

Appendix 1: Trout Lake

Overview

Here we show the LM, and GAM analysis for the Trout Lake dataset. For complete code, see the [full quarto document](#)

Approach for running LTER-NTL Trout Lake data using temporally structured GAMs and linear regression models with time periods defined a-priori.

First we start with looking at three time periods using linear regression models:

1. The historical regime with low water clarity
2. A clear water regime where the introduction of Lake Trout into the system from stocking in 2006.
3. A novel regime following the introduction of invasive, predatory water flea (*Bythotrephes*) in 2014 which lead to a reversion of water clarity to a less clear state.

To examine this we start by looking at a few key food web conditions using intercept only models through time:

1. Water clarity
2. Phosphorus - which impacts water clarity and is a common bottom-up process that could impact water clarity and we examine as an alternative hypothesis to the top down processes of Lake Trout and invasive speceis.
3. Abundance of large zooplankton *Daphnia* and *Calanoids*
4. Chlorophyll

LM

We approach this by fitting a linear model with the *a priori* time periods as a factor and compare AIC to a single intercept model for each variable.

We find that water clarity, chlorophyll, and large zooplankton abundance are all better explained by a model that includes *a priori* defined time periods improves model fit (Table S1). This indicates that the means for these variables change through time. By examining the time series plot (Figure S1) we can see that large zooplankton and water clarity appear more correlated after 2006, when Lake Trout were stocked in the system. This aligns with our hypothesis that the introduction of top down control in the system has made large zooplankton abundance more tightly coupled with water clarity.

Next we consider whether there are changing relationships between water clarity and these ecosystem dynamics by including a slope parameter and its interaction with time period. We only include an investigation into large zooplankton-water clarity relationship in the main text, but here we also explore chlorophyll-water clarity.

Both Chlorophyll and Large Zooplankton best explain water clarity with a time-varying relationship model, rather than a time-varying abundance model. Next, we examine how these relationships change through time, with a focus on large zooplankton.

We can see from these results that there was a weak relationship from 1980 - 2006 between zooplankton abundance and water clarity, that switched to a strong, positive relationship in 2007 - 2014 as large zooplankton were released from top down pressure, and a slightly stronger relationship after 2014 with the introduction of *Bythotrephes* (Figure S2 & Table S3).

GAM

If we take the Zooplankton-water quality relationship and fit a temporally structured gam and compare it to the linear model, we find similar results. Both predictions also accurately identify 2006 as a breakpoint and a second break point in 2016, although the GAM indicates that the slope of this relationship is a continuously changing trend (Figure S4) and the intercept more closely tracks abundance (Figure S5).

Figures & Tables

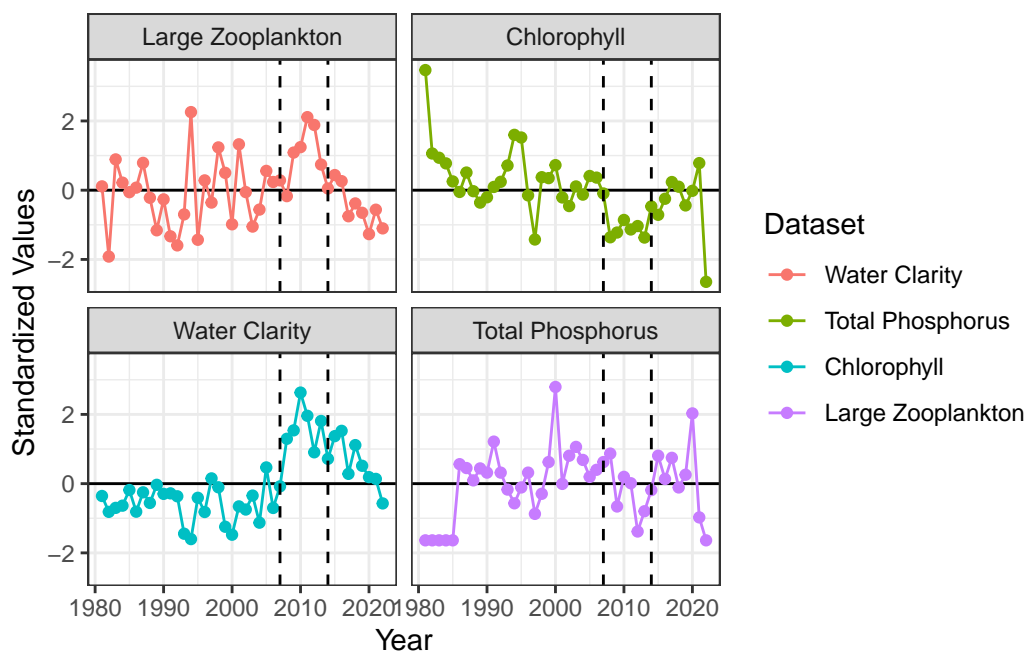


Figure S1: Standardized time series of ecological conditions observed in Trout Lake.

