Some techniques used in the investigation of habitat utilization by red kangaroos in North-western New South Wales.

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The problems confronting those concerned with the management of wildlife, particularly the larger species of wildlife such as kangaroos, are similar to the problems of those involved in range management. Both groups wish to know the potential stocking rate of an area and the number and condition of the animals presently in that area. In Australia, because of competition between large wildlife species and their domesticated counterparts, it is desirable that decisions concerning the density and variety of animal species within an area are made in the light of information that is easily and rapidly available. The information required before making any decisions involves the number and condition of a native species that is occupying an area and the amount and quality of food available to that species within the area.

Information of food availability is required to estimate stocking rate, whilst the observed stocking rate, i.e. density of animals can be contrasted to this estimated value. Finally, information on the condition of the animals allows a picture to be drawn of the use being made by an animal of an area and the potential that area may have for different stocking rates in the future. These predictive models are the type of approach which National Parks and Wildlife authorities must nowadays be making when decisions are made concerning the setting aside of land for the conservation of wildlife or in decisions concerning the multiple use of land by different groups of people.

Body condition is usually measured in terms of body weight, although in animals which store quantities of fat, measurements of specific parts of the body, e.g. tail butt circumference in marsupial mice or skin thickness in pigs are used. In kangaroos, fat storage is low, the proportion of body fat to total body weight is about 2% (Tribe and Peel, 1963). Variations in this amount of fat would be difficult to measure, consequently body weight is the main criteria used to estimate body condition in kangaroos.

Measurements of body weight alone will not give reliable estimates for inter and intraspecific comparison and these measurements must be related to some other body measurement which does not change with variations due to nutrition, breeding condition, season etc. Many studies use age as the other criterion. However, in kangaroos, age is difficult to estimate in the field, particularly on live animals. Measurements of various bone lengths or organ weights are reliable criteria which can be measured from carcases.

Once a relationship has been established for animals in good condition (this can be judged from other observations) then any deviation from this relationship will indicate a change in body condition. In this study a relationship for red kangaroos in good condition was developed from data taken from a group of red kangaroos shot during 1975. All animals were male and their full weights ranged from 32 to 91 kg (mean 57 kg). The weights of the following were measured; full carcase, dressed carcase, gastrointestinal tract plus contents, liver, heart, kidney and tail. Linear measurements were fore-arm length, pelvis width, hind-foot length and forearm circumference. In Table I are the relationships established between full body weight and the other measurements. These relationships are presented as linear regressions. Relationships also exist between dressed carcase weight and the other measurements and would be useful when information can be obtained from a kangaroo boning works.

Obviously for live caught animals, only linear measurements are used. Foot length ($r=0.28$ for dressed carcase weight versus foot length) was too variable to be used reliably and fore-arm circumference shows marked sexual dimorphism (the circumference of the fore-arm of male red kangaroos increases rapidly during the period of sexual maturation). However, pelvic width, fore-arm length and tail butt circumference can be used to give reliable estimates of body condition. Another relationship developed since 1975 is between full body weight and crus length (distance from foot to approximate top of tibia). This also gives reliable estimates of body condition (r=0.898, crus length=0.36 full weight + 37.5, n=227).

It was important to test the efficiency of assessing body condition by this method. It was found to be impossible to place an arbitrary statistical level ona series of values and attempt to draw functional conclusions from any deviation from this level. In an investigation into the effects of water deprivation on various physiological parameters of red kangaroos, animals were placed in cages and deprived of water until their body weights reached 80% of their original value (Denny and Dawson, 1975). Although the animals appeared emaciated, when the values for body weights were plotted on a graph showing the relationship between body weight and fore-arm length (figure 1) it was found that even after 20% of the body weight is lost the body weights do not fall outside the 95% confidence limits calculated for the regression.

