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STUDIES OF MACROPODIDAE IN QUEENSLAND

2. AGE ESTIMATION IN THE GREY KANGAROO, THE RED KANGAROO, THE EASTERN WALLAROO AND THE RED-NECKED WALLABY, WITH NOTES ON DENTAL ABNORMALITIES

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SUMMARY

Methods of estimating ages of pouch young of the grey kangaroo (*Macropus major* Shaw), the eastern wallaroo (*Osphranter robustus* Gould) and the red-necked wallaby (*Wallabia rufogrisea* Desmarest) from lengths of tail and hind feet are described. Regressions relating age to an index of molar progression for older specimens of these species and the red kangaroo (*Megaleia rufa* Desmarest) are also provided. Several abnormal dental conditions involving supernumerary and unerupted teeth are described and a measure of the frequency of occurrence of each abnormality in the four species is given.

I. AGE ESTIMATION

(a) Introduction

Although the macropodid marsupials include some of the most abundant and economically important mammals native to Australia, ecological studies of these animals have been undertaken only in recent years. Few methods of age estimation, which are essential aids to ecological studies of wild animals, are available for macropodid species and of these most are only for the pouch

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young. Guiler (1960) used several measurements of body parts and total weight of the pouch young of the potoroo (*Potorous tridactylus* Kerr) to indicate age; Shield and Woolley (1961) and Sadlier (1963) used total body-weight and lengths of hind foot and tail to indicate age in pouch young of the quokka (*Setonix brachyurus* Quoy and Gaimard) and the euro (*Osphranter robustus cervinus* Thomas), respectively. Kirkpatrick (1964) described a method of measuring the forward progression of the molar teeth of macropods generally, which when applied to the grey kangaroo (*Macropus major* Shaw) allowed ages of animals between one and three years to be estimated accurately. More recently, Sharman, Frith, and Calaby (1964) used several measurements of body parts and total weight of the pouch young, and an index of eruption of the molar teeth of older animals, to indicate age in the red kangaroo (*Megaleia rufa* Desmarest).

In this paper, methods for estimating age in the grey kangaroo, the eastern wallaroo (*Osphranter robustus* Gould) and the red-necked wallaby (*Wallabia rufogrisea* Desmarest) from birth to old age are described. Data provided by Sharman, Frith, and Calaby (1964) for the red kangaroo have been adapted and used for comparative purposes.

(b) Materials and Methods

All data were secured from animals held captive at the Department of Primary Industries Research Station, Hermitage.

Pouch young.—Pouch young born to captive animals, with date of birth known, were measured regularly. Measurements taken were lengh of underside of tail, from point of junction with body to tip excluding hair, and length of plantar surface of both hind feet from heel to toe excluding nail. Data were secured from 17 pouch young of the grey kangaroo, 9 of which completed pouch life; 10 pouch young of the eastern wallaroo, 9 of which completed pouch life; and 15 pouch young of the red-necked wallaby, 8 of which completed pouch life.

Juveniles, subadults and adults.—Molar index, as defined previously (Kirkpatrick 1964), was the age dependent measurement used for animals which had completed pouch life. Of the animals available for this study, some were born in captivity, others were collected as pouch young from wild mothers; ages of these at capture were estimated from tail and hind foot measurements. A few older animals were donated by members of the public; these were used only if date of capture could be confirmed by reference to a diary or some unmistakable event. Ages of such specimens at capture could be estimated to within about one month by using descriptions and photographs: relative to the ages involved, inaccuracy of this degree was insignificant. Skulls of two aged animals (Nos. CM525 and CM695) were lent by Mr. J. Calaby (Division of Wildlife Research, Commonwealth Scientific and Industrial Research Organization, Canberra), known ages being 24 and 16 years respectively. Fifth molars were considered to be present in the 24-year-old animal; this is discussed in the notes on abnormalities.

Molar indices were read from the cleaned skulls of sacrificed known age specimens and from radiographs of the heads of living animals (Figure 1). Radiographs were taken using a Phillips "Super Practix" portable X-ray unit on "Kodirex" no-screen film backed by a lead plate. An exposure of 15 milli-amp seconds was used for most animals; this was increased to 20 milli-amp seconds for the largest specimens. The head was held with the lower edge of the mandible flat on the film, which was 90° to the X-ray unit. This ensured that the relation between orbits and palate was such that molar index could be read directly from the radiograph. The accuracy of this technique was confirmed in 13 animals which died subsequent to radiography; in all but one the molar index read from the radiograph was found to be correct. The single exception, a red-necked wallaby, was found to have nocardiosis (lumpy jaw) (Barker, Calaby, and Sharman 1963), which had caused the head to be positioned incorrectly for the radiograph.

