

SHORT COMMUNICATION

THE DETECTION OF CLIMATE IMPACTS: SOME METHODOLOGICAL CONSIDERATIONS

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ABSTRACT

Recently, the search for evidence of climate-change impacts has been intense. Long-term and not so very long-term data are being examined for evidence of climatic response. Three commonly used methods involve (i) correlation with an ever-increasing number of climatic variables, (ii) examining trends through time and (iii) a comparison between two points in time. In this paper we provide examples designed to emphasize the need for impassionate and critical examination of findings, the so-called 'eclectic' approach, involving a combination of empirical and conceptual evidence. Copyright © 2005 Royal Meteorological Society.

KEY WORDS: climate change; long-term studies; trends; white stork

1. INTRODUCTION

There is a gathering momentum on reporting findings from climate impact studies. The potential value of long-term data is being recognized and attempts are being made to extract any climate signal contained therein (e.g. Stenseth *et al.*, 2002; Walther *et al.*, 2002; Parmesan and Yohe, 2003). These efforts to safeguard historic data, to ensure continuation of high-quality data collection, and to exploit resources collected at considerable human involvement and cash costs are to be applauded. But, in the flurry of activity to identify climate-change impacts, are scientists being rigorous enough in a critical examination of their own data? Manuscripts that are submitted for publication describing as little as 3 years of data as 'long-term' and seeking to extract a climate signal from these usually fall at the first fence. However, the published literature does contain many examples of papers with conclusions based on as little as 8 years of data (e.g. Järvinen, 1994; Smith *et al.*, 1998; Møller and Erritzøe, 2003). The literature also contains inferences drawn from differences between two recorded points in time (e.g. Sagarin *et al.*, 1999; Archaux, 2004).

Climatic data have become much easier to obtain; whilst this must be encouraged, it does create a very large potential number of climatic variables at varying scales with which to seek a significant relationship with recorded or discovered data.

In this paper we hope to persuade climate impacts researchers to pause slightly during their research and consider the following questions

- Are the results plausible?

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- Is there a known mechanism driving the change?
- Are the results supported by work elsewhere, over the longer term and by expert judgement?
- Is too much effort being expended in finding examples to support preconceived ideas?

To illustrate some potential dangers we present examples based solely on data from white stork *Ciconia ciconia* populations. We chose white stork for three reasons. Firstly, because it is a species used as a traditional sign of spring in much of Europe and was successfully used in phenological studies (e.g. Ptaszyk *et al.*, 2003). Secondly, because it is a species with a long-term complete detailed global monitoring program (Lack, 1973; Bairlein and Henneberg, 2000). Thirdly, because the white stork has been used as a classical example to interpret correlation in statistics (Heath, 1995; Matthews, 2000). Although we refer in this paper to a number of published studies, this should not be treated as a criticism of their content *per se*, rather that they represent examples of where opportunities for false conclusions exist.

2. THE CORRELATION–CAUSATION DILEMMA REVISITED

Because meteorological events in experimental studies cannot be controlled, other than at the small scale, correlation is a very common method used to understand how climate change affects wildlife (review of examples in Walther *et al.* (2002) and Parmesan and Yohe (2003)). Even despite frequent reminders to the contrary, the impacts community still needs warning that correlation does not imply causation. One classical example of this is the often quoted relationship between stork populations and human birth rates (Heath, 1995; Matthews, 2000; Höfer *et al.*, 2004). Is there a plausible reason why this relationship may hold? Is it coincidence, or might general environmental health benefit both human and stork populations, all other things being equal? The criticism from a statistical viewpoint is that the relationship depends only on both white stork population and human birth rate changing in the same direction over time (Heath, 1995). Another criticism (Wirhs, 2003) was that the correlation was driven by a single influential point (called King Kong) in the data set. The data presented by us are from the stork and human populations in Wielkopolska in western Poland for each year in the period 1973–2002. Data on white stork population size and productivity were collected in the Leszno district, a predominantly farming area, by standard white stork monitoring techniques (for details see Tryjanowski and Kuźniak (2002)). Figure 1 reveals, in contrast to traditional belief, that there was a negative correlation between white stork and human performance ($r = -0.611$, $P < 0.001$). Has there been a fundamental change in the historical relationship and could this be ascribed to climate change? Possible mechanisms for such relationships must be considered. In this case, as frequently occurs, both are related to a third variable, i.e. time. The human birth rate has been dropping markedly ($r = -0.894$, $P < 0.001$) while

