



A field technique using iridium-192 for measuring subsurface depths in free-ranging Namib Desert beetles

The Namib dune sea, in spite of its very poor vegetation cover and extreme aridity, supports a surprising variety of animal species. Many of these, including mammals, reptiles, and arthropods, use the subsurface environment extensively. In contrast to subsurface animals of other terrestrial habitats, many do not construct burrows: they swim through the sand as if it were a fluid medium.¹⁻⁴ Little is known about the physiology and behaviour of the animals while below the surface.

A major obstacle to experimental work on dune animals using the subsurface environment is the lack of a suitable technique for locating and tracking free-ranging animals when they are within the sand. The use of trailing threads to establish depth below the surface is unsatisfactory, because of the resistance imposed to movement and the circuitous routes the animals follow in the sand. Digging up the animals also does not work, because digging disturbs the animals and because it is impossible to dig a stable-sided hole in dune sand. These two problems can be partially overcome by rapidly excavating animals from a confined space, for example a large bucket submerged into dune sand,⁵ but the effect of such a procedure on the natural subsurface behaviour of the animals is not known. Edney *et al.*⁶ followed the subsurface movements of desert cockroaches (*Arenivaga investigata*) by tagging them with the isotope technetium-99m. Although successful in the laboratory, the technique is not suitable for studying free-ranging animals under natural conditions, because the radiation detector used is a gamma camera which is neither portable nor field-compatible.

We describe here a technique for locating animals by means of radioactive tags, which we have used successfully to measure subsurface depths in free-ranging tenebrionid beetles. The technique depends on tagging captured animals with a γ -emitting isotope and then releasing them. The decrease in radiation flux with distance from the emitter is used to estimate the distance of the animal from a detector positioned on the surface. The same principle has been applied to measure depth in the material-handling industry and elsewhere. We used platinum-coated iridium, in the form of fine diameter (0.3 mm) wire employed in radiotherapy (Amersham, UK). Iridium is a mixed β - and γ -

emitting isotope, but the platinum coating filters out the β emission. The isotope had decayed so that the wire was no longer suitable for medical use, but the activity was still quite adequate for our purpose.

Radiation flux was detected using a 50-mm sodium iodide crystal and photomultiplier tubes, connected to a portable ratemeter. The assembly was mounted on a rigid frame, on skis, so that it could be drawn over the sand. Though the prototype we used was somewhat clumsy, the equipment could be miniaturized. We calibrated each length of wire individually by lowering it down a non-absorbing pipe, sunk into the same substrate in which the animals were to be released, and then measuring surface flux with the emitter at various depths down to 600 mm.

We field-tested the procedure by tagging *Onymacris unguicularis* and *Lepidochora discoidalis* beetles, as well as a few individuals of other *Lepidochora* species. Single lengths of wire (4–6 mm; 0.5 μ Ci) were glued, using a rubber-based glue, on to the dorsal surface of the elytra in such a position that the beetle's mobility was not affected. We released the tagged animals on the slipface of a dune at times of the day when they would bury naturally, that is towards the end of an activity period. For safety reasons, we monitored the animals at all times when surface activity could occur. At the end of the experiment the beetles were recaptured and the wire removed.

The procedure required the beetles to be captured once, following which they theoretically could be tracked for months, provided that the attachment of the wire to the animal remained intact. Using suitable radiation detectors, the beetles could be tracked even if they undertook considerable lateral movement. We easily tracked a *L. kahani* beetle which emerged and moved about 40 m from the original site under cover of darkness. Provided standard precautions for radiation safety are applied, there is little risk to personnel involved. All sources should be recoverable, in the normal course of events. The only situation we envisage in which recovery probably would be prevented would be when a tagged animal is carried off by a predator, particularly a bird.