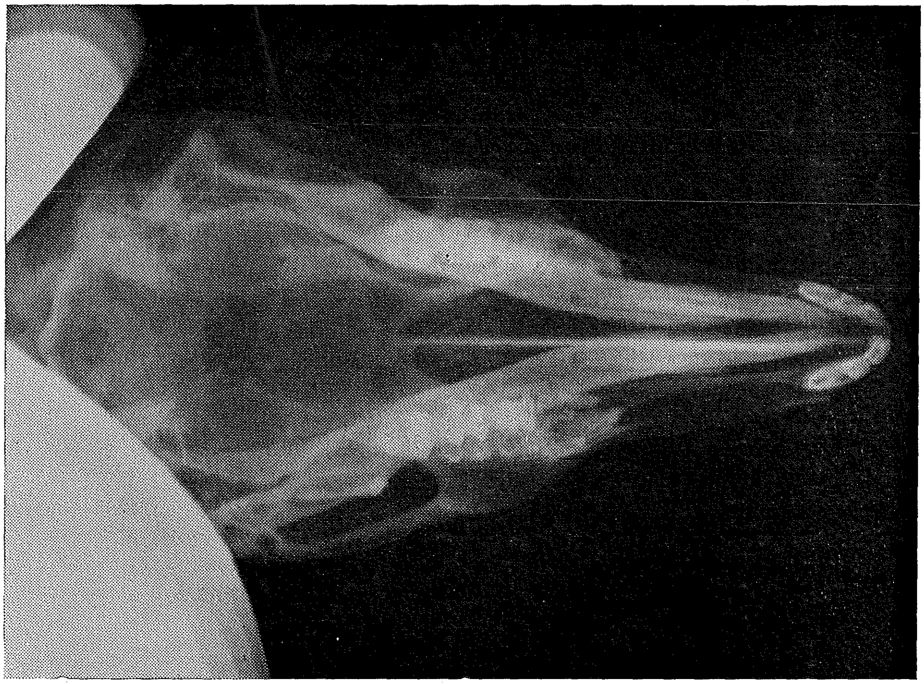

Fig. 1.—Radiograph of skull (x $\frac{5}{6}$) of a red-necked wallaby: age 2115 days; molar index 3.1.

Data have been secured from 56 grey kangaroos to 24 years, 16 eastern wallaroos to 11 years and 18 red-necked wallabies to 7 years. Data given by Sharman, Frith, and Calaby (1964) for the red kangaroo have been adapted, so far as circumstances would permit, to allow a preliminary examination of the relationship between molar index and age in this species. Confirmation of the accuracy of the relationship so obtained was provided by the molar indices of six specimens of known age held at Hermitage.

(c) Results

Pouch young.—Tail length and mean length of hind feet are plotted against age in scatter diagrams (Figures 2-4). Tables 1 and 2 were derived from these data by fitting lines through calculated averages, and allow mean ages to be read for any tail length or mean length of hind feet. Time of completion of pouch life is also indicated.

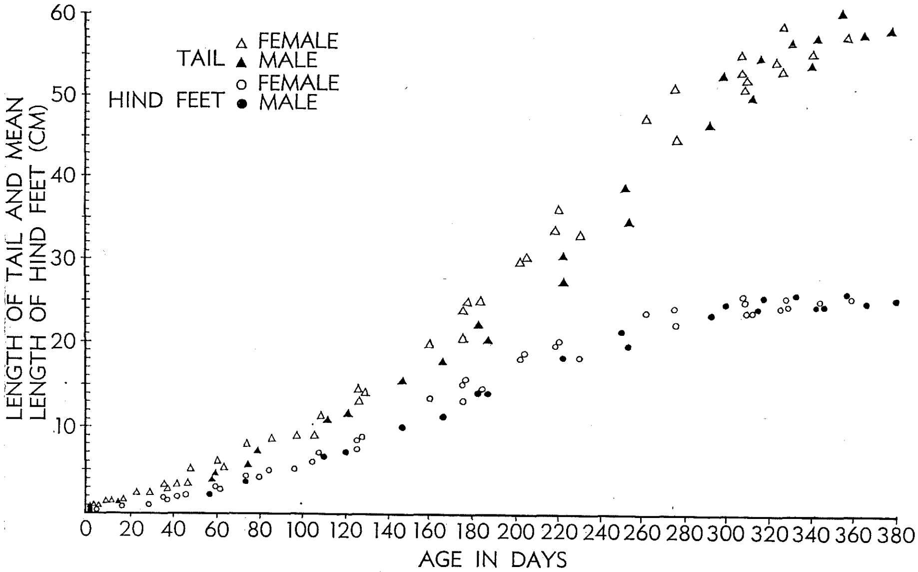

Fig. 2.—Pouch young of grey kangaroo: length of tail, mean length of hind feet, and age. Mean duration of pouch life, 297 days.

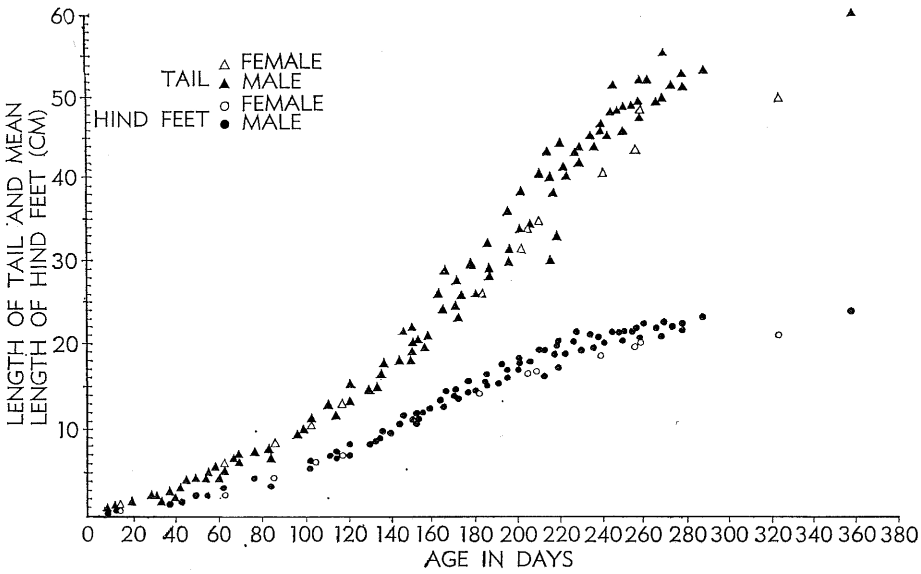

Fig 3.—Pouch young of eastern wallaroo: length of tail, mean length of hind feet, and age. Mean duration of pouch life, 254 days.