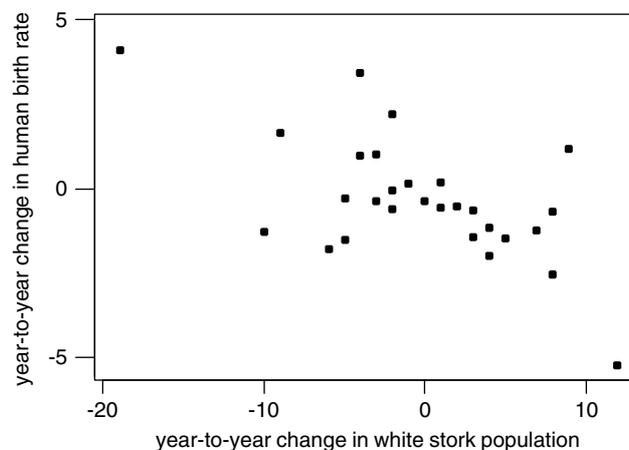


Figure 1. Change in white stork population in relation to change in human birth rate, western Poland 1973–2002

stork productivity per pair has increased ($r = 0.382$, $P < 0.05$). Blind acceptance of all highly significant correlations such as this is not good science. We feel that logical considerations must be blended with empirical conclusions.

There are a growing number of available sources of climate data providing temperature, precipitation and other variables at various temporal and spatial scales. With such an abundance of variables to consider it is not surprising that it is easy to detect a significant correlation with one or more variables. Common failings include a comparison between data and subsequent climate (e.g. spring bird migration with summer temperature), linking bird morphology changes with climate changes (because both animal size and temperature changed directionally over time; e.g. Yom-Tov, 2001), or using multiple measures of the North Atlantic oscillation (NAO) to find a potential effect on spring arrival times (e.g. Hubálek, 2003). In Figure 2 we show that the same stork population in western Poland is related to the winter NAO index 2 years later ($r = -0.508$, $P < 0.01$). Does this unlock a secret of climatology? Lorenz (1963) described how a butterfly flapping its wings can cause a tidal wave on the other side of the globe, so have we discovered a variation on this theme or is it pure coincidence?

3. RECENT TRENDS: HOW LONG IS LONG ENOUGH?

In examining trends over time it is not surprising that researchers use all available data. But do they have any knowledge of how the series performed outside of their data limits? Less than 10 years of results have been used in many published studies (e.g. Veit *et al.*, 1997; Koontz *et al.*, 2001; Martin, 2001; Orlandi *et al.*, 2002; Sergio, 2003; Sainio *et al.*, 2004) and 8 years have been used as a minimum series length to qualify as 'long-term' (e.g. Wiens, 1984; Houlahan *et al.*, 2000). Figure 3 displays the population size of white stork in Oldenberg, Germany, from 1928 to 2000 (Bairlein and Henneberg, 2000). The population is now much lower than at the beginning of data collection. However, by varying the start and finish dates of our series we could draw very different conclusions. Figure 4 shows a matrix of start and finish dates and the polarity and significance of the regression coefficient. Whereas the majority (91%) of time series of varying length produce a negative trend in agreement with the general impression from Figure 3, 120 of the 2211 series generate a significant positive trend. These are associated with the three short-term increases to 1940, 1960 and 2000.

More typically, researchers will be dealing with series of various durations until current time. The effect of varying start date on series ending in 2000 is shown in Figure 5. The longest series consistently demonstrate a negative trend, but those since 1980 would indicate a significant positive trend in population size. Since this

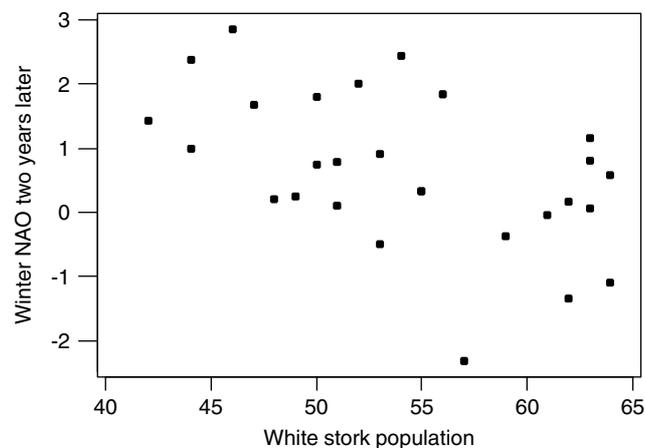


Figure 2. The relationship between white stork population in western Poland 1973–2002 and winter NAO index 2 years later. Note, NAO is treated here as the dependent variable

