Resilience to Eutrophication – Fact Sheet

Linking lake research with end users for positive environmental outcomes

Defining Lake Resilience

Not all lakes with the same nutrient availability exhibit the same trophic state. Some lakes are more resilient to eutrophication, which means that they degrade only gradually in response to increasing nutrient loading — at least initially (Fig. 1).

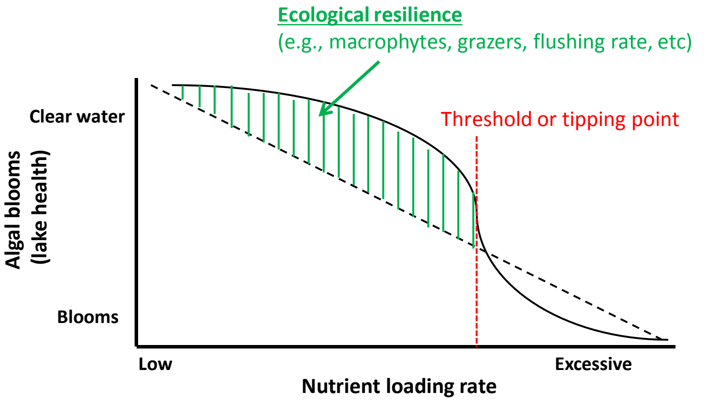

Figure 1. Illustration of the meaning of lake resilience to eutrophication. The zone of resilience is shown in green.

What Makes Lakes More or Less Resilient?

Previous studies have shown that at least 37 shallow lakes in New Zealand have undergone rapid changes (“flipping”) in trophic state as the catchment area used for pasture (% pasture) increased (Schallenberg & Sorrell 2009)[1]. Flipped lakes were also found to be associated with the presence of the invasive macrophyte, *Egeria densa*, and some invasive fish species.

In this Critical Step, an analysis of 43 shallow lakes was conducted to correlate algal biomass to the proportion of their catchment that was in pasture. Lakes with low algal biomass, higher macrophyte biomass, lower sediment resuspension and shorter water residence times (i.e. the lakes that tended to be resilient) were associated with lower proportions of pasture in their catchment.

In contrast, lakes that tended to be more vulnerable typically contained goldfish and/or perch. Thus, in shallow lakes, the presence of these non-indigenous fish was correlated with unusually high algal biomass.

We also analysed factors related to resilience and vulnerability to eutrophication in a dataset of 23 deep lakes. In this dataset, only the smaller lakes tended to be degraded (large, deep lakes had close-to-pristine water quality). Nevertheless, our analysis showed that the presence of perch (and non-indigenous fish species in general) in some of the lakes tended to result in higher algal biomass for a given proportion of pasture in the lake’s catchment (Fig. 2).

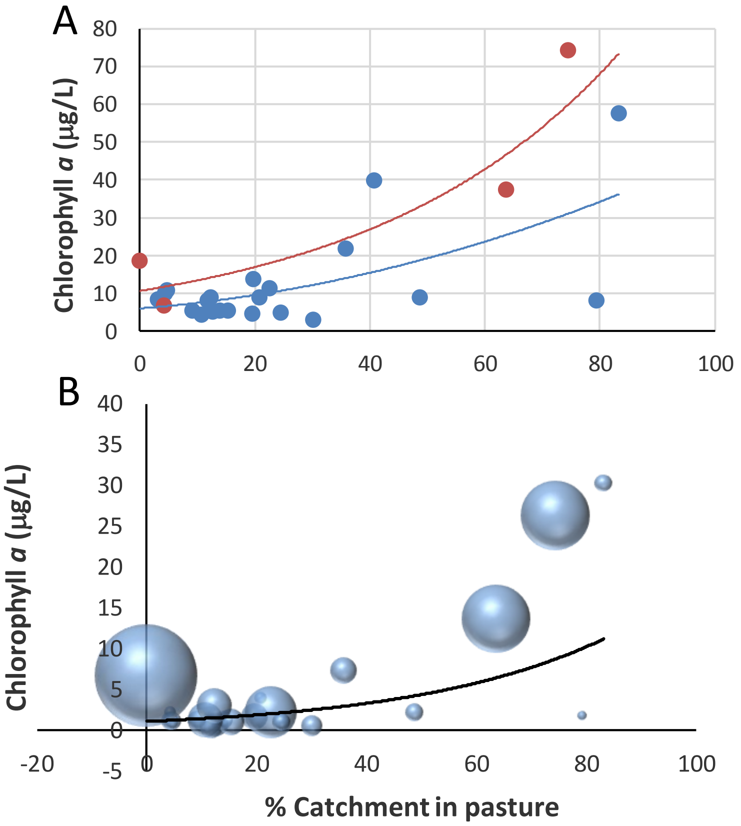

Figure 2. Relationship between the presence of perch (A—red data) and the proportion of fish species present that are non-indigenous (B– indicated by the size of the bubble) with algal biomass (chlorophyll *a*) across a gradient of % pasture in lake catchments. The data show that the presence of perch and the proportion of non-indigenous fish species correlate with higher algal biomass in lakes.