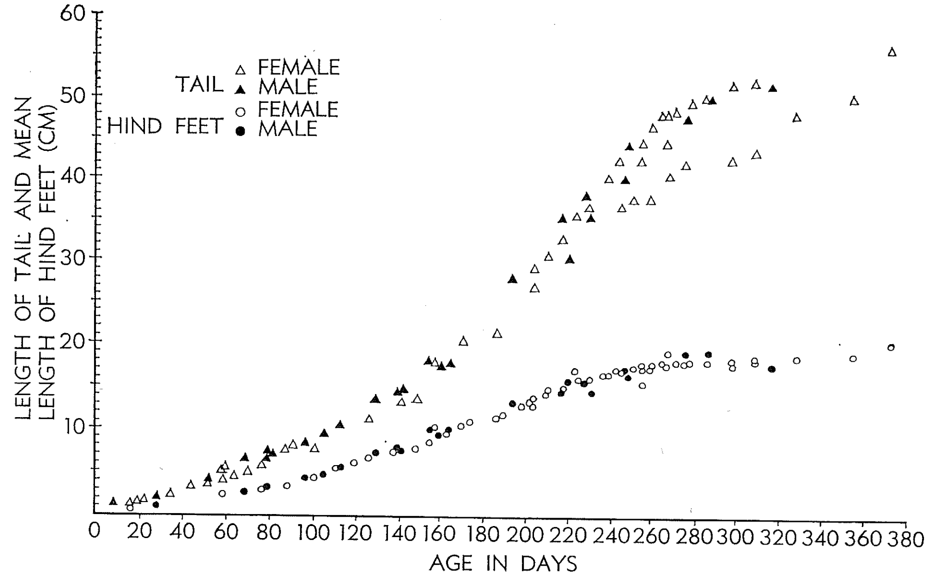

Fig. 4.—Pouch young of red-necked wallaby: length of tail, mean length of hind feet, and age. Mean duration of pouch life, 275 days.

TABLE 1

Ages of Grey Kangaroo, Eastern Wallaroo and Red-necked Wallaby Pouch Young Estimated from Length of Tail

Length (cm)	Grey Kangaroo		Eastern Wallaroo		Red-necked Wallaby	
	Age (days)	Days Added per Additional mm	Age (days)	Days Added per Additional mm	Age (days)	Days Added per Addtional mm
1	7	1·5	9	1·7	7	1·8
2	22	1·2	26	1·2	25	1·7
3	34	1·1	38	1·0	42	1·0
4	45	1·0	48	0·9	52	1·0
5	55	0·8	57	0·8	62	0·9
10	97	0·7	98	0·7	109	0·7
15	135	0·6	125	0·4	146	0·5
20	166	0·6	146	0·4	172	0·5
25	196	0·5	166	0·3	195	0·4
30	221	0·3	181	0·3	214	0·3
35	235	0·3	197	0·3	230	0·4
40	250	0·4	213	0·4	248	0·8
45	271	0·5	232	0·5	288	
50	293	0·8	257	0·6		
51	301	1·0	263	0·6		
52	311	1·0	269			
53	321	1·0				
54	331	1·0				
55	341	1·0				
56	351	1·2				
57	363					
Standard deviations (days) at ages:—	10	± 2	10	± 2	10	± 2
	50	± 4	50	± 3	50	± 4
	100	± 5	100	± 5	100	± 5
	200	± 13	200	± 9	200	± 7
	300	± 15	250	± 11	250	± 16

TABLE 2

AGES OF GREY KANGAROO, EASTERN WALLAROO AND RED-NECKED WALLABY POUCH YOUNG ESTIMATED FROM MEAN LENGTH OF HIND FEET

Length (cm)	Grey Kangaroo		Eastern Wallaroo		Red-necked Wallaby	
	Age (days)	Days Added per Additional mm	Age (days)	Days Added per Additional mm	Age (days)	Days Added per Additional mm
1	25	1·9	24	1·9	25	3·0
2	44	1·8	43	1·8	55	2·0
3	62	1·5	61	1·8	75	1·9
4	77	1·3	79	1·3	94	1·4
5	90	1·2	92	1·1	108	1·4
6	102	1·0	103	0·9	122	1·2
10	143	0·9	138	0·7	170	1·0
14	179	0·9	166	0·7	210	1·2
16	197	0·9	181	1·0	235	1·8
17	206	0·9	191	1·1	253	1·9
18	215	1·0	202	1·2	272	2·3
20	234	1·2	225	1·9	318	
21	245	1·2	244	2·2		
22	257	1·4	266			
23	271	2·4				
24	295	6·5				
25	360					
Standard deviations (days) at ages:—	10	± 2	10	± 2	10	± 2
	50	± 4	50	± 3	50	± 3
	100	± 5	100	± 5	100	± 5
	200	± 10	200	± 13	200	± 6
	300	± 17	250	± 15	250	± 15

Juveniles, subadults and adults.—The regression between molar index (M.I.) and log age (days) has been calculated for each species: the relevant equations, with 95% confidence limits, are as follows:—

Grey kangaroo: log age (days) $= 2 \cdot 4546 + 0 \cdot 2934$ M.I. Confidence limits (95%) lie between 15% and 16% of estimated age.

Eastern wallaroo: log age (days) $= 2 \cdot 2972 + 0 \cdot 3488$ M.I. Confidence limits (95%) lie between 21% and 26% of estimated age.

Red-necked wallaby: log age (days) $= 2 \cdot 2340 + 0 \cdot 3716$ M.I. Confidence limits (95%) lie between 17% and 20% of estimated age.

Red kangaroo: The equation derived from data adapted from Sharman, Frith, and Calaby (1964), was log age (days) $= 2 \cdot 211 + 0 \cdot 3604$ M.I. Confidence limits have not been estimated, as the related data were not from the same series of skulls.

Estimated and known ages of six red kangaroos held at Hermitage are given in Table 3.

TABLE 3

KNOWN AGES OF SIX RED KANGAROOS HELD AT HERMITAGE COMPARED WITH AGES ESTIMATED FROM MOLAR INDEX

Kangaroo No.	Molar Index	Known Age (days)	Estimated Age (days)
W 917	3·15	2,025	2,220
W 193A	2·1	1,035	929
W 759	1·5	562	565
W 758	1·5	560	565
W 191A	1·2	476	440
W 758A	1·15	427	422

All data for the grey kangaroo are illustrated in Figure 4.

Molar indices at 1-year intervals for the four species are given in Table 4.

TABLE 4

MOLAR INDICES OF GREY KANGAROO, RED KANGAROO, EASTERN WALLAROO AND RED-NECKED WALLABY AT 1-YEAR INTERVALS FROM 1 TO 20 YEARS

Age (years)	Molar Index			
	Grey Kangaroo	Red Kangaroo	Eastern Wallaroo	Red-necked Wallaby
1	0·36	0·97	0·76	0·88
2	1·39	1·80	1·61	1·69
3	2·0	2·29	2·12	2·16
4	2·42	2·64	2·43	2·50
5	2·75	2·91	2·76	2·79
6	3·01	3·13	2·99	2·97
7	3·24	3·31	3·18	3·16
8	3·44	3·48	3·34	3·31
9	3·61	3·62	3·49	3·45
10	3·77	3·74	3·62	3·57
11	3·91	3·86	3·74	3·68
12	4·04	3·96	3·85	3·78
13	4·16	4·06	3·95	3·88
14	4·27	4·15	4·04	3·97
15	4·37	4·23	4·13	4·05
16	4·47	4·31	4·21	4·12
17	4·56	4·38	4·28	4·19
18	4·64	4·45	4·35	4·26
19	4·72	4·52	4·42	4·33
20	4·80	4·58	4·49	4·39
Confidence limits	$\pm$ 0·2		$\pm$ 0·3	$\pm$ 0·25

(d) Discussion

Ages of pouch young of all species can be estimated closely to the end of pouch life from tail length and mean length of hind feet, and there are no differences between sexes. In practice, an average of ages estimated from both measurements should be used, as errors tend to be compensatory.

Molar index can be relied on into old age (see Figure 5); 95% confidence limits indicate that a grey kangaroo of estimated age of, say, 13 years would be almost certainly between 11 and 15 years: this is satisfactory for a field technique, as the number surviving in nature above an estimated age of 13 years is relatively small (Kirkpatrick, unpublished). A regression published previously for grey kangaroos between one and three years old (Kirkpatrick 1964)—Age (days) $= 219 \cdot 1 + 378 \cdot 0$ M.I.—has been confirmed by all data subsequently collected and is preferable for animals younger than three years (molar index of $2 \cdot 0$); the present regression covering the entire life of the animal involves some sacrifice of accuracy at the younger ages. Accuracy is less satisfactory in the other regressions; when more data are available, however, it should be possible to reduce the range of the 95% confidence limits. The equation for the red kangaroo is provisional only.

The rate of molar progression is indicated by the regression coefficient; evidently this is least in the red-necked wallaby and greatest in the grey kangaroo. Associated with the slower rates is the retention of the "permanent" premolar (P_4^4 of Tate 1948) for greater periods of time. In the red-necked wallaby and the eastern wallaroo, in fact, P_4^4 is rarely lost, often being retained after M_1^1 has been shed. It may be that this retention of P_4^4 led Thomas (1888) to state that molar progression did not occur in wallabies.

