spermathecal sac (*B* in the figure).

It was impossible to estimate the number of sperm cells for comparison between the control and group 1, but it is unlikely that sperm had been removed in the course of the short copulations because the inseminatory canal is very narrow, about the diameter of a sperm cell[4], and relatively long.

We doubt that there was a transfer of some substance that could selectively incapacitate the sperm of other males[5] or cause its removal by the female[6] during the first phase of copulation. Such substance, if deposited by the first four males in group 2, should have remained active and caused considerable decrease in female fecundity. But this was not the case (see table).

We conclude that during copulation in *C. berlesei* (and, presumably, in other acarid mites) males first transfer some substance which can push the previously deposited sperm away from the basal part of the spermatheca and the efferent ducts leading to the ovaries, and only then sperm is transferred. The chance that sperm repositioned and dispersed in the spermatheca will reach the efferent ducts again must be very low. It seems possible that this sperm is decomposed and finally resorbed by microvilli rich walls of the spermatheca[4].

JACEK RADWAN

Department of Zoopsychology and Animal Ethology,
Institute of Environmental Biology,

WOJCIECH WITALIŃSKI

Institute of Zoology,
Jagiellonian University,
Karasia 6,
30–060 Krakow, Poland

1. Parker, G. A. *Biol. Rev.* **45**, 525–567 (1970).
2. Birkhead, T. R., Hunter, F. M. *Trends Ecol. Evol.* **5**, 48–52 (1990).
3. Radwan, J. *Behav. Ecol. Sociobiol.* (in the press).
4. Witalinski, W., Szlendak, E. & Boczek, J. *Expl. Appl. Acarol.* **10**, 1–31 (1990).
5. Silberglied, R. E., Shephred, J. G. & Dickinson, J. L. *Am. Nat.* **123**, 255–265 (1984).
6. Gilbert, D. G., Richmond, R. C. & Sheehan, K. B. *Evolution* **35**, 21–37 (1981).

Terpenes and forest decline

SIR – Becker *et al.* imply[1] that reactions of terpenes with ozone could have a more important role in the formation of hydrogen peroxide than the disproportionation reaction of peroxy radicals, thereby contributing to forest decline. The importance of the oxidation of terpenes to the atmospheric H_2O_2 budget can be estimated by using the authors' reported molar yields and terpene fluxes from coniferous forests. Lamb *et al.*[2] reported α-pinene fluxes of 1.15×10^{-5} mol m^{-2} h^{-1} for a Loblolly pine forest (T = 30 °C). If one assumes a mixing height of 1 km and that β-pinene, Δ^3 -carene and *d*-liminone fluxes are similar, the resulting H_2O_2 production rate would be less than 6 p.p.t.v. (parts per 10^{12} by volume) h^{-1}. The disproportionation of peroxy radical $HO_2\cdot + HO_2\cdot \rightarrow H_2O_2$ would produce 25–700 p.p.t.v. H_2O_2 h^{-1} ($k_r = 5.5 \times 10^{12}$ cm^3 per molecule s^{-1}; T = 25 °C; relative humidity of 50%)[3] at HO_2 levels of 10–15 p.p.t.v. (which are thought to be typical midday levels)[4]. Hence these calculations indicate that H_2O_2 production from the oxidation of terpenes may not be as important a source of atmospheric H_2O_2 as Becker *et al.* suggest.

The concentrations of reactants used by Becker *et al.* $[O_3]_0 = 2-60$ p.p.m.v., $[\text{alkene}]_0 = 5-35$ p.p.m.v.) are not relevant to the atmosphere. Concentrations of O_3 in rural areas are generally of the order of 30–70 p.p.b.v.[5]; concentrations of terpenes, both in absolute terms and relative to O_3 levels, in the ambient atmosphere are also much lower. Measurements indicate that total terpene concentrations in forest air during the summer are of the order of 0.1–10 p.p.b.v.[3,6]. Highest concentrations are generally found at night since convection and vertical transport are lower; total terpene concentrations at midday are seldom larger than 1 p.p.b.v. Fluxes of terpenes from forests are dependent on various factors, including the plant species, time of year and leaf temperature[7].