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[1] Schallenberg M, Sorrell B. 2009. Regime shifts between clear and turbid water in New Zealand lakes: environmental correlates and implications for management and restoration. *New Zealand Journal of Marine and Freshwater Research*. **43:** 701-712.

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Resilience to Eutrophication – Fact Sheet Continued

The Role of Stabilising Feedbacks

Resilience to eutrophication comes about due to the presence of stabilising feedback mechanisms. Usually these have a biological (aquatic plants, grazers) or chemical (oxygen) mechanism. These stabilising feedback mechanisms inhibit the proliferation of algae, but only up to a threshold of nutrient loading, beyond which the nutrient availability and algal productivity (and other related factors) will overwhelm the stabilising feedbacks (Table 1). Once the stabilising feedback mechanisms have been saturated, the system will cross a tipping point.

Table 1. Mediating factors that provide stabilising feedback mechanisms for three types of inland water bodies. Examples of New Zealand water bodies which have exceeded thresholds are also shown.

Type of system	Response variable	Mediating factor	Stabilising feedback	Example lakes
Shallow lakes	Trophic state, water clarity	% of lake bed covered by aquatic plants	• Nutrient uptake • Sediment stabilisation • Sediment oxygenation	At least 37 lakes throughout NZ (Schallenberg & Sorrell 2009)
Deep lakes	Trophic state/cyanobacteria blooms	Deep water oxygen concentration	• Assures binding of P on sediments • Prevents excessive internal P loading	Rotoiti (Bay of Plenty) Tutira (Hawkes Bay) Hayes (Otago) Johnson (Otago)
Coastal lakes and lagoons	Trophic state/cyanobacteria blooms, water clarity	% of lake bed covered by aquatic plants	• Nutrient uptake • Sediment stabilisation • Sediment oxygenation	Whakaki (Hawkes Bay) Ellesmere (Canterbury) Forsyth (Canterbury) Wainono (Canterbury) Tomahawk (Otago)

Evidence of Resilience, or Lack Thereof, from Time Series Data

The behaviour of trophic state variables over time can give an indication of whether lakes are stable (resilient) or vulnerable to change. We analysed a number of long-term lake datasets to derive patterns of responses in chlorophyll *a* over time to help identify lakes that are showing instabilities, with the potential to cross tipping points. The patterns of change in algal biomass differ remarkably among lakes but four fundamental patterns were derived. One pattern reflects strong seasonality in algal production. In such lakes, annual means or medians do not illustrate flipping behaviour as well as seasonal, or maximum annual, algal biomass does (Fig. 3). Thus, the careful analysis of time series data can identify lake resilience, vulnerability and instability associated eutrophication.

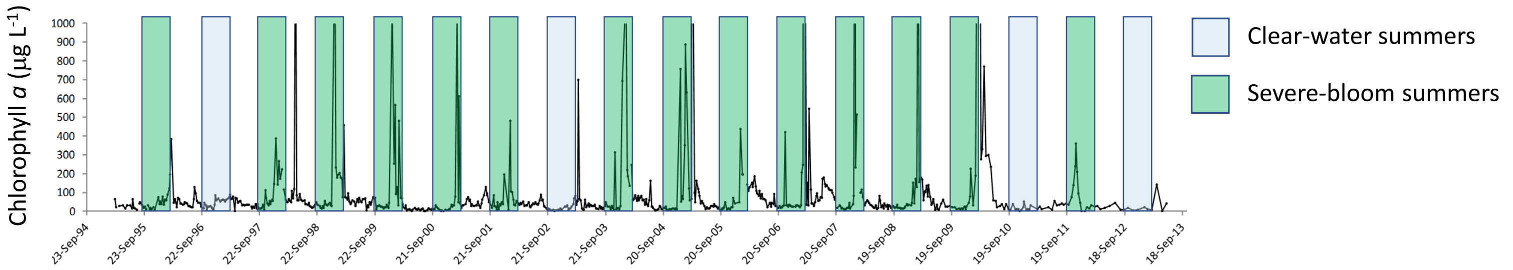

Figure 3. Time series of Wairewa/Lake Forsyth algal biomass time series data from 1994 to 2013, illustrating the instability (lack of resilience) of this lake. The instability can be observed in inter-annual differences in summer chlorophyll *a* maxima.

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