MEMOIRS
1973

Workman, G.H. 1973
"An Experiment in Underground Living"
NCMRS, Memoirs Vol.2 No.3, pp.105-116

Published by the

THE NORTHERN CAVERN & MINE RESEARCH SOCIETY
SKIPTON U.K.

NB
This publication was originally issued in the 10 by 8 inch format then used by the society. It has now been digitised and reformatted at A5. This has changed the original pagination of articles, which is given in square brackets.

AN EXPERIMENT IN UNDERGROUND LIVING

G.H. Workman

Summary
Some of the results are described of research work carried out while the author was camped alone for 103 days in a cave. The experiments indicated the adaptability of the human body and the relative ease with which a human being can remain alone below ground for very long periods without suffering harm or loss, the main requirements being correct planning and an average degree of self discipline. Tests on eyesight and hearing showed very little change and dark glasses and earplugs were shown to be not required on emergence from the cave. Of special interest were graphs of the potassium content of urine which indicated a natural physiological day of slightly over 24 hours. The author considers that with a few ammendments a stay of over a year should be fairly easy.

———————

Historical Introduction

In 1953 the author camped alone for 14 days in Gaping Ghyll pothole in Yorkshire at a depth of approximately 300 feet (90m). The main object of the expedition was to show that underground camps for prolonged periods could be safely carried out, and that they could form a useful technique in cave exploration. At the end of the 14 days I proved that it was still possible to climb up a 100 ft. (30m) rope ladder carrying a pack full of expedition equipment. Although I later heard of speleologists in other countries exceeding what was believed to be, then, a world record, no plans were made for further and longer underground camps. This was considered unnecessary because by successfully beating the record another explorer would, in fact, be merely adding further support to the evidence that it was a practical technique. This was basically the position until 1962.

Origins of the 1963 Expedition

In 1962 the national press reported that a Frenchman, Marcel Siffre, had created a world record by remaining alone underground for 62 days in the Scarasan Caves in the French Alps. The reports in the newspapers suggested that he was in a state of physical and

psychological breakdown at the end, and he had to be helped out of the cave. Luckily, he made 8 very rapid recovery afterwards in hospital and did not appear to suffer from any permanent adverse effects. Although press reports are often grossly inaccurate this was still regarded by many of my caving friends as a setback to the theory of the oomp1ete adaptibi1ity of nan to his environment.

A further setback was experienced soon afterwards when Bill Penman in Australia was reported as being forced to give up after 64 days. This was due to general deterioration and failing eyesight.

It was suggested that two months represented the limit of human endurance whilst living alone underground. The temperature of the cave was apparently not important as Siffre had been in a very cold cave and Penman in a very warm one. After hearing M. Siffre give an excellent lecture on his expedition to the Cave Research Group of Great Britain I was convinced that the apparent limit was a false one. one. It appeared that the fault lay not in the human body, nor in the individuals concerned, but in the techniques and methods used. With the available evidence and experience it appeared to me that a stay of at least three months should be reasonably possible with the explorer still fighting-fit at the end. It was apparent that another expedition was needed to verify this conclusively.

Planning and Logistics

In organising such an expedition a tremendous amount of planning is required. Every smallest detail must be exactly right to ensure success.

The question of which cave to use was difficult because in Britain all caves are easily accessible to day trippers and therefore good security was essential to ensure solitude. The cave must have a looked door or be permanently guarded. The latter was not possible so I was limited to the non-tourist extensions of tourist caves. The number of caves where one can get far enough away from the tourist section to be completely isolated in every respect is very limited, and I was very fortunate to obtain permission to use the Stump Cross Caverns near Pateley Bridge in Yorkshire.

In these caves a low passage leading away from the tourist section goes via a couple of short descents to over a mile of lower caves with adequate water supply. Upstream and downstream were both impenetrable; a gentle air current flowed from the lower caves to the tourist sections.

The site chosen for the camp was about 100 feet (30m) below the surface and roughly 600 yards (540m) down the Lower series.

In common with most Yorkshire caves the temperature was about 45 degrees Fahrenheit (7 deg. C.) and the relative humidity about 100%.

One of the conditions under which permission to use the cave was given was that telephone communication should be made with the owner every day. This was in case of emergency or accident and the Upper Wharfedale Fell Rescue Association agreed to be on stand-by during the expedition in case they should be needed.

For security and isolation there was a stout door in the low passage between the tourist cave and the lower caves, which was kept looked during the experiment. There was a further wooden door at the head of the short vertical drops.

The biggest difficulty lay in obtaining funds for the work as speleology was not subsidised at that time in Britain. The total budget came to about £950. Discounts and gifts from suppliers out this by nearly £100 leaving £850 still required. The only solution was to sell the story to a newspaper, in order to raise more funds. I had hoped to avoid having to do this but the expedition would have been impossible without. The Daily Express finally offered £400 for a story before and after, with fortnightly reports over the telephone during the expedition. This still left £450 but with the help of extended credit from the local Cooperative Retail Society I was just able to scrape through, although heavily in debt.

There was over 10 cwt of supplies and equipment for the expedition and the assistance of the Pegasus Caving Club of Nottingham was freely given for the transport and carrying of this into the cave.

Food supplies were mostly dehydrated or concentrated except for a few luxury items (for example: 4 tins of fruit salad). They weighed 2½ cwts and contained almost 500,000 K. Calories. A small primus stove was used for cooking, with paraffin at the rate of two gallons per month, and Meta fuel for priming at four bars per day. Lighting was by candles in camp (144) and 4.5 volt batteries (72) with the normal helmet lamp for working away from the camp. A hand torch was also carried as a spare.

To prevent rot and mildew in the 100% humidity the tent and sleeping bag were of terylene. The tent was kept tightly fastened up while I was in it, as by this means the humidity can easily be lowered to comfortable levels. The importance of this had been previously suggested by F. Trombe[1] and demonstrated in the Gaping Ghyll experiment in 1953.

Adequate supplies of spares, repair kits, first aid and medical supplies and other emergency equipment also had to be taken. Host of the supplies were in air tight metal boxes or in polythene bags, but a small quantity was in cardboard boxes. The latter rapidly went mouldy and. had to be buried away from the camp. Considerable attention had also to be given to matters of hygiene and cleanliness as these can make or destroy an expedition of this nature.

Programme

It was decided to make the maximum use of the expedition by arranging as comprehensive and extensive a programme of research as possible. The only restrictions on research work were made in order to avoid introducing too many variables into already over complex equations.

The largest part of the research work lay in the medical field as it was felt that the most useful results could be produced in that direction. Before the expedition blood and urine samples were collected over a period for analysis and this was repeated for a further four day period at the end of the expedition. 24 hour urine samples were also collected for analysis at weekly intervals during the expedition. As it was essential for these to be analysed quickly a small hole about 5 inches by 4 inches was left by the locked door. During the night, when the outer cave door was also locked I could push the small box of samples through this hole to be collected the following morning. By this means the scientific data was made available without any loss of security or isolation. The usual clinical checks were also made before and after the expedition.

Throughout the length of the expedition measurements were also taken of pulse, temperature, general fitness, muscular strength, intelligence, colour perception, eyesight, hearing, sleep variations and any variations in physiological activities.

A psychologist carried out investigations before and after the expedition and also at fortnightly intervals during the expedition by telephone” Observations were also made on hallucinations.

Research on the cave environment included measurements on air temperature and humidity, barometric checks and air currents, carbon dioxide content of the atmosphere, water temperature, pH tests, water flow off stalactites, analysis of silt samples and variations of speleotherms etc.

It was not planned to do any work on the cave biology, although a number of observations were actually made during the expedition.[2]

It was also planned to carry out a photographic coverage of the cave and enough film and flash bulbs for 250 exposures were taken.

The structure of the cave was to be examined topographically by survey and also by geological observations.

Finally, it was planned to examine all the possible points of excavation in the cave; to work out which might prove to be fruitful digs and to carry out such digging as might be considered worthwhile.

All the camp equipment was bought over the counter at sports and camping suppliers. I avoided having anything specially made to show that equipment already available was adequate for such a camp. During the entire length of the expedition I used the minimum amount of equipment in camp so that I was existing on the borderline of comfort and discomfort as near as possible. This was done to give some actual measurement of the quantity and quality of the equipment really necessary. I also had a reasonable quantity of spare equipment in case it was needed but much of this was never unpacked from its sealed containers.

The Start of the Expedition
After some difficulties due to some of the press representatives the cave was eventually entered at approximately l300hrs on Sunday 16th of June, 1963.

The camp site had not been prepared beforehand and all the equipment was carried as far as a depot chamber about 1000ft (300m) in the cave, while a small party continued on to the camp site to level a place for the tent. The site chosen was on top of a sand bank in a dry gallery. This gave protection against rising flood water and excessive accumulations of carbon-dioxide gas. Telephone lines were laid, last minute checks made on apparatus, photographs taken and finally at l600hrs the support party left and the stout door was locked. I was not to see anyone else until 1100hrs on Sunday 29th September - 105 days later. Back at the depot the telephones were again checked before I started the considerable task of organising the camp site into an orderly working unit.

A Typical Day
The day usually commenced by recording the time of waking, dressing, and boiling the kettle for a cup of tea. Whilst waiting for the water to boil I would record such measurements as pulse, temperature and grip strength.

Breakfast would follow, and then after washing (a very important regular item) further medical tests would be carried out. These would include such checks as intelligence, eyesight, fitness etc. The next two hours would probably be spent on photographic work or surveying. It would then be about time to prepare a midday meal.

After a good meal I would spend about three hours exploring the various parts of the cave and carrying out investigations on the cave environment. This would include notes on geology and meteorology. This would take me to the third meal of the day.

The rest of the time would be spent in writing up the log book, checking the equipment and carrying out any necessary repairs. Also, at some prearranged time of the day, the cave owner would telephone to check that I was all right. As there was nobody on permanent duty by the telephone, it was not possible for me to call the surface if I ever had the desire to do so.

There were, of course, many variations from the typical day, but the account probably represents a fair average of how I lived during the expedition. In order to keep the camp clean and tidy it was necessary to spend more time than would be done in a surface camp. This is probably an advantage as it is essential to keep oneself busy as well as clean, under the conditions or solitary underground camps.

Sleep

For the first three weeks I went to bed at about my usual time of 22.30hrs. The attempt to keep regular hours was, however, completely frustrated by the fact that I was gradually taking longer to fall asleep each ‘night’, and was waking up later each ‘morning’. Eventually I was compelled to give up working to the clock and went to bed when I felt tired, and got up when I woke and felt sufficiently refreshed. On this system, I was able to fall asleep almost immediately.

The results of the physiological tests made by Dr. J. Mills (see below) showed that the sleep rhythm was being forced on me by some internal working of the body, over which I had no apparent conscious control. I was averaging about nine hours sleep per night and most nights slept fairly well. I had a few restless nights, but that is hardly surprising really. The average length of my physiological day during the free running period of 12 weeks was 24.71 hours based on the time of going to sleep and 24.72 hours based on the time of waking-up. The difference between the two may be due to a tendency to sleep slightly longer towards the end of the expedition, than at the beginning, but as there is a probability of error of plus or

minus 0.01 in both figures, this may in fact cancel out the differences. Sleep periods are shown plotted graphically in figure three.

Circadian Rhythms

Closely linked with the sleep measurements was the work carried out on an analysis of blood and urine samples by Dr. J. Mills of the Medical School at Manchester University. This was largely in connection with research into Circadian rhythms of the renal functions.

Once a week, all the urine passed during a period of two 'nights' and one 'day' was measured and the times noted. A small quantity of each sample was kept for transit to Manchester University for analysis. Similar measurements were made on the day before the expedition and also on two further control days the following December. Rates of excretion of potassium, sodium and chlorides were plotted graphically. The K graph showed a circadian rhythm with a superimposed sine curve wavelength of a little over 24½ hours. The rhythm was similar to the sleep cycle. Na and Cl followed K for eight weeks and then became disassociated from it, becoming increasingly irregular. It may be interesting to note that the disassociation started after two months underground (ie the previous supposed limit) The samples were analysed for phosphate, which was found to fall about waking time, and for creatinine, which was always low during sleep.

The results were found to be very comparable to those of Siffre[3] and Aschoff and Wever.[4] J.N. Mills[5] noted "it is remarkable that the sleep cycle of Workman, who was well aware of the time, of the subjects of Aschoff and Wever, and of Siffre, who was unaware of the time and made such erroneous estimates, were of similar duration. All clearly displayed a free-running system". He continues: "the approximate synchrony between the sleep cycle and potassium excretion.. . suggest a common cause for both rhythms: that some intrinsically rhythmic process, a biological clock, governed alike the rhythmicity in sleep and potassium excretion, and that this clock was not keeping perfect 24 hour time".

It is impossible to give much of the evidence and observations in this paper and you are referred to J.N. Mills paper for further details.[5]

Pulse. Temperature. and Muscular Strength

Pulse, temperature and muscular strength measurements were taken at various times each day and little difference could be detected between the beginning of the expedition and the end. The following

table shows the total variation of measurements on the first full day (June 17th) and also on September 22nd. Muscular strength was measured on a grip dynamometer calibrated in arbitrary units.

Table 1.	Temp. deg.F.		Pulse Rate		Grip (arbitrary units)	
	Min.	Max.	Min.	Max.	Min.	Max.
June 17.	96.8	98.9	77	91	78	83
Sept 22.	97.0	98.5	75	85	82	97

It was noted that the thermometer appeared to behave very sluggishly. Although it was marked as a ½ minute thermometer I had frequently to keep it under the tongue for two or three minutes before getting a correct reading. Readings taken at one minute intervals would be successively higher as the mercury slowly rose.

Once a week the grip test was carried out every five minutes for the first hour after rising with the following results (Table 2).

Table 2.

June 19.	78	82	80	79	73	84	84	84	80	80	81	81	80
Sept 22.	82	85	90	87	86	86	87	83	93	92	92	95	94

Five minute grip tests

In each case a somewhat erratic early portion settles into a more stable later portion. Similar tests on pulse rates gave very comparable results, but five minute tests on temperature indicated a low start, rising slowly to normal in about ¾ of an hour. Above average temperatures and pulse rates were sometimes observed, but these were due to occupational causes; for example eating and working.

An estimation of the change in general fitness was made by measuring the pulse rate before and after standard exercise consisting of stepping on and off an 18 inch high box forty times in two minutes. The results of the first two days tested and the last two tests are indicated in table 3.

Table 3.	Step Test Results			
	First two tests		Last two tests	
Before exercise	86	75	80	82
After exercise	91	80	82	85

A more detailed analysis of the pulse rates before and after exercises show the following results (table 4). The figures represent; the actual number of pulse beats in half a minute.

Table 4.	Half-Minute Pulse Measurements					
Before exercise	40	40	40			
After exercise	43	39	37	37	38	38

A pulse count taken quickly after the exercise would thus give a result of 82, while a half minute delay in starting to count would drop the figure to 76. It is also apparent that the actual rate immediately after the exercise must be over 86. The only solution to the difficulty would be to use an instantaneous reading pulse meter.

Intelligence

A quantitative check on variations in intelligence or mental alertness was made by measuring the time taken to complete crossword puzzles of standard difficulty. This tests was carried out on most, but not all, days.

Table 5.	Crossword Times.
June l7th-22nd.	
Minutes taken each day:	41 19 35 21 11 53
September 23rd-29th.	
Minutes taken each day:	10 8 9 11 10 9

I actually started doing these crosswords a fortnight before the expedition so that natural improvement would be more or less completed before the tests proper. It was noticed that the time taken to complete the crossword was considerably longer if attempted before breakfast or last thing at night i.e. when at a low energy level. This accounts for some exceptionally long times in the first three weeks; after then the test was carried out shortly after breakfast. The period August 5th to 7th was one of psychological stress which caused two very poor scores (26 & 29). Better than average scores were achieved during the last month, when the expedition could be considered to be on its last lap. A connection is indicated between the times taken and the psychological state. A twelve day control test was carried out at home in the summer of the following year with the following results. (table 6).

Table 6.	Crossword Control Test												
Day :	1	2	3	4	5	6	7	8	9	10	11	12	Average:
Time:	6	12	6	10	9	10	14	14	12	11	8	8	10 mins

Colour Perception and Eyesight

For testing colour perception I used eight small coloured cards, one each of brown, red, pink, orange, yellow, green, blue and mauve, with the colour written on the back of the card. After shuffling, these were looked at one at a time and the estimated colour written down. The cards were then turned over and the estimates checked. Of the 30 tests carried out (two per week) 29 showed a score of 8 out of 8 correct, and one test (on June 29th) scored 7 out of 8 correct. The error was that I took the red to be a brown. At that time the lamp battery was nearly exhausted and the light very dim and yellowish, so this would easily account for the error.

Standard colour perception charts were not used, as in an experiment of this length~ the subject would too easily 'learn' the charts and the results would become meaningless. For the same reason no charts were used to obtain any quantitative checks on eyesight. Qualitative tests were made however, ·as I was writing each day and reading the fairly small print of the crossword puzzle clues. No change in reading ability was noted during the period of the expedition, and the print appeared clear at all times. Strength of illumination (ie new or old torch batteries) appeared to make very little difference except for a few seconds of adjustment.

The ability of the iris to adjust to varying levels of illumination was also checked purely qualitatively. The lamp battery would be allowed to run-down excessively low and then a rapid change made to a new battery. The sudden change in illumination was accommodated in a few seconds. Once a fortnight during the final months I also carried out a similar test with a paraffin pressure lamp with similar results (a very bright light). Ability to see in the dim light in comfort returned in only a few seconds after turning out the bright light.

On coming out of the caves I was stopped at the middle door by the television camera team. Their brilliant flood lamps merely caused a moment or two of blinking before the eyes accommodated to this exceptional light. On emerging into daylight no strain was felt on the eyes at all. It was apparent that with normal eye muscles the need for dark glasses was nothing more than a myth.

Hearing

Observations on hearing were made in three ways: apparent audibility of the background noises of the cave; apparent audibility of the telephone; the maximum distance at which I could hear a watch ticking. No appreciable difference was observed in any of these after the first day. On meeting the recovery party at the end of the

expedition and on emerging to the crowd of onlookers, all sounds appeared to be normal. Medical opinion had said that the noise of the people outside would be too great after the quiet of the cave and that I should need earplugs for a while, but this was also shown to be wrong.

Psychology

On leaving the cave I was taken to the psychologist again for a further interview. In order to get rid of press reporters the car was driven exceedingly fast round winding and hilly country lanes. The general opinion of psychologists was that the appearance of rapidly approaching objects would cause considerable fear after the peace and quiet of the cave. No such strain was noticed.

During the expedition a halucination was observed on a few occasions. It consisted of a fnint and somewhat distant sounding telephone bell. At first this occured when I was asleep, and I was woken up by the apparent noise; but later I experienced it whilst fully awake. On each occasion the telephone was quite dead when I picked it up. The sound was heard on eight occasions and the psychologists report showed that these had all been when I was subject to stress conditions; for example when I had beon told that someone had threatened to break into the cave and wreck the experiment.

The telephone was the only link with friends and assistance if required, and the subconscious apparently created the sound as being the most desired thing. This is perhaps similar to desert travellers halucinations.

Conclusions

i Human

The general conclusions of the human research show that although some renal functions became erratic after the first 8 weeks, there was no measurable deterioration in general fitness, eyesight, hearing, intelligence, psychological condition etc. There is even a suggestion in the reports of a slight improvement in some directions. There was no sign at all of any approaching human barrier to a very much longer stay. The human body had thus been shown to be completely adaptable to the conditions of the experiment.

ii Equipment

For a very much longer stay a better quality of equipment would probably be needed as this was proving to be the weakest link in the system. The equipment repair log shows an extensive maintenance operation in the period between the 40th and 50th days, and also between the 85th and 90th days. 45 days would thus appear to be the extent of trouble-free life of standard equipment under

the conditions of the particular cave. It is considered that with a greater quantity of spares and tools, and a few specially made items, the equipment should be able to survive a nmch longer stay underground.

iii General

For catering a moderately varied and interesting diet can be prepared without recourse to too many tinned foods. Good packing is vital to keep the food in good condition. Spices, herbs, and savouries are important to keep the diet interesting and varied in flavour, if not in chemical content. Nothing can be more demoralising than a diet of monotonous flavour and texture.

Camp cleanliness and personal hygiene are of obvious, vital importance and should on no account be neglected. A little self discipline may be required here as it is all too easy to not bother.

A natural air current to ventilate the cave and a good, reliable water supply are required. Underground streams are generally not filtered and stalactite drip is probably safer for drinking and cooking. With several cans for collecting it can be adequate.

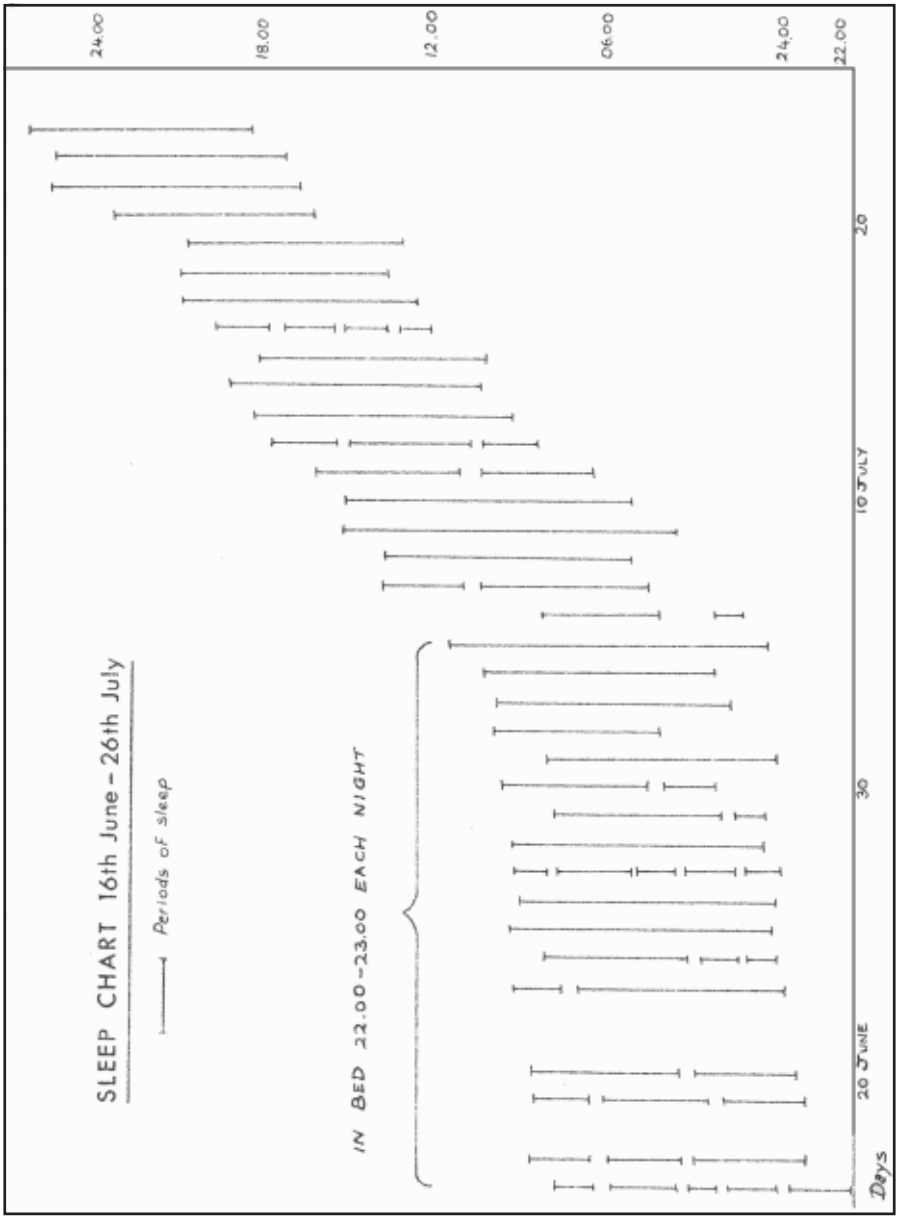
With the experience and knowledge gained so far, I should feel perfectly happy in organising a stay below ground of a full year. The two most important items needed for a successful expedition of such a nature are good planning with correct logistics, and self discipline. Without the first, one could well fail to survive physically; without the second one could fail to survive psychologically or physically. From the psychological angle keeping busy is very useful; if you give yourself plenty to do you will not have time to get worried.

References

1. Trombe.F. 1952. Ch. III of Traite dep Speleologie. Paris, Payout
2. Workman, G.H. 1972. Observations of Bats in Stump Cross Caverns. NCMRS Memoirs, Vo1.2 No.2, August 1972, p67-70.
3. Siffre, M. 1963. Hors du Temps. Paris. Tulliard.
4. Aschoff, J. & Wever, R.1962. Spontanperiodik des Menchen bei Ausschluss aller Zeitgeber. Naturwissenschaften, 15, 337-342.
5. Mills, J.N. 1964. Circadian Rhythms during and after three months in solitude underground. Journ. Physiol. 174. p2l7-23l.

G.H.Workman
Stonebrack
Greenhow Hill
Pateley Bridge
Nr Harrogate, Yorkshire.

MSS Received February 1972.


SLEEP CHART 16th June – 26th July
Periods of sleep
IN BED 22.00–23.00 EACH NIGHT
24.00
18.00
12.00
06.00
24.00
22.00
20 JUNE
30
10 JULY
20
Days