When measuring depth of an animal, we located the detector directly over the emitter, as judged by maximum counts on the ratemeter. We measured flux for three consecutive 30-second or 1-minute periods, depending on the depth, and adjusted for decay of the isotope subsequent to calibration, using a half-life of 74 days. Background measurements were made in the same vicini-

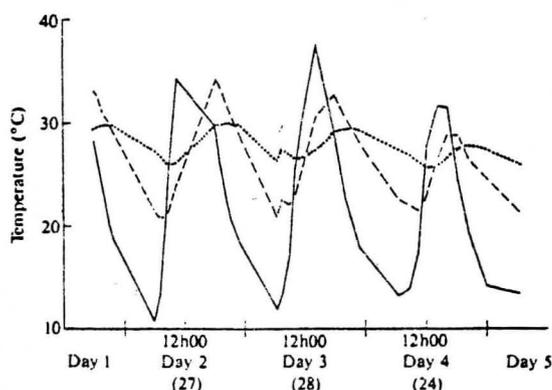


Fig. 1. Subsurface sand temperatures at -10 mm (—), -100 mm (- - -) and -200 mm (· · ·). Maximum daily ambient temperatures at 1 m above surface are given below day number, in parentheses.

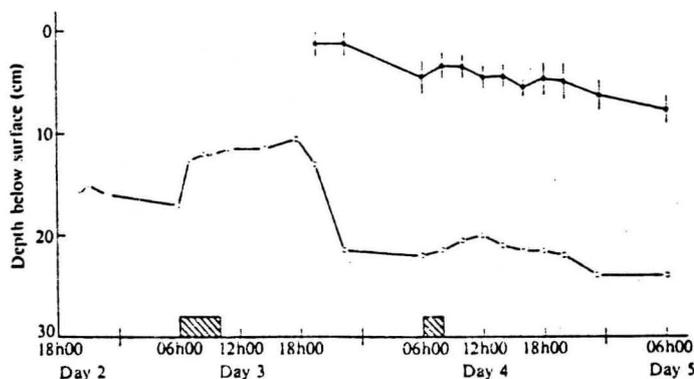


Fig. 2. Movements of tagged *Lepidochora discoidalis* as determined from radiation flux measurements on the surface. Vertical bars and closed circles = means \pm s.e. of six individuals; open circles = one individual; hatched bars = fog.

Fig. 3. Movements of seven individually tagged *Onymacris unguicularis*. Hatched bar = fog.

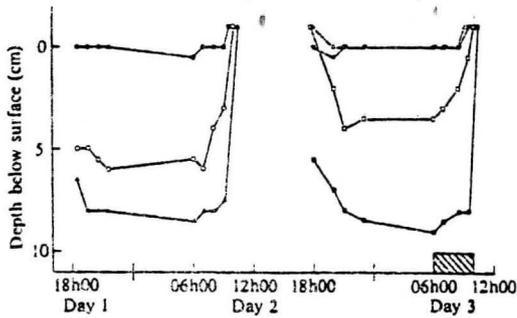
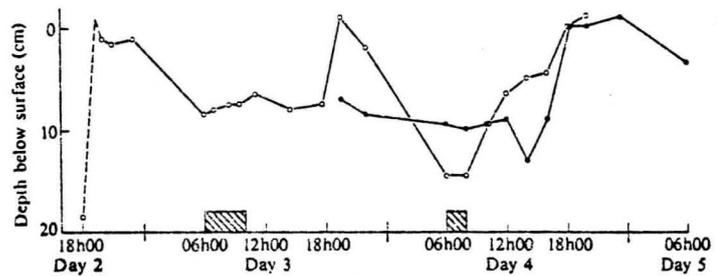


Fig. 4. Movements of one *Lepidochora kahani* (open circles) and one *Lepidochora portii* (closed circles). Hatched bars = fog; dashed line shows initial excavation of *L. kahani*.



ty, but with the emitters absent.

We calibrated and used nine different radiation emitters. To linearize the calibration curve, we had to take into account the position of the detector in its frame, relative to the source on or under the substrate surface. We fitted least-squares regression lines to the calibration, and the standard error of the estimate of depth from log (counts per minute) averaged 5 mm (range 2 to 10 mm) for the nine emitters, down to a depth of about 600 mm. The correlation coefficient of depth against log c.p.m. was $r = 0.997$ for depths from 60 to 300 mm and $r = 0.999$ from 350 to 600 mm. The procedure therefore allowed us to locate the radiation source to within 10 mm. With the emitters we used, the range of measurements extended to a depth of about 600 mm: at this depth the radiation flux of the emitters fell to less than the background count. The range could have been extended by using emitters of greater specific activity, but this range proved adequate for our biological measurements.