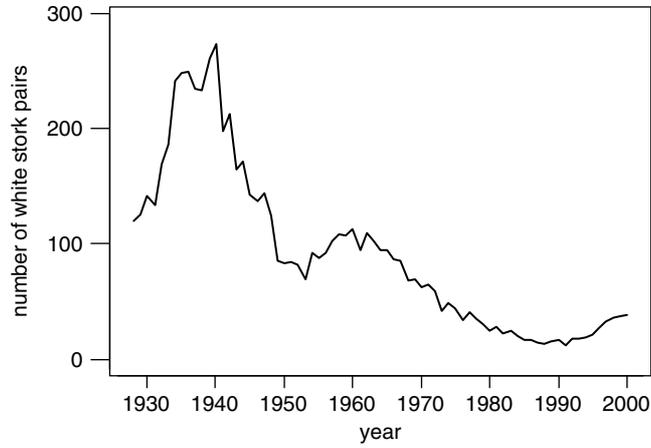


Figure 3. Number of pairs of white storks in Oldenberg, Germany, 1928–2000

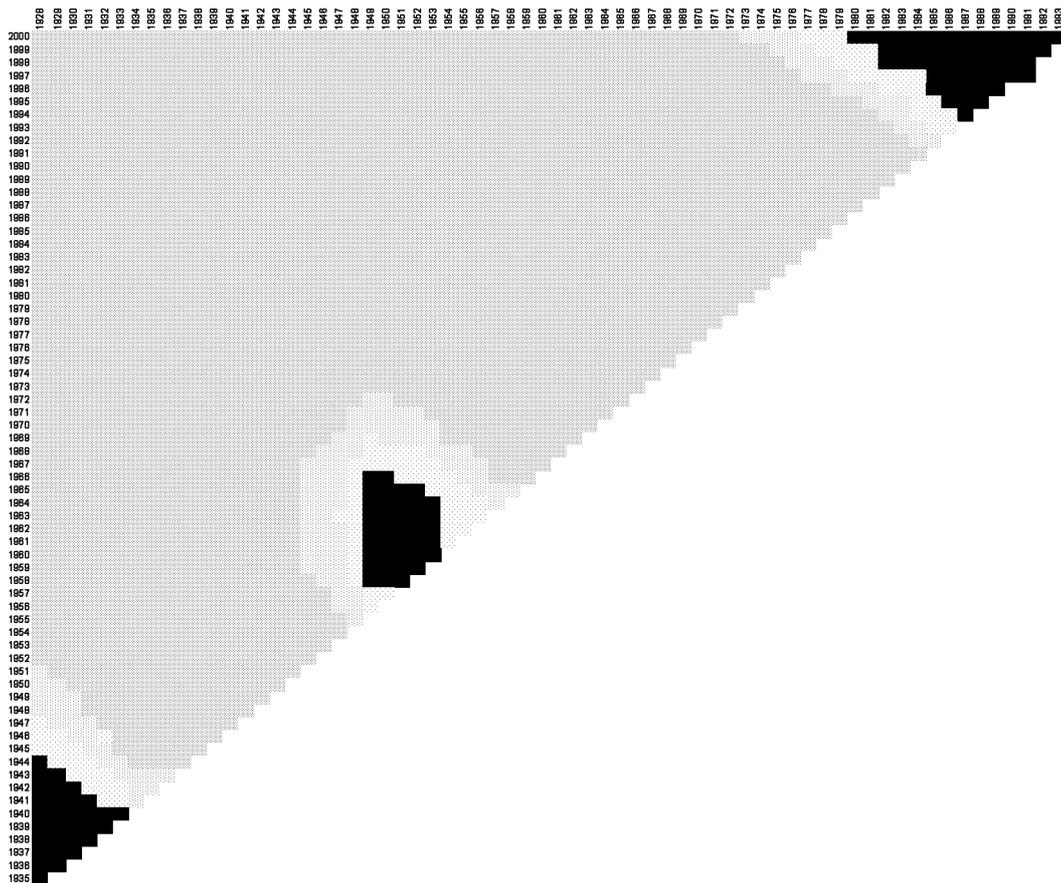


Figure 4. The polarity and significance of regression coefficients in the Oldenberg white stork population varying start date (columns) and end dates (rows). Key: solid black, significant positive trends; light stipple, nonsignificant positive trends; medium stipple, nonsignificant negative trends; heavy stipple, significant negative trends

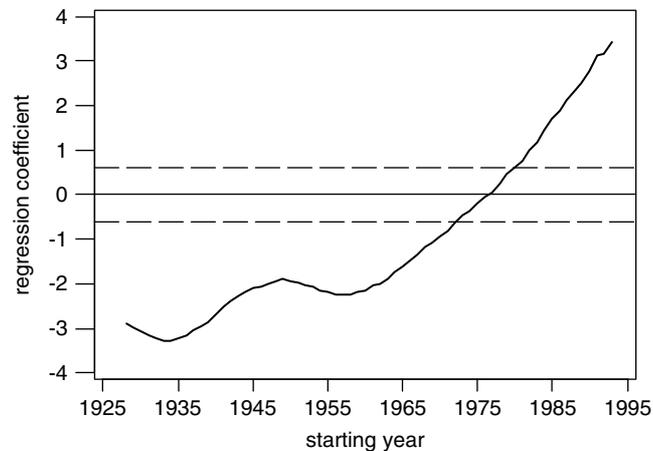


Figure 5. Regression coefficients of Oldenberg white stork population on year for series of various lengths ending in 2000. The solid horizontal line indicates the change from negative to positive trend, and coefficients outside of the horizontal dashed lines are significant

period is also associated with marked climate warming, would we also attribute the change in population to climate amelioration? A warning bell should be ringing; there is a danger of recent trends in time, whatever their cause, being ascribed to recent climate warming. Much more rigorous, as exemplified by McCleery and Perrins (1998), is to observe responses in a time series long enough to contain both cooling and warming periods.

4. THE TWO TIME POINTS RESPONSE

Rediscovery of old data surveys often prompts researchers to repeat them in order to examine change. Distributional change (e.g. Grabherr *et al.*, 1994; Thomas and Lennon, 1999; Archaux, 2004; Konvicka *et al.*, 2004), community change (e.g. Pounds *et al.*, 1999; Sagarin *et al.*, 1999; Lemoine and Böhning-Gaese, 2003; Peñuelas and Boada, 2003) and population change (e.g. Archaux, 2004) can all be detected from such repeat work. But, without a knowledge of what is plausible, should any change between year x and year y be ascribed to a warming climate? How much background change is 'normal' between years and even within years? Figure 6 shows the changes in the failure rates of white stork pairs at Oldenberg between 1928 and 2000. The series fluctuates greatly between years, but there is only a hint of an increasing failure rate with time ($r = 0.204$, $p = 0.085$). There are 2556 possible pairs of years, and Figure 7 shows a histogram of all possible differences between years in which there is a slight bias towards positive differences. Undertaking tests of two binomial proportions would suggest that, of all possible pairs of years, 13% would be declared as significantly decreasing and 22% significantly increasing. Without supporting evidence, is the choice of time points a lottery?

5. DISCUSSION

We will be criticized for producing some 'obvious' examples in the above text, but emphasize that these derive from otherwise high-quality data sets, in our case on white stork populations. Interpretation of information contained within data may be suspect if all statistically significant results are blindly declared as being valid or important. This is plainly not desirable. Unquestioning loyalty to empirical evidence without a supporting conceptual argument does science a disservice. We acknowledge that unexpected discoveries can be made by data trawling and would not want to diminish their importance. Of course, one can always report results with a caveat that supporting evidence from other studies is likely to be necessary. In an ideal world all possible

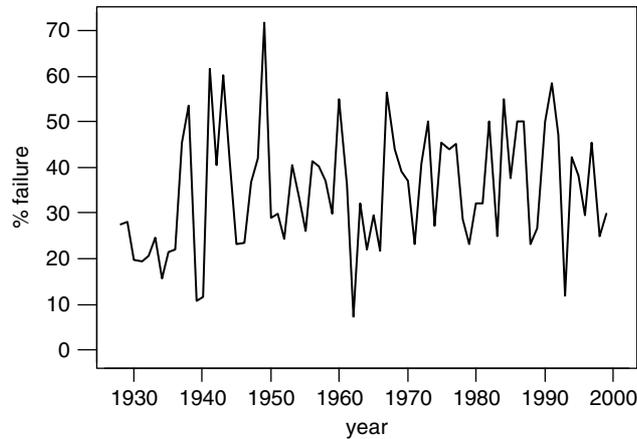


Figure 6. Percentage of white stork pairs failing to breed in Oldenberg, Germany, 1928–2000

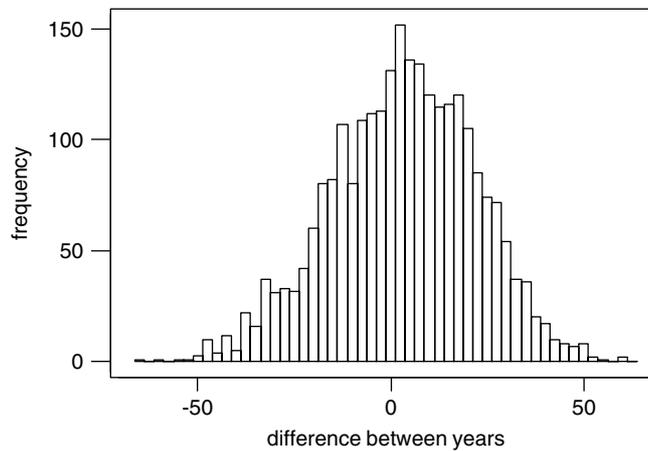


Figure 7. A histogram of all pairwise difference in annual failure rates in the Oldenberg white stork population

shortcomings in data and results would be acknowledged, but would scientists open themselves to adverse reviewer comments if they did so? Although we may here be repeating common warnings on statistical inference, it is plainly evident that this is both very necessary and timely. We hope that by making (repeating) these comments we encourage researchers to assess their own conclusions critically.

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