Becker *et al.* also noted that H_2O_2 production increased with addition of water to the reaction chamber. They attributed this to the acid/base catalysed reaction of the Criegee radical with water to form H_2O_2. However, with their experimental design and the blank tests reported, one cannot exclude reactions of water and O_3 on glass surfaces to account for a portion of the increases in H_2O_2 concentrations, even though "rapid" appearance of H_2O_2 was observed. Such reactions are known to cause serious errors in H_2O_2 measurements[8,9].

HOWARD B. ROSS
CLAES DE SERVES

Department of Meteorology,
Stockholm University,
S-106 91 Stockholm, Sweden

BECKER *ET AL.* REPLY — Ross *et al.* imply that the reactions of terpenes with ozone do not play an important role in the formation of hydroperoxides in the atmosphere and consequently in forest decline. Their estimation of the atmospheric hydrogen-peroxide budget using total terpene concentrations of about 1 p.p.b.v. is incorrect. The total terpene concentrations at midday are seldom higher than 1 p.p.b.v. because of the high oxidation rates. The estimation cannot be simply deduced from our reported values from the H_2O_2-yield table; these values were measured under high concentrations of O_3 and terpenes, which result in high losses for the Criegee biradical by reactions with other species (such as HCHO and higher aldehydes). The estimation of the H_2O_2 formation rate, resulting from the reaction of the biradicals with water vapour, is only possible by a full kinetic simulation of forest-air chemistry. These simulation calcuations must include the emission rates of the terpenes[10,11], the rate constants for the reactions $R_2COO + H_2O \rightarrow H_2O_2$ and the yield for H_2O_2 formation for the different terpenes.

Ross *et al.* mention that the high concentrations used in our experiments were not relevant to the atmosphere. The relevance to atmospheric chemistry is given not by the concentrations used but by the occurrence of the reaction $R_2COO + H_2O \rightarrow H_2O_2$ in atmospheric photo-oxidant systems. The reactions were carefully analysed by evaluating "concentration-independent" kinetic parameters in the case of C_2H_4 and tetramethylethene and O_3. The clearly established new reaction of water with biradicals seems to be an important H_2O_2 source in forest air and can possibly contribute to forest decline.

Heterogeneous formation of H_2O_2 on glass surfaces was ruled out by extensive blank tests. Details of these tests and their consequences for the kinetics of the reaction of the Criegee biradical with water were not reported in our paper[1]. Blank tests with even higher ozone concentrations (up to 400 p.p.m.v.) in the presence of water vapour (1–10 torr) have shown no H_2O_2 formation. References 8 and 9 are irrelevant to our work. These describe experiments in which O_3 was bubbled through water. H_2O_2 formation in such systems can lead to interference in wet-chemical methods for H_2O_2 measurement, but certainly plays no role in our experiments. The high H_2O_2-yields recently observed with the wet-fluorescence method in the reactions of biogenic hydrocarbons with ozone in the presence of water vapour[12] are possibly due to such interference. An

1. Becker, K. H., Brockmann, E. J. & Bechara, *J. Nature* **346**, 257–258 (1990).
2. Lamb, B., Geunther, A., Gay, D. & Westberg, H. *Atmos. Environ.* **21**, 1433–1445 (1987).
3. Kircher, C. C. & Sander, S. P. *J. phys. Chem.* **88**, 2082–2091 (1984).
4. Trainer, M. *et al. J. geophys. Res.* **92**, 11879–11894 (1987).
5. Logan, J. A. *J. geophys. Res.* **90**, 10463–10482 (1985).
6. Lamb, B., Guenther, A., Gay, D. & Westberg, H. *Atmos. Environ.* **8**, 1693–1705 (1987).
7. Altshuller, A. P. *Atmos. Environ.* **17**, 2131–2165 (1983).
8. Zika, R. G. & Saltzman, E. *Geolphys. Res. Lett* **9**, 231–234 (1982).
9. Helkes, B. G. *Atmos. Environ.* **20**, 1433–1445 (1984).
10. Lamb, B., Westberg, H. & Allwine, G. J. *J. geophys. Res.* **90,** 2380–2390 (1985).
11. Zimmermann, P. R., Greenberg, J. P. & Westberg, C. E. *J. geophys. Res.* **93,** 1407–1416 (1988).
12. Simonaitis, R., Olszyna, K. J. & Meagher, J. F. *Geophys. Res. Lett.* **18,** 9–12 (1991).