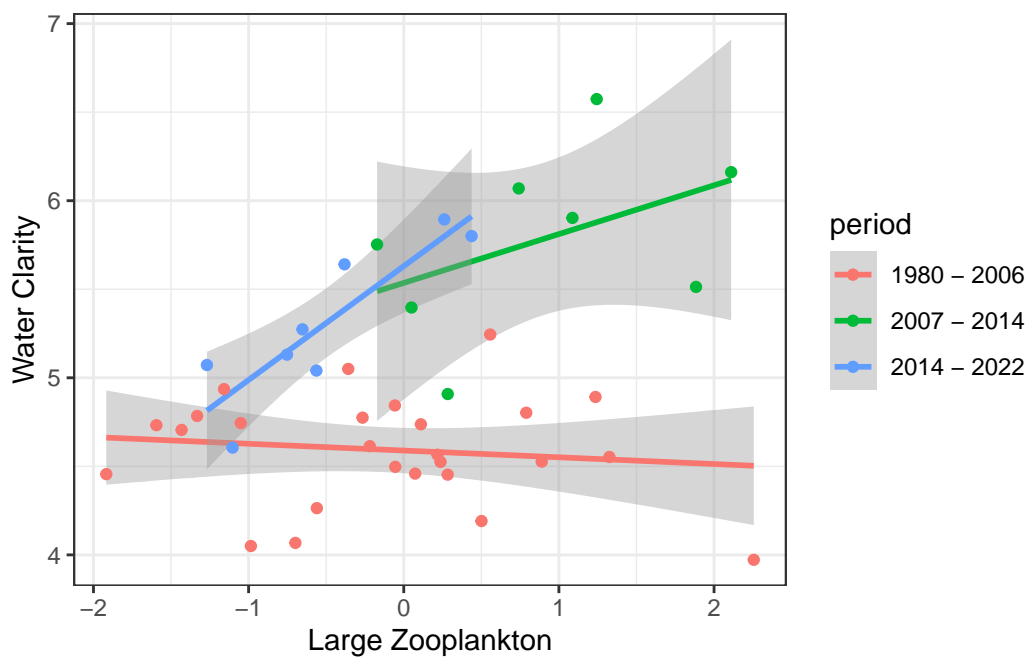


Figure S2: Relationship between large zooplankton abundance and water clarity for three time periods defined *a priori*.

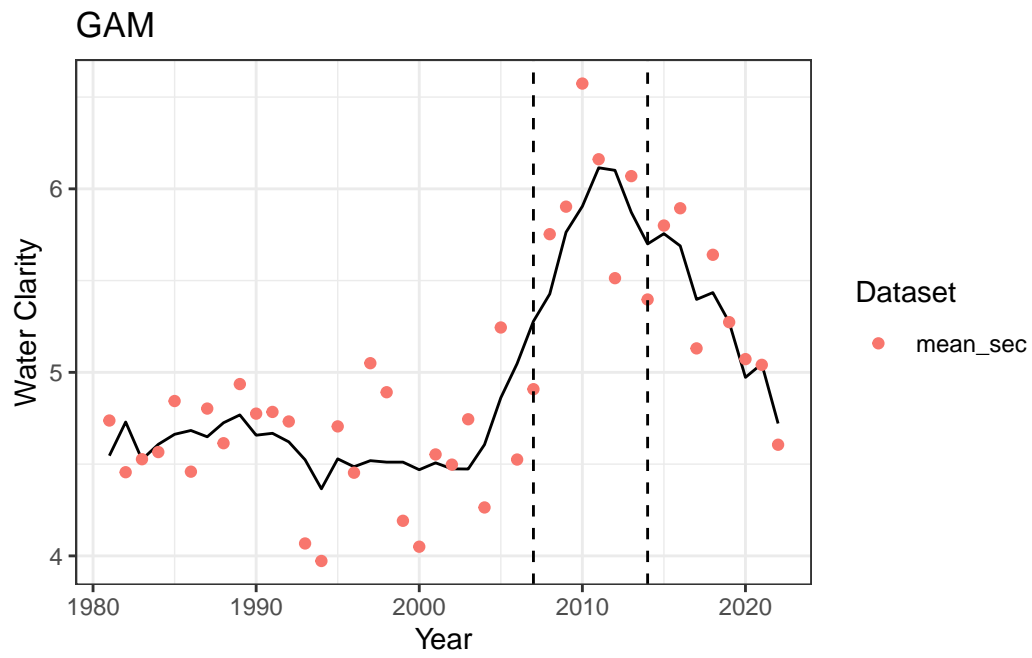


Figure S3: Predicted values of water clarity (black line) compared to observed values (red points) using a time-varying relationship with zooplankton abundance.