However, by using a chi-squared test to find any difference between observed body weight and that calculated from the appropriate bone length regression equation, a useable technique has been established. The results of two examples involving the use of the chi-squared test are given in Table II. The first set of data was taken from red kangaroos shot at Fowler's Gap Station during a minor drought in 1967 and the second set of data from a group of grey kangaroos found marooned upon an island in Burrendong Dam, near Wellington in 1977. The results of the test show that both groups of kangaroos were in poor body condition when compared with animals known to be in good condition in 1975. Even more subtle changes in body condition can be detected by using linear measurement-body weight relationships. Groups of red kangaroos live caught within Sturt National Park, Tibooburra during 1975 and 1976 have shown an increase in body weight (38.0±1.52 kg (226) in 1975 and 47.5±1.27 kg (230) in 1976, $P < 0.001$) but there was no obvious sign of better body condition in those animals caught in 1976(one may have just caught larger sized animals in

1976). However, if the relationships between fore-arm length and body weight are plotted for each year, a series of lines eventuates which shows that same-sized kangaroos caught in 1976 were heavier than when caught in 1975 (see figure 2). Towards the 60 kg body weight value the three plotted lines converge. This convergence is consistent with the data presented by Frith and Calaby (1969) from a series of shot animals where it was found that a male kangaroo's growth rate tapers off after 60 kg.

Range condition can be defined in terms of the potential a particular area has of sustaining a certain stocking rate and any estimate of range condition usually requires a relatively full knowledge of the floral species within the area by the researcher. However, many people involved in wildlife management have not had suffieient botanical training to be competent in such an assessment. Also, the time taken to build up a plant inventory can be great and many of the decisions in wildlife management must be made relatively quickly because of external pressures, political and otherwise.

Consequently a method was developed to evaluate range condition which relied entirely upon measurements of the quantity and quality of vegetation within an area, and not upon taxonomy. Samples of vegetation were measured in an area by means of $\frac{1}{4}m^2$ plots. Within a relatively uniform area 8 samples were taken, however in other areas, particularly where rapid changes were occurring, e.g. after fire, then up to 100 sample plots were measured.

Within each $\frac{1}{4}m^2$ plot the vegetation was divided into grasses and forbs and three measurements were taken of each floral group. The measurements were plant height, plant density (as percentage cover) and plant greenness. Plant greenness is a subjective assessment ranking the greenness of plants from 1 to 5. Rank number one represents a completely dry plant, number two represents a plant with a green base, number three represents a plant with green on the stem, number four represents a plant that is green all over and number five represents a plant recently eaten by the animal studied (figure 3). Once the investigator has been shown examples of each rank, it is usually easy for comparable results to be obtained.

Because of the relative uniformity of the vegetation within each $\frac{1}{4}m^2$ plot, it is usual for plants to be even in height and greenness throughout the plot. However, if this does not occur it is simple enough to divide the vegetation into further categories such as tall and short grasses etc and measure each category accordingly. Plant density is measured in units of 5% unless density is less than 5%, in which case 1% units are used. The number five rank is difficult to use outside a national park where there is grazing competition with kangaroos from sheep and cattle.

Also included within the inventory are tree height, tree density, tree shelter (number of trees used recently by kangaroos recently for shade), shrub height, shrub density and shrub shelter. The division between trees and shrubs was one of height (up to 2m for shrubs) although one tended to place different species into one category or the other, e.g. Eromophilia (sp), Cassia (sp) were classed as shrubs and mulga and whitewood species as trees.

This method allows one to assess an area and relate it to the numbers of animals occupying that area. For instance, a study of movements of red kangaroos within the Tibooburra region has used this method of range condition assessment to explain why these animals are in a certain area at a certain time. Densities of kangaroos were estimated along certain transects inside and outside Sturt National Park and it was found that these densities change significantly from one land system to another, and even within a single land system. Many of these differences in utilization of an area by kangaroos can be explained by such parameters as nearness to water and shelter. However, many of the patterns of kangaroo distribution can be related to differences in the vegetation characteristics within the area. For instance, within a particular land system the areas along one particular creek were found to contain greener and more dense grass than beside another creek. Kangaroo numbers were higher near the creek with the greener and more dense grass.