The applicability of these data from captive animals to wild specimens is supported by the following observations. Estimated ages of wild collected pouch young of all species with eyes just opening and pelage appearing, taken from a wide range of areas in Queensland, were the same as the ages at which these events occurred in captive animals. The molar indices of 21 grey kangaroos between one and two years of age accompanying their mothers, also collected from widely separated areas in Queensland, were found to be close to those expected if the ages of such animals could be assumed to equal the estimated age of the young in the mother's pouch plus one year, the normal interval between successive births (Kirkpatrick 1965). A further 20 juveniles of this species were found to have molar indices greater than expected; this could be simply explained by assuming that the mother either had failed to conceive at the first oestrus following eviction of the first pouch young, or had lost the second at an early age and had later given birth to a third offspring. Similar, but more limited, confirmatory data were available for the red kangaroo and the wallaroo: none was available for the red-necked wallaby, as a juvenile of this species rarely accompanies its mother for long (Kirkpatrick, unpublished).

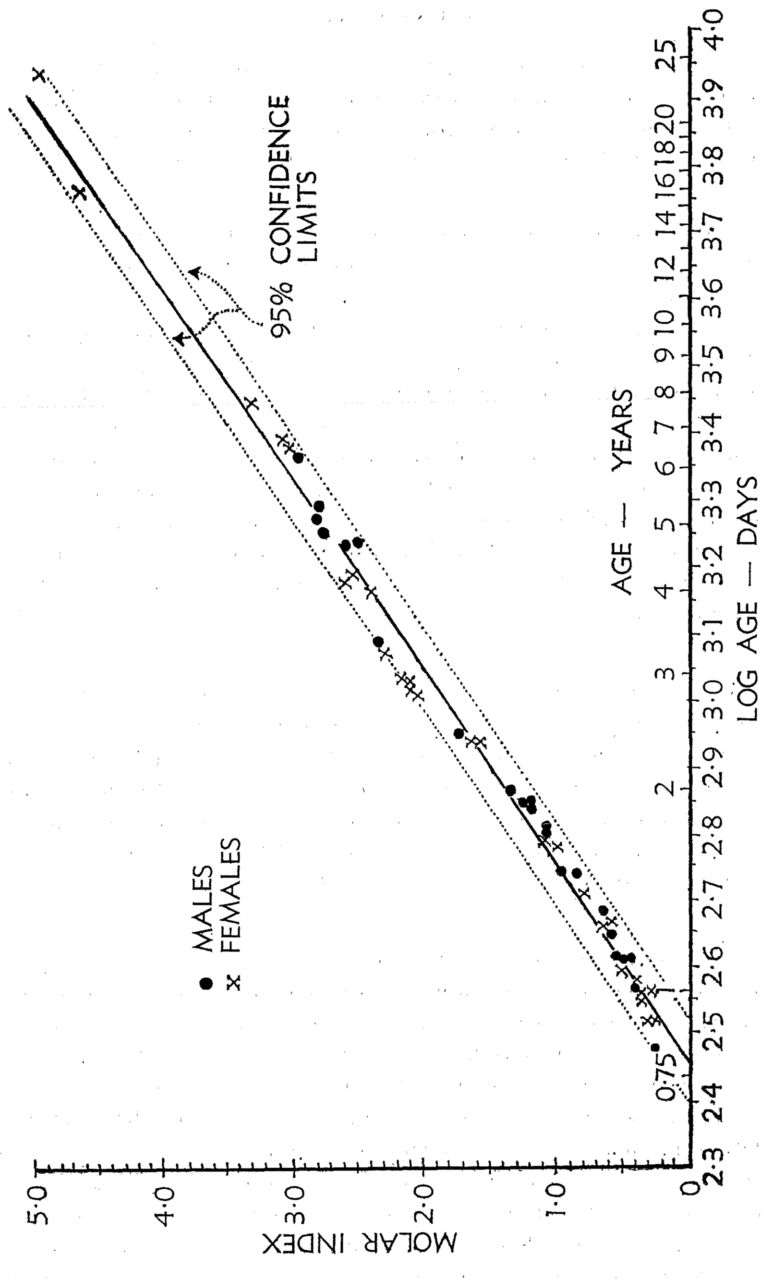

Fig. 5.—Grey kangaroo: regression of molar index on log age.

The greatest molar indices encountered in the field, with estimated ages, were as follows: grey kangaroo 4·8 (19·9 ± 3 years); red kangaroo 4·7 (22 years, limits not known); eastern wallaroo 4·4 (18·6 ± 4·5 years); and red-necked wallaby 4·3 (18·6 ± 3·4 years). As the normal maximum ages in captivity for all species are commonly given as from 15 to 20 years, these estimated ages for wild specimens are not unreasonable.

II. NOTES ON DENTAL ABNORMALITIES

(a) Introduction

Supernumerary and unerupted teeth are potential sources of error in the use of age-determining methods involving tooth identification and are also of interest to students of taxonomy and phylogeny.

(b) Normal Dentition

To describe abnormalities, the normal dentition must be defined. The dentition considered normal for each species follows the known macropod pattern (Thomas 1888; Tate 1948). The "permanent" dentition is usually described by the formula $I_1^3\ C_0^1\ PM_1^1\ M_4^4$.

The canine is vestigial and rarely persists beyond pouch life. The "permanent" premolar is usually called P_4^4, and is preceded by two others usually called P_3^3 and dP_4^4. P_3^3 and P_4^4 are sectorial teeth, dP_4^4 is molariform. P_3^3 and dP_4^4 are shed early in life, usually simultaneously but either may be shed before the other and the order of loss may differ among the four tooth rows in one animal. P_4^4 replaces dP_4^4 as this tooth is shed, which is simultaneous with the early eruption of M_3^3 in the red kangaroo, during the eruption of M_3^3 in the grey kangaroo, and some time between the late eruption of M_3^3 and the early eruption of M_4^4 in the eastern wallaroo and the red-necked wallaby.

