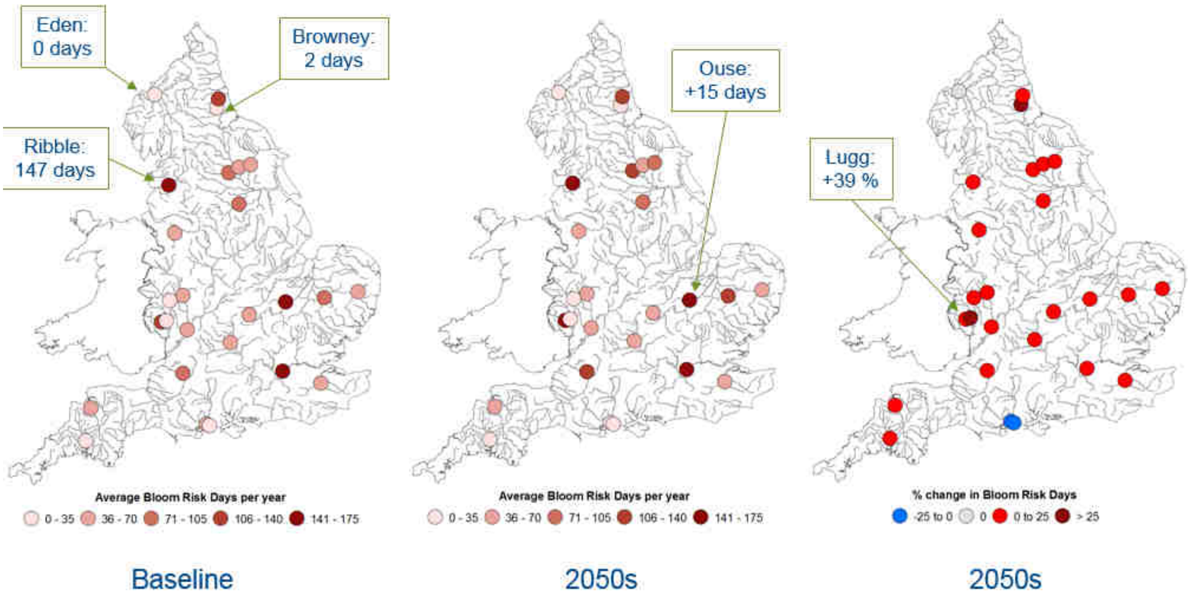

Figure 1. Average number of days per year all four thresholds are met in the baseline period and 2050s periods and percentage change between the periods.

4 SUMMARY AND CONCLUSIONS

Eutrophication risk increases into the 2050s. Phosphorus thresholds are always exceeded so that management strategies may not be effective in reducing the risk of algal blooms occurring in slow flowing rivers. Management strategies focusing on reducing sunlight and thermal interactions (both through river shading by trees) may be particularly effective at reducing risk of blooms on some rivers in the future.

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