We also measured certain microclimatic variables, including dry-bulb temperature and vapour pressure (by sling psychrometry), as well as temperature profiles in the boundary layers above and below the sand surface. The boundary layer temperatures were measured using an array of copper-constantan thermocouples, mounted on a thermally inert rod, and connected via a low-e.m.f. multipole switch to a portable thermocouple thermometer (Bailey Bat 4). Figure 1 shows the microclimatic conditions prevailing at the time. Fortunately, the early morning fog, which is characteristic of the Namib ecosystem and occurs on about 90 days of the year,⁷ occurred on two successive days during our study.

Figures 2, 3 and 4 show the results of the field tests in which we tracked individuals of various tenebrionid beetle species. Of the seven *Lepidochora discoidalis* beetles we tagged (Fig. 2), six stayed within 100 mm of the surface throughout the measurement period, and only two emerged after burrowing. One aberrant individual stayed under the surface for the 58 hours we tracked it, and during this time it moved between 100 mm and 240 mm below the surface, but hardly at all laterally. This behaviour is consistent with that previously observed for *L. discoidalis* under confined conditions in the dune environment.⁵

We tracked seven *Onymacris unguicularis* beetles over 24-hour periods (Fig. 3). Three remained on the surface or within 10 mm of it over the entire period, even though the sand temperature there varied between 10.7°C and at least 35.3°C (Fig. 1). The other four beetles buried to a depth of between 40–90 mm at night; at this depth the sand was warmer (not less than 20°C) (Figs 3 & 1), and the variations were attenuated. All four emerged at about 10h00, a time at which sand and air temperatures were rising rapidly.

The single *L. kahani* that we tracked was adventurous. Twice it emerged and set off from the study site. *L. kahani* is nocturnal in surface activity, and on both occasions emerged at about 19h00. At other times it was as much as 150 mm below the surface. *L. portii*, another nocturnal tenebrionid, remained buried

between 90–130 mm below the surface throughout one day and night, but emerged for five hours from 18h00 on the second night.

Those beetles that emerged exhibited different surfacing behaviour before emerging. All appeared to move through the last few centimetres rapidly. However, the *O. unguicularis* individuals started to move upwards about four hours before emerging, at a time when the sand temperature at their depth was still dropping (Figs 3 & 1). On one occasion the *L. kahani* moved upwards gradually over a 12-hour period before emerging.

All the beetles we tracked are known to use the fog as a water supply, either by basking⁸ or by digging condensation trenches.⁹ During our study period, none of our tagged beetles used this behaviour and we did not observe other individuals in the vicinity using these fogs either. Although the relative humidity of the air was about 95% for three hours on each of the two days, and the fog was sufficiently dense to bring the subsurface water vapour pressure into equilibrium with the air, fog water precipitation on both mornings was negligible.

The subsurface activity patterns observed by using radioactive tags are in agreement with those estimated by use of other mechanical methods.⁵ As the radioactive tags allow complete freedom of movement of even these small animals underground, their use may prove valuable in establishing movement patterns in relation to environmental conditions within the Namib dune sand and other similar habitats.

We are grateful to Mr C. Bain of NUCOR for advising us on the use of the isotope and associated instruments, and Mr Johan Hanekom of NUCOR for his enthusiastic help with the measurements. We thank the Foundation for Research Development of the CSIR, the Transvaal Museum, and the Universities of Cape Town and the Witwatersrand for financial support, the SWA Department of Agriculture and Nature Conservation for facilities and permission to work in the Namib-Naukluft Park, and Sue Nicolson and Clifford S. Crawford for reviewing the manuscript.

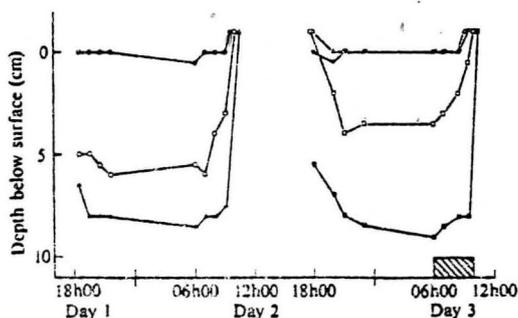
M.K. SEELY¹
D. MITCHELL²
G.N. LOUW³

¹Desert Ecology Research Unit,
P.O. Box 1592,
Swakopmund 9000, Namibia.

²Department of Physiology, Medical School,
University of the Witwatersrand,
Johannesburg 2193.

³Department of Zoology,
University of Cape Town,
Rondebosch 7700.

Fig. 3. Movements of seven individually tagged *Onymacris unguicularis*. Hatched bar = fog.



ty, but with the emitters absent.

We calibrated and used nine different radiation emitters. To linearize the calibration curve, we had to take into account the position of the detector in its frame, relative to the source on or under the substrate surface. We fitted least-squares regression lines to the calibration, and the standard error of the estimate of depth from log (counts per minute) averaged 5 mm (range 2 to 10 mm) for the nine emitters, down to a depth of about 600 mm. The correlation coefficient of depth against log c.p.m. was $r = 0.997$ for depths from 60 to 300 mm and $r = 0.999$ from 350 to 600 mm. The procedure therefore allowed us to locate the radiation source to within 10 mm. With the emitters we used, the range of measurements extended to a depth of about 600 mm: at this depth the radiation flux of the emitters fell to less than the background count. The range could have been extended by using emitters of greater specific activity, but this range proved adequate for our biological measurements.

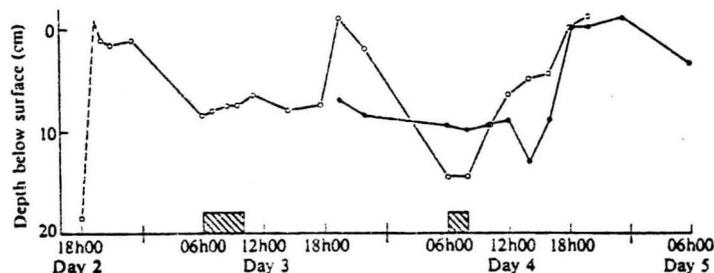
We also measured certain microclimatic variables, including dry-bulb temperature and vapour pressure (by sling psychrometry), as well as temperature profiles in the boundary layers above and below the sand surface. The boundary layer temperatures were measured using an array of copper-constantan thermocouples, mounted on a thermally inert rod, and connected via a low-e.m.f. multipole switch to a portable thermocouple thermometer (Bailey Bat 4). Figure 1 shows the microclimatic conditions prevailing at the time. Fortunately, the early morning fog, which is characteristic of the Namib ecosystem and occurs on about 90 days of the year,⁷ occurred on two successive days during our study.

Figures 2, 3 and 4 show the results of the field tests in which we tracked individuals of various tenebrionid beetle species. Of the seven *Lepidochora discoidalis* beetles we tagged (Fig. 2), six stayed within 100 mm of the surface throughout the measurement period, and only two emerged after burrowing. One aberrant individual stayed under the surface for the 58 hours we tracked it, and during this time it moved between 100 mm and 240 mm below the surface, but hardly at all laterally. This behaviour is consistent with that previously observed for *L. discoidalis* under confined conditions in the dune environment.⁵

We tracked seven *Onymacris unguicularis* beetles over 24-hour periods (Fig. 3). Three remained on the surface or within 10 mm of it over the entire period, even though the sand temperature there varied between 10.7°C and at least 35.3°C (Fig. 1). The other four beetles buried to a depth of between 40–90 mm at night; at this depth the sand was warmer (not less than 20°C) (Figs 3 & 1), and the variations were attenuated. All four emerged at about 10h00, a time at which sand and air temperatures were rising rapidly.

The single *L. kahani* that we tracked was adventurous. Twice it emerged and set off from the study site. *L. kahani* is nocturnal in surface activity, and on both occasions emerged at about 19h00. At other times it was as much as 150 mm below the surface. *L. portii*, another nocturnal tenebrionid, remained buried

Fig. 4. Movements of one *Lepidochora kahani* (open circles) and one *Lepidochora portii* (closed circles). Hatched bars = fog; dashed line shows initial excavation of *L. kahani*.



between 90–130 mm below the surface throughout one day and night, but emerged for five hours from 18h00 on the second night.

Those beetles that emerged exhibited different surfacing behaviour before emerging. All appeared to move through the last few centimetres rapidly. However, the *O. unguicularis* individuals started to move upwards about four hours before emerging, at a time when the sand temperature at their depth was still dropping (Figs 3 & 1). On one occasion the *L. kahani* moved upwards gradually over a 12-hour period before emerging.

All the beetles we tracked are known to use the fog as a water supply, either by basking⁸ or by digging condensation trenches.⁹ During our study period, none of our tagged beetles used this behaviour and we did not observe other individuals in the vicinity using these fogs either. Although the relative humidity of the air was about 95% for three hours on each of the two days, and the fog was sufficiently dense to bring the subsurface water vapour pressure into equilibrium with the air, fog water precipitation on both mornings was negligible.

The subsurface activity patterns observed by using radioactive tags are in agreement with those estimated by use of other mechanical methods.⁵ As the radioactive tags allow complete freedom of movement of even these small animals underground, their use may prove valuable in establishing movement patterns in relation to environmental conditions within the Namib dune sand and other similar habitats.

We are grateful to Mr C. Bain of NUCOR for advising us on the use of the isotope and associated instruments, and Mr Johan Hanekom of NUCOR for his enthusiastic help with the measurements. We thank the Foundation for Research Development of the CSIR, the Transvaal Museum, and the Universities of Cape Town and the Witwatersrand for financial support, the SWA Department of Agriculture and Nature Conservation for facilities and permission to work in the Namib-Naukluft Park, and Sue Nicolson and Clifford S. Crawford for reviewing the manuscript.

M.K. SEELY¹
D. MITCHELL²
G.N. LOUW³

¹Desert Ecology Research Unit,
P.O. Box 1592,
Swakopmund 9000, Namibia.

²Department of Physiology, Medical School,
University of the Witwatersrand,
Johannesburg 2193.

³Department of Zoology,
University of Cape Town,
Rondebosch 7700.

1. Coineau Y., Lancaster N., Prodon R. and Seely M.K. (1982). Burrowing habits and substrate selection in ultrapsammophilous tenebrionid beetles of the Namib Desert. *Vie Milieu* 32, 125-131.
2. Koch C. (1962). The Tenebrionidae of southern Africa XXXI. Comprehensive notes on the tenebrionid fauna of the Namib Desert. *Ann. Transv. Mus.* 24, 61-106.
3. Robinson M.D. and Seely M.K. (1980). Physical and biotic environments of the southern Namib dune ecosystem. *J. arid. Environ.* 3, 183-203.
4. Seely M.K. (1983). Effective use of the desert dune environment as illustrated by the Namib tenebrionids. In *New Trends in Soil Biology*, edit. P. Lebrun, H.M. André, A. de Medts, C. Gregoire-Wibo and G. Wauthy, pp. 357-368. Dieu-Brichart, Louvain-la-Neuve, Belgium.
5. Seely M.K. (1979). Irregular fog as a water source for desert dune beetles. *Oecologia (Berlin)* 42, 213-227.
6. Edney E.B., Franco P. and Wood R. (1978). The responses of *Arenivaga investigata* (Dictyoptera) to gradients of temperature and humidity in sand studied by tagging with technetium 99m. *Physiol. Zool.* 51, 241-255.
7. Seely M.K., Lewis C.J., O'Brien K.A. and Suttle A.E. (1983). Fog response of tenebrionid beetles in the Namib Desert. *J. arid Environ.* 6, 135-143.
8. Hamilton III W.J. and Seely M.K. (1976). Fog basking by the Namib Desert beetle, *Onymacris unguicularis*. *Nature* 262, 284-285.
9. Seely M.K. and Hamilton III W.J. (1976). Fog catchment trenches constructed by tenebrionid beetles, *Lepidochora*, from the Namib Desert. *Science* 193, 484-486.