Progression of the molar teeth in the jaws leads to progressive loss of the anterior teeth, particularly in the grey and red kangaroos; in the eastern wallaroo and red-necked wallaroo P_4^4 may remain until M_1^1 is shed. Aged specimens of all species have been found with only one or two rear molars remaining in each jaw.

(c) Dental Abnormalities

Deviations from the normal encountered in approximately 1500 skulls of the four species collected from southern Queensland during 1959-1964 are listed in Table 5; some are illustrated (Figures 6-11). The number of skulls examined in which each abnormality, if present, could be detected is given as a measure of the frequency of its occurrence. For example, only skulls with M_4^4 more than half erupted could be scored for the presence or absence of partial sets of M_5^5 (i.e. additional molars present in some, not all, of the four possible positions), and only skulls with all P_3^3 and dP_4^4 still present were scored for the presence of additional premolars. No measure could be given of the frequency with which P_4^4 failed to erupt.

TABLE 5

DENTAL ABNORMALITIES AND FREQUENCIES OF OCCURRENCE IN GREY KANGAROO, RED KANGAROO, EASTERN WALLAROO AND RED-NECKED WALLABY

Tooth Series	Description of Abnormality	Grey Kangaroo		Red Kangaroo		Eastern Wallaroo		Red-necked Wallaby	
		No. of Skulls		No. of Skulls		No. of Skulls		No. of Skulls	
		Examined	Abnormal	Examined	Abnormal	Examined	Abnormal	Examined	Abnormal
Canine ..	Prominent canine on L. maxilla (Fig. 6)	811	..	211	..	139	..	314	2
Premolar ..	Single cusped premolar on both maxillae with diastema between it and P^3 (Fig. 7)	300	..	84	..	71	1	106	..
	Sectorial premolar on one maxilla, immediately anterior to P^3 (Fig. 8)	300	..	84	..	71	2	106	..
	Unerupted P^4 on both maxillae (Fig. 9)	..	10	..	1	..	..	..	..
	Unerupted P^4 on one maxilla	..	8	..	..	..	..	..	1
Molar ..	Paired M^5 on maxillae (Fig. 10) ..	219	4	57	4	30	..	164	..
	Paired M_5 on mandible	219	1	57	..	30	1	164	..
	M^5 on one maxilla (Fig. 11)	219	2	57	2	30	..	164	2
	M^5_5 on one maxilla, one mandible ..	219	1	57	..	30	..	164	..
	Paired M^5 on maxillae, M_5 on left mandible	219	1	57	..	30	..	164	..
	M^5 on right maxilla, paired M_5 on mandible	219	1	57	..	30	..	164	..

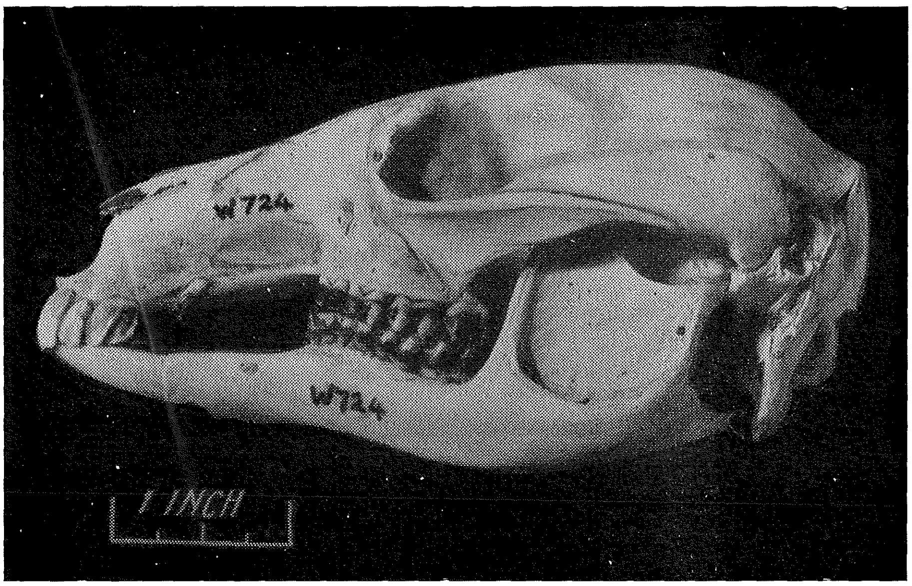

Fig. 6.—Red-necked wallaby: canine-like tooth on left maxilla.