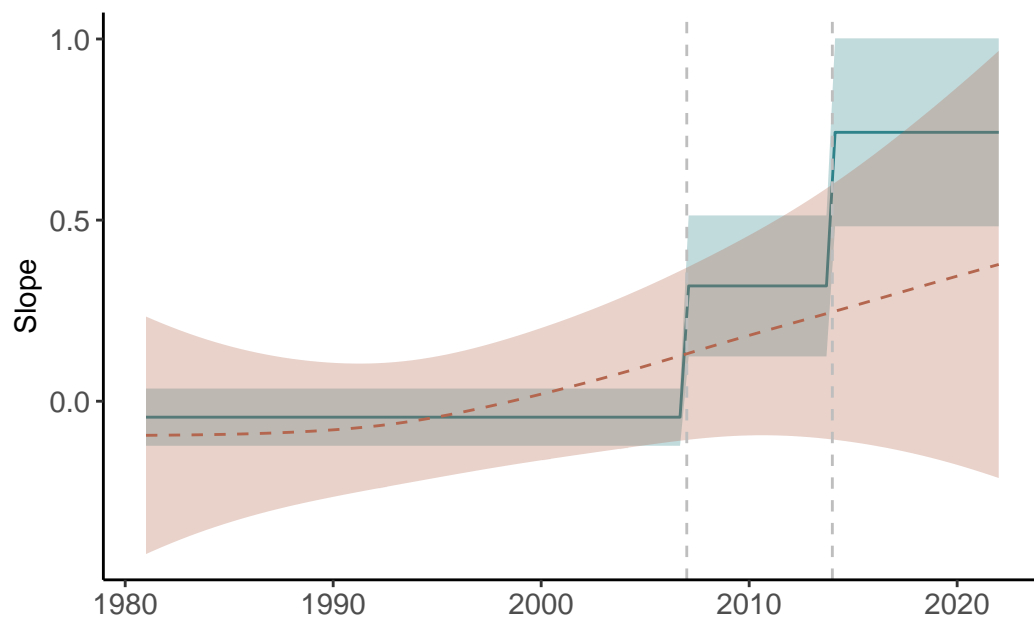


Figure S4: Estimates of the slope of the relationship based on a time-varying LM (blue) and a time-varying GAM (red)

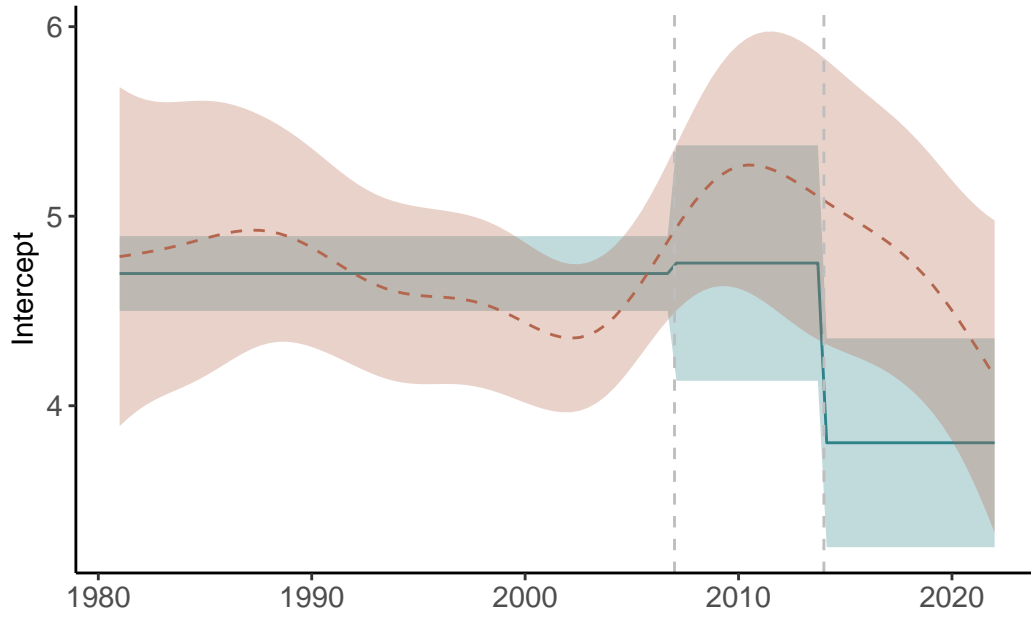


Figure S5: Estimates of the intercept of the relationship based on a time-varying LM (blue) and a time-varying GAM (red)

Variable	No.Period.AIC	Period.AIC	Best.Model
Water Clarity	122.18	83.43	Period
Total Phosphorus	122.18	125.75	No difference
Chlorophyll	122.18	111.00	Period
Large Zooplankton	122.18	115.84	Period

Table S1: AIC values comparing linear models with *a priori* defined time periods (time-varying model) and no time period (time-invariant model)

Covariates	Period	Interaction
Chlorophyll	43.99	39.56
Total Phosphorus	44.45	46.31
Large Zooplankton	43.58	35.99

Table S2: AIC values comparing linear models comparing time-varying abundance models versus time-varying relationship models

term	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	4.70	0.20	23.80	0.00
Large	-0.04	0.08	-0.56	0.58
as.factor(period)2	0.06	0.62	0.09	0.93
as.factor(period)3	-0.89	0.55	-1.62	0.11
Large:as.factor(period)2	0.36	0.19	1.86	0.07
Large:as.factor(period)3	0.79	0.26	3.03	0.00

Table S3: Model coefficients for the time-varying relationship model between large zooplankton and water clarity