Nitrogen cycle

Nitrate leaching from grassland

from R.E. White

RECENTLY, interest has revived in the effect that nitrate leached from agricultural land may have on the quality of surface and underground water used for human consumption. The consensus of scientific opinion, as presented in The Royal Society Study Group's report 'The nitrogen cycle of the United Kingdom', published in December 1983, is that most of the nitrate leached comes from arable land and represents approximately one-third of the nitrogen (N) applied annually to that land as fertilizer. The report concludes that little of the 900,000 tonnes of fertilizer N spread on grassland is leached out of the root zone. By contrast, results published in *Nature* this week (page 50), from J.C. Ryden, P.R. Ball and E.A. Garwood of the Grassland Research Institute at Hurley, suggest that loss of nitrate by leaching from intensively-managed grazed grassland may be five to six times higher than losses from comparable swards cut for hay or silage. The average annual loss from the grazed sward was 162 kg N per ha, which exceeded by far the range of 52–93 kg N per ha per year quoted in The Royal Society report for nitrate leached from arable land into the unsaturated zone of Chalk aquifers.

The Hurley researchers took soil and subsoil samples at 0.33 m intervals to a depth of 8 m from two adjacent plots (0.123 ha) on a loamy soil of the Frilsham series on Upper Chalk near Hurley. Both plots were sown to perennial ryegrass in the year April 1976 to March 1977 and fertilized with ammonium nitrate at the rate of 420 kg N per ha per year between April 1977 and December 1982. The 'cut' sward was mown every 4 weeks during the growing season while the 'grazed' sward was stocked with yearling steers for 1 week in 4 at an average stocking rate of 9.3 head per ha. From measurements of the drainage rate of nearby lysimeters, it was estimated that percolating water from the drainage season immediately following 1976–77 should have reached a depth of 5.5–5.8 m by December 1982. This coincided very closely with the depth of 6 m at which nitrate concentrations in the soil water below the cut and grazed swards were not significantly different. Above that depth, nitrate concentrations under the cut sward ranged from 5.4 to 13.3 mg N per litre, whereas the concentrations beneath the grazed sward exceeded the 'acceptable' range of 11.3–22.6 mg N per litre set by the World Health Organization.

Following the December 1982 sampling, the swards were ploughed and cropped to spring barley and winter wheat. A further sampling to 3 m depth in December 1983 confirmed the pronounced mineralization of soil organic N that occurs when grass-

land is ploughed. Allowing for the 80 kg per ha of fertilizer N applied in 1983, some 275–310 kg per ha of N in excess of crop requirements were mineralized, most of it being nitrified and therefore vulnerable to leaching.

Ryden and co-workers attribute the greater loss of N from the grazed sward to the inefficiency of ruminant animals in converting fertilizer N to protein, less than 20 per cent of the N input to grassland being recovered in animal products. The return of much of the ingested N in dung and urine creates 'hot spots' in the soil where the uptake of N by the grass fails to match the supply. The excess mineral N is then vulnerable to leaching.

The results of the new study are especially interesting because most previous work has been done on cut swards exposed to smaller amounts of N fertilizer (<250 kg

N per ha per year). The Royal Society report makes passing reference to nitrate concentrations of 10–100 mg N per litre in profiles beneath grass receiving >400 kg N per ha per year, but adheres to the central view that nitrate concentrations in water percolating below grassland are generally <10 mg N per litre. Even so, much of the drainage water from less heavily-fertilized grassland will exceed the new European Community guide level of 5.7 mg N per litre. Grazing and fertilizer combined are likely to push the average concentrations above the new maximum level of 11.3 mg N per litre. As Ryden *et al.* point out, 37 per cent of the grassland of England and Wales now receives >200 kg N per ha per year and 5 per cent receives >400 kg N per ha per year. Further intensification of livestock farming is therefore likely to exacerbate the problem of nitrate pollution of water supplies at a time when politicians and the public are becoming more concerned about the potential health hazard of high nitrate in drinking water. □

R.E. White is in the Department of Agricultural Science, Parks Road, Oxford OX1 3PF.

Astrophysics

Galaxies in collision

from M.G. Edmunds

GRAVITY never fails to surprise. The exotic predictions of general relativity have perhaps rather overshadowed the quite remarkable effects that can occur with nothing more than simple inverse square Newtonian force. Interesting things happen when galaxies collide, and recent dynamical simulations suggest that some quite strange morphological features of galaxies can be attributed simply to gravitational interaction.

The discovery of 'shells' — sharply defined extended arcs of low brightness — around elliptical galaxies was first reported in *Nature* four years ago (ref. 1 and see Fig. 1). The features were so unexpected that at first sight it seemed that they must be some kind of false diffraction image. Familiar artefacts of this type are the spikes seen on photographs around the images of bright stars, caused by diffraction at the structural supports of the telescope's prime focus. Nevertheless, investigations using different telescopes and of many galaxies have shown that the shells are real and occur around about 11 per cent of elliptical galaxies. No spiral galaxy has so far been found to have them.

The shells are generally aligned with the major axis of the galaxy, but do not completely surround it. Around a single galaxy there can be up to twenty shells, ranging over a factor of 30 in radius. Particularly intriguing is the observation that where several shells occur, they are generally interleaved, such that the next

shell out in radius from the centre is on the opposite side of the nucleus. The colours of the shells² are consistent with the colours of the population of stars in the galaxies, so it seems that the shells are composed of stars, though not particularly young ones.

How do stars come to be organized into such sharp-edged configurations? One possible explanation is that they formed there. Gas lost from stars in the main body of the galaxy³ or from an active galactic nucleus⁴ could blow out of the galaxy, cool and suddenly form into a narrow shell of stars as conditions became suitable. But why the regular spacing of multiple shells (unless it is the result of recurrent events) and, even more strange, why the alternation of shells on either side of the galaxy? An argument against the suggestion of an active nucleus is that the galaxies with shells seem, on average, to show radio emission less often than do similar galaxies without shells.

An explanation of shells on purely dynamical grounds⁵ was examined by P.J. Quinn (formerly of the Australian National University and now at Caltech) in his thesis work, and has now been published⁶. The basic idea is that a disc galaxy collides with a very much more massive — perhaps by a factor of 10 or 100 — elliptical galaxy. The massive elliptical acts as a potential well in which the stars from the disc become trapped. Computer simulations, performed with certain simplifying assumptions, show that the