There also appears to be a relationship between those parameters used to describe range condition as outlined above and the parameters used to estimate primary productivity of an area. Such parameters are plant biomass (wet and dry), plant water content and total digestible nitrogen. Biomass (both wet and dry) and plant water content have been estimated for several areas in the Tibooburra region and the results compared to plant height, density and greenness. There appears to be a relationship between biomass and plant volume (plant height times density) and between plant water content and plant greenness (see figures 3 and 4). Both give regression coefficients which indicate a close relationship between the parameters measured. However it must be stressed that the sample sizes are still much too small to use these relationships with confidence and more reliable relationships await further results. One example where the similarities between the different parameters measured became apparent was during an experimental burn on Sturt National Park. Range condition was assessed both before and after the fire and both methods of assessment were used, i.e. plant height, density and greenness was measured as well as plant biomass and water content. It was found that after the fire, grass and forb height and density fell whilst plant greenness rose. Similarly, the biomass of the grass and forbs fell after the fire whilst plant water content increased (Table III).

The final set of information required for wildlife management decisions is the number of animals within an area. Census of an animal population can be undertaken in many ways, all having their respective merits and faults. The three methods used in censusing kangaroo populations in north-western N.S.W. were ground and aerial counting and a capture-mark-release-recapture technique (C.M.R.R.).

Aerial censusing involved flying at a set speed (about 100 knots) and height (about 100 metres) and counting the number of animals seen within a set strip (approximately 200 metres) during the flight. Considerable discussion has surrounded this method of censusing animals (a workshop devoted entirely to aerial censusing methods was recently held in Canberra (Australian National Parks and Wildlife Service, 1977)). This method will give a value for population numbers relatively rapidly and, after appropriate adjustments, the value appears as accurate as that arrived at by any other method. However, the calibration of this technique is still difficult, particularly in regard to the sightability of animals in different habitats, and one does not always have a plane on hand to use for this form of census.

Censusing from a vehicle (ground counts) is more time consuming but would appear to give a more accurate estimate of population density than by aerial counting. It also allows the observer time to relate the animals seen to their immediate environment and gives an opportunity for the observer to undertake a range condition estimate at the same time.

Estimation of population numbers by use of a C.M.R.R. technique requires considerable setting up, particularly if kangaroos are concerned. The animals must be caught (either trapped or drugged), marked (e.g. collared) and released. A certain proportion of this marked population must be recaptured, shot or observed after an appropriate time. This method gives similar results as the above two methods (Table IV) but the time and equipment required restricts its use. Its advantage is that all animals captured are handled so that body condition estimates can be obtained.

The use of the techniques described above is still only tentative and the data obtained preliminary and one can still see room for improvement. Criticisms of each method can be made, for instance, it may only be possible to use the method for body condition assessment on animals weighing less than 60 kg and without plant taxonomy it will be difficult to relate range condition measurements to an animal's dietary habits. However, these faults are inherent in many other methods and will hopefully be eliminated as the methods improve.

As a rapid method of assessing an area these three techniques are extremely useful and, it is hoped, will be used in the future by people not only involved in the management of wildlife but also in the overall management of the Australian rangelands.

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References:

Denny, M.J.S. and Dawson, T.J. (1975) Effects of dehydration on body-water distribution in desert kangaroos. Am. J. Physiol. 229: 251-254

Frith, H.J. and Calaby, J.H. (1969) Kangaroos. F.W. Cheshire, Sydney.

Tribe, D.E. and Peel, L (1963) Body composition of the kangaroo (Macropus sp) Aust. J. Zool. 11: 273-289.

Table I. Relationships between full body weight, bone lengths and organ weights of male red kangaroos, expressed as linear regression equations.
$y = a+bx$ where x = full weight (kg)

	Mean of X	Mean of Y	Intercept a	Slope b	Correlation Coefficient	Number of values
Liver weight (kg)	57.3	0.42	0.01	0.139	0.830	70
Heart weight (kg)	57.3	0.42	0.005	0.108	0.816	71
Kidney weight (kg)	56.6	0.87	1.23	17.82	0.873	30
Tail weight (kg)	57.3	3.82	0.07	-0.10	0.973	71
Pelvic width (cm)	56.6	21.99	0.18	11.69	0.85	47
Butt circumference (cm)	64.8	41.9	0.25	25.56	0.867	34
Forearm length (cm)	57.3	32.33	0.288	15.825	0.937	71
Forearm circumference(cm)	57.2	20.57	0.232	7.297	0.909	71

Table II. Differences between observed and predicted body weights of kangaroos in poor body condition.

A. Red kangaroos shot at Fowler's Gap Station in 1967.

Observed body weight (kg)	Expected body weight (kg)*	Significant difference using chi-squared test
30.1 ± 1.95 (50)+	38.8 ± 2.68 (50)	Sig. at 0.01%

B. Eastern Grey Kangaroos marooned in Burrendong Dam in 1977.

Observed body weight (kg)	Expected body weight (kg)	Significant difference using chi-squared test
(1) Female		
14.7 ± 1.48 (16)+	27.2 ± 4.08 (16)**	Sig. at 0.001%
(2) Male		
12.8 ± 3.34 (9)+	19.0 ± 5.16 (9)**	Sig. at 0.001%

\+ Means ± standard error (number of animals)

* Expected body weights calculated from relationship between crus length and body weight (see Table I)

** Calculated from data supplied by P. Hopwood

Table III. Characteristics of the vegetation within a grasslands plot.

A. Prior to Burning

(i) Range condition assessment

Grass height	48.1 ± 7.02	cms	(9)*
Grass density	39.4 ± 6.72	%	(9)
Grass greenness	3.2 ± 0.15		(9)
Forb height	11.9 ± 4.20	cms	(13)
Forb density	3.3 ± 0.92	%	(13)
Forb greenness	3.1 ± 0.36		(13)

(ii) Biomass measurements

Grass	wet weight	446.1 ± 102.03	g/m^2	(10)*
	dry weight	308.3 ± 76.05	g/m^2	(10)
	moisture	138.0 ± 27.67	g/m^2	(10)
	moisture	32.1 ± 1.89	%	(9)
Forb	wet weight	184.4 ± 30.67	g/m^2	(10)
	dry weight	81.8 ± 39.01	g/m^2	(10)
	moisture	102.7 ± 42.42	g/m^2	(10)
	moisture	68.1 ± 7.05	%	(9)

B. After Burning

(i) Range condition assessment

Grass height	14.3 ± 2.18	cms	(10)*
Grass density	5.6 ± 1.22	%	(10)
Grass greenness	3.8 ± 0.47		(10)
Forb height	4.3 ± 1.20	cms	(3)
Forb density	5.0 ± 2.65	%	(3)
Forb greenness	4.0 ± 0.00		(3)

(ii) Biomass measurements

Grass	wet weight	22.7 ± 5.72	g/m^2	(8)*
	dry weight	16.4 ± 4.48	g/m^2	(8)
	moisture	10.3 ± 2.05	g/m^2	(8)
	moisture	45.1 ± 3.90	%	(8)
Forbs	wet weight	6.9 ± 3.10	g/m^2	(3)
	dry weight	13.6 ± 13.20	g/m^2	(2)
	moisture	12.2 ± 11.80	g/m^2	(2)
	moisture	48.6 ± 13.8	%	(2)

* Means ± standard error (number of samples).

Table IV. Estimation of kangaroo population desnity within Sturt National Park during November 1976.

Estimation of population density by	Kangaroo density (kangaroos/km^2)
1. Aerial counting	8.01
2. Ground counting	8.77
3. C.M.R.R.	10.62

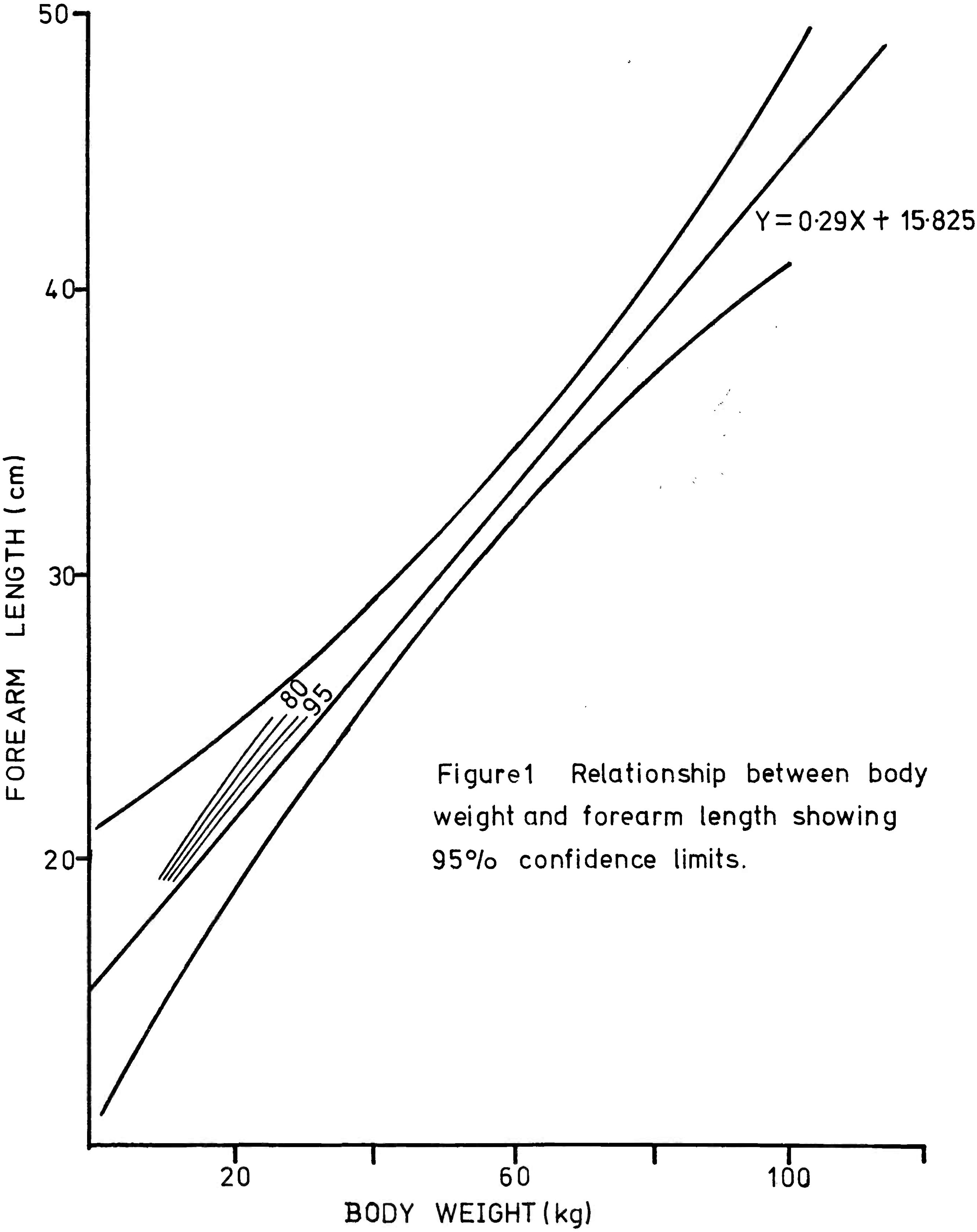

Figure1 Relationship between body weight and forearm length showing 95% confidence limits.

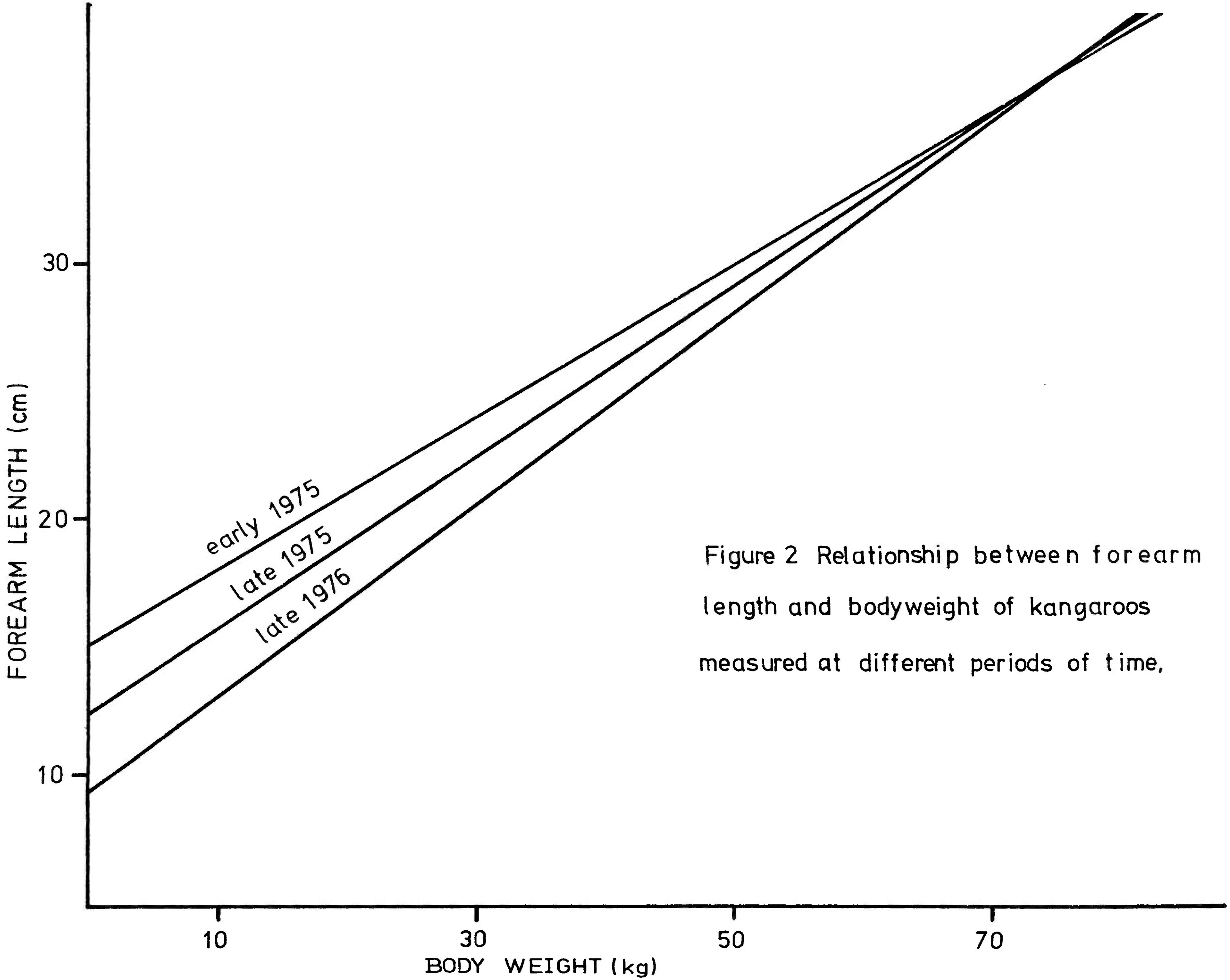

Figure 2 Relationship between forearm length and bodyweight of kangaroos measured at different periods of time,

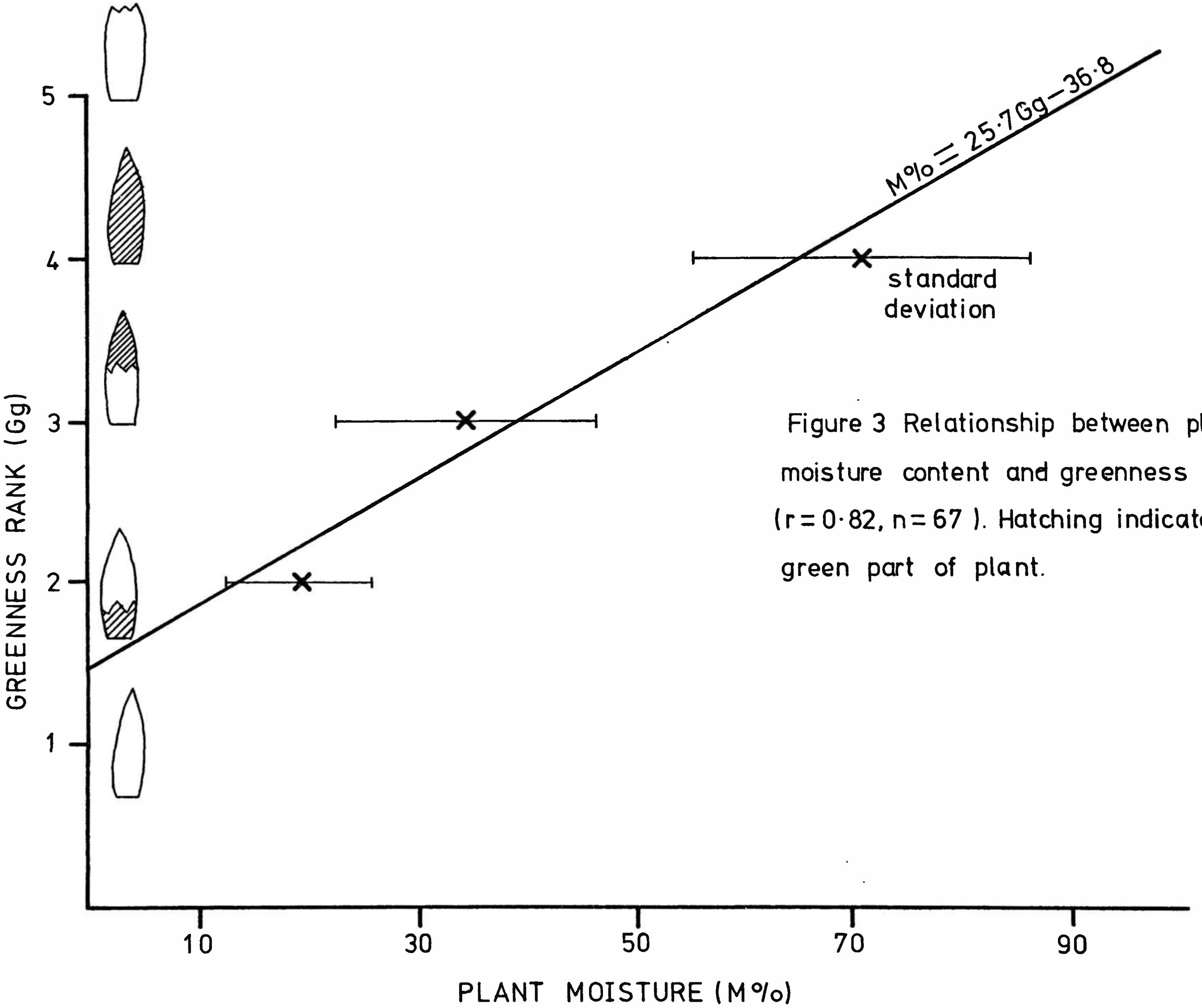

Figure 3 Relationship between plant moisture content and greenness ($r = 0{\cdot}82$, $n = 67$). Hatching indicates green part of plant.

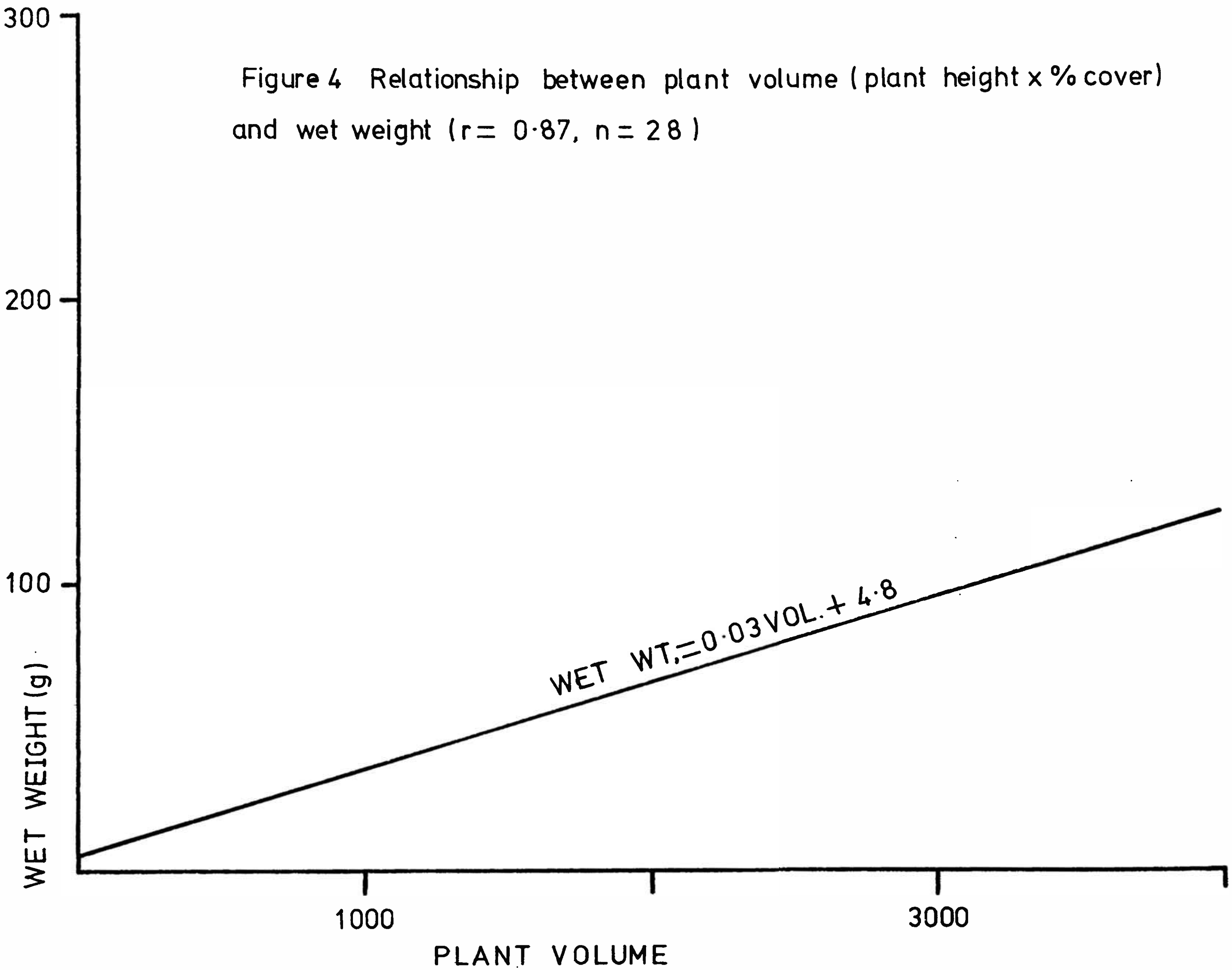

Figure 4 Relationship between plant volume (plant height x % cover) and wet weight (r = 0·87, n = 28)