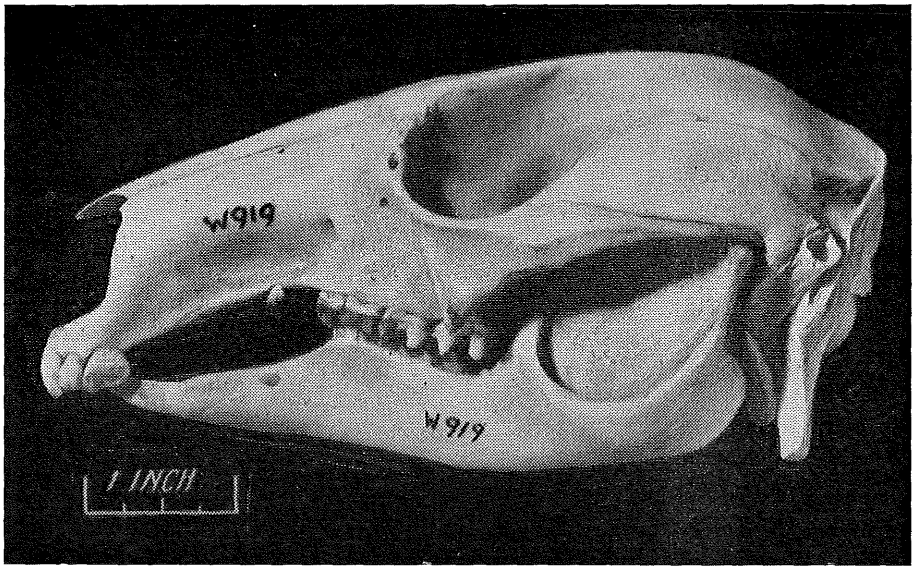

Fig. 7.—Eastern wallaroo: supernumerary single-cusped premolars anterior to P^3 on both maxillae.

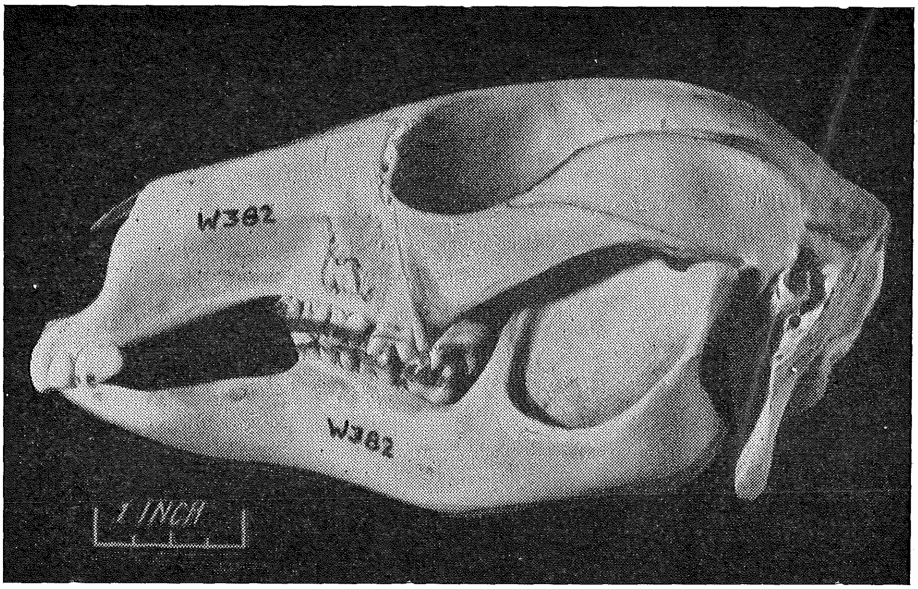

Fig. 8.—Eastern wallaroo: supernumerary sectorial premolar anterior to P^3.

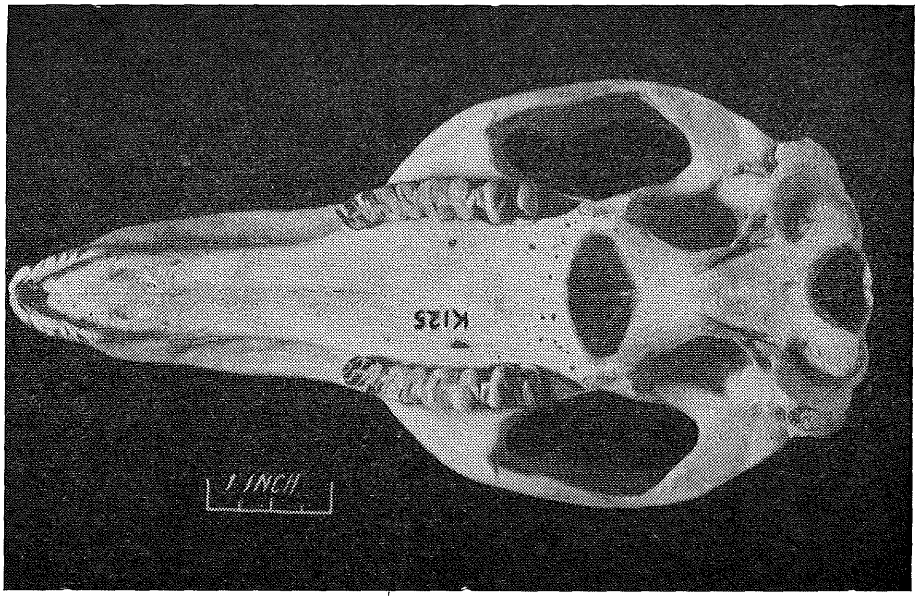

Fig. 9.—Grey kangaroo: P^4 failed to erupt; persistent dP^4.

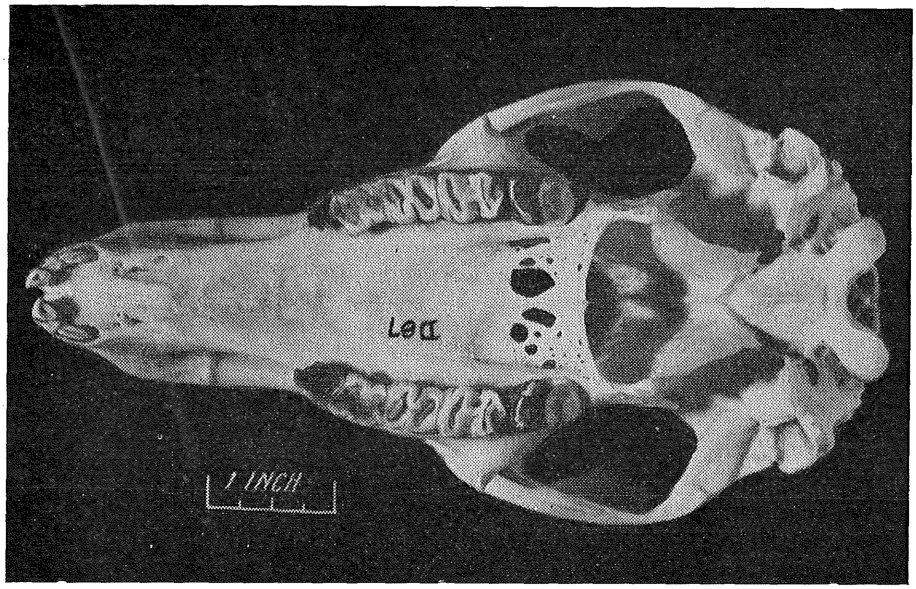

Fig. 10.—Red kangaroo: paired M^5.

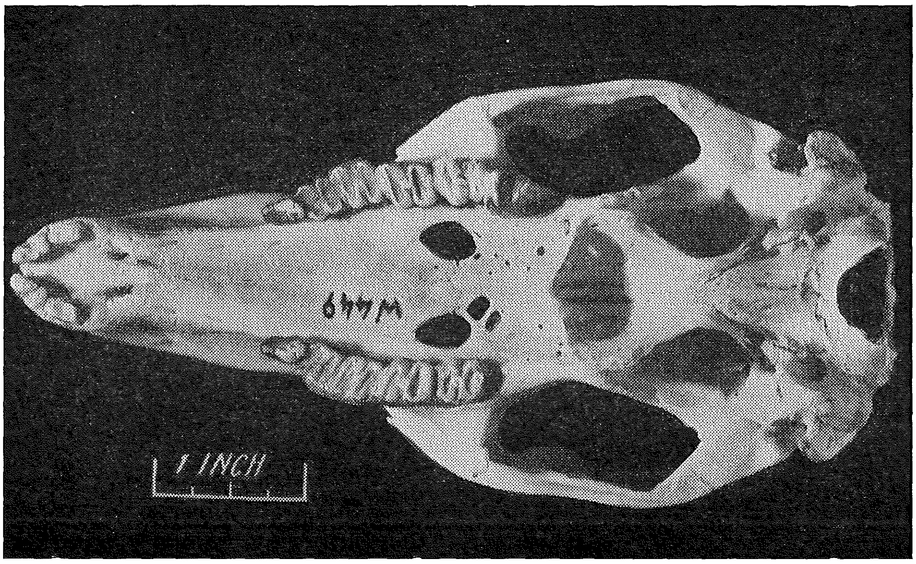

Fig. 11.—Red-necked wallaby: M^5 on left maxilla only.

Well-developed canines (Figure 6) have been found only in the red-necked wallaby and supernumerary premolars (Figures 7 and 8) only in the eastern wallaroo. These abnormalities are of possible taxonomic and phylogenetic interest, particularly the premolars, which are in two positions. Confusion could be caused in the estimation of age in specimens with such premolars, as two sectorial premolars are likely to be identified as P^3 and P^4. Specimens of the grey kangaroo with unerupted P^4 are not uncommon; in such specimens dP^4 usually remains long after it would normally have been shed and can easily be mistaken for M^1 (Figure 9). The frequency of this condition may be linked with the obviously non-functional nature of P^4_4 in this species.

Paired M^5 are not uncommon in the grey and red kangaroos and are likely to cause confusion, particularly as identification is often impossible unless both upper and lower jaws can be compared. Even when five molariform teeth are present, the first tooth may be identified as a persistent dP^4_4 rather than as M^1_1. Full sets of M^5_5 could not be detected once P^4_4 and M^1_1 were shed, and in fact no skull with this condition positively identified is available, probably because numbers of suitable skulls (with P^4_4 present in at least one toothrow, M^4_4 more than half erupted) have been low in those species where supernumerary molars are common. Several skulls are held, however, in which incisor wear and general bone fragility are such as to make age estimated from molar index much lower than expected unless fifth molars were present in all positions. Skull No. CM695, from a 24-year-old animal, is an example. The great age of this animal, together with the extraordinarily low molar index were fifth molars not present, and the comparatively unworn condition of the remaining molars, can be explained satisfactorily only by postulating the presence of a full set of M^5_5.

The incidence of these confusing abnormalities is such, particularly in the grey and red kangaroos, as to represent a real source of error and should be allowed for in data secured by oral examinations.

III. ACKNOWLEDGEMENTS

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