WILDLIFE
RESEARCH
BULLETIN
WESTERN AUSTRALIA

Number **13**

EXPLOITATION OF KANGAROOS AND WALLABIES IN WESTERN AUSTRALIA

I. A Review to 1970, with special emphasis on the Red and Western Grey Kