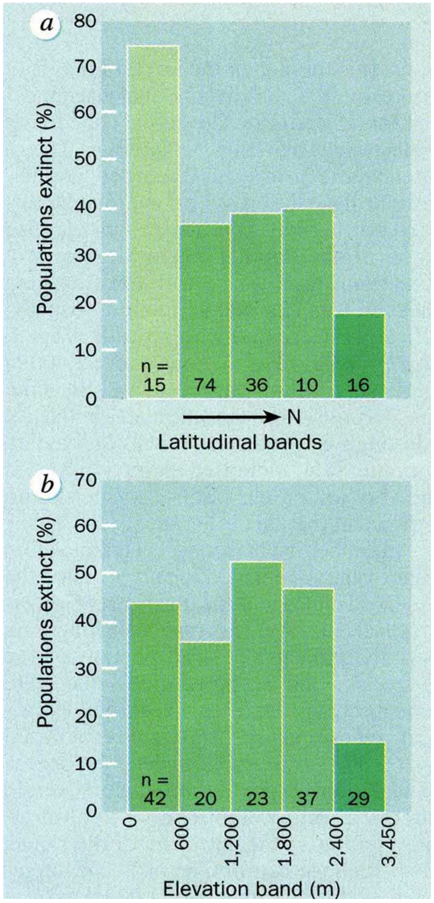

FIG. 2 Proportions of extinct populations in five latitudinal (*a*) and elevational (*b*) bands. a, Analysis with latitude as a continuous variable: Mann–Whitney rank test comparing latitudes of the two state groups, extinct and persistent (mean extinct group = 38.5°N, mean present group = 40.6°N, tied *Z*-value = –2.60, n=151, P = 0.009). Analysis with latitude as a categorical variable: to test for significant break points, I analysed extinctions by latitudinal bands with a 5 × 2 contingency table (5 levels of latitude evenly divided from 30° N to 53° N; 2 levels of status, extinct or present) using a log-likelihood ratio test: G = 15.75, d.f. = 4, P = 0.003. I performed post-hoc sub-divided analyses to test for significant differences among adjacent bands. Latitudinal bands of different shades of green are significantly different from each other at $P \leqslant 0.05$. *b*, Analysis with altitude as a continuous variable: Mann–Whitney rank test on altitude between the two state groups, extinct and persistent (mean extinct group = 1,280 m, mean present group = 1,585 m, tied *Z*-value = –2.05, n=151, P = 0.04). To test the significance of an apparent break point at 2,400 m, I analysed extinctions by elevational bands with a 5 × 2 contingency table (5 levels of elevation; 2 levels of status, extinct or present) using a log-likelihood ratio test: G = 12.16, d.f. = 4, P = 0.016. I performed post-hoc sub-divided analyses to test for significant differences among subsets of the elevational bands. Elevational bands of different shades of green are significantly different from each other at $P \leqslant 0.05$.

nally symmetrical: low at the extremes of the range, with about 20 % of previously recorded sites degraded in Mexico (n = 10) and 17 % in mainland Canada (n = 24), and higher for all other latitudes.

Thus, it is unlikely that the observed latitudinal cline in net extinctions was caused by differences in initial population isolation or subsequent land-use changes. This result, in conjunction with earlier detailed studies of climate-caused population extinctions in this butterfly[14,18–21], suggests climate change as the cause of the observed range shift. However, conclusive evidence for or against the existence of the predicted biological effects of climate change will come, not from attempts to analyse all possible confounding variables in single studies such as this one, but from replication of this type of study with additional taxa in other regions. Until this has been done, the evidence presented here provides the clearest indication to date that global climate warming is already influencing species' distributions.

Camille Parmesan
National Center for Ecological Analysis and Synthesis,
735 State Street, Suite 300,
University of California at Santa Barbara,
Santa Barbara, California 93101-3351, USA
e-mail: *parmesan@nceas.ucsb.edu*

Base-rate errors and rain forecasts

SIR — The nature of the base-rate error - the neglect of prior probabilities in judging the probability of events — has recently been discussed[1]. Yet despite its potentially serious implications for many real-life issues, the base-rate error has yet to achieve wider recognition. I would therefore like to draw to readers' attention the effect of the base-rate error on a familiar (indeed, notorious) dilemma — that of how to respond to weather forecasts.

It seems obvious that decisions affected by the weather (going for a walk, for example) are best made by putting one's faith in the most accurate forecast available. Surprisingly, however, the base-rate effect can make this a sub-optimal approach.

The UK Meteorological Office's 24-hour forecasts of rain currently achieve around 83 per cent accuracy, while the probability of rain on the hourly timescale relevant to walks is around 0.08. The table reveals the impact of the base-rate error in the interpretation of forecasts of rain. With forecast accuracies of 83 per cent, one might expect that a forecast of rain during the one hour walk would be correct 83 per cent of the time. However, the hourly base-rate of rain in the United Kingdom is so low that forecasts of rain are more than twice as likely to be wrong as right: from the table, the probability of rain, given a forecast of rain — that is, P(rain|forecast of rain) — is 66/222=0.30, whereas P(no rain|forecast)=156/222 =0.70

THE VARIOUS OUTCOMES OF FORECAST AND WEATHER OVER 1,000 1-HOUR WALKS

	Rain	No rain	Sum
Forecast of rain	66	156	222
Forecast of no rain	14	764	778
Sum	80	920	1,000

This result suggests that those who ignore Meteorological Office forecasts may fare better than those who abide by them. A decision-theoretic analysis shows that this is indeed the case. Let R, F and W represent the events of rain falling during the walk, rain being forecast, and going on the walk, respectively. Then

$$P(\mathrm{R}\&\mathrm{W})=P(\mathrm{R})[P(\mathrm{F}|\mathrm{R}).P(\mathrm{W}|\mathrm{F})+P(\sim\mathrm{F}|\mathrm{R}).P(\mathrm{W}|\sim\mathrm{F})] \quad (1)$$

with similar expressions for the three other permutations of R, W and negations ~R, ~W. The forecasting accuracy is captured by $P(\mathrm{F}|\mathrm{R}) = A$ and $P(\mathrm{F}|\sim\mathrm{R}) = B$, while the responses to the forecasts are represented by $P(\mathrm{W}|\mathrm{F}) = m$ and $P(\mathrm{W}|\sim\mathrm{F}) = n$; (1) then becomes

$$P(\mathrm{R}\ \&\ \mathrm{W}) = P(\mathrm{R})[Am + (1-A)n] \text{ etc} \quad (2)$$

Let L_{tot} represent the loss function, comprising the losses resulting from the outcomes of the various decisions:

$$L_{\mathrm{tot}}=L_{00}P(\mathrm{R}\&\mathrm{W})+L_{11}P(\sim\mathrm{R}\&\sim\mathrm{W})+L_{10}P(\sim\mathrm{R}\&\mathrm{W})+L_{01}P(\mathrm{R}\ \&\sim\mathrm{W}) \quad (3)$$

Optimal strategies minimize L_{tot}. Substituting from equation (2), and keeping only terms in m and n,

$$L_{\mathrm{tot}}\sim m\{P(\mathrm{R})AK-P(\sim\mathrm{R})B\}+n\{P(\mathrm{R})(1-A)K-P(\sim\mathrm{R})(1-B)\} \quad (4)$$

$$\text{where } K = (L_{00}-L_{01})/(L_{11}-L_{10}) \quad (5)$$

represents the relative losses resulting from the outcomes in equation (3). With A = 0.83, B = 0.17, $P(\mathrm{R})$ = 0.08, we find that basing our decision on Meteorological Office forecasts (m=0, n=1) gives $L_{\mathrm{tot}}\sim (K-56)/74$, whereas ignoring forecasts of rain ($m = n = 1$) gives $L_{\mathrm{tot}} \sim (K-12)/13$. Thus unless one is particularly concerned about getting wet ($K > 2$), the base-rate effect makes disregard of forecasts of rain the optimal strategy.

Similar reasoning also reveals that, contrary to popular belief, always carrying an umbrella is a sub-optimal strategy unless one is morbidly afraid of getting wet ($K > 56$). Indeed, unless $K > 12$, the base-rate effect makes even insouciant optimism a better strategy.

Robert A. J. Matthews
Department of Computer Science,
Aston University,
Birmingham B4 7ET, UK

1. Goodie, A. S. & Fantino, E. *Nature* **380**, 247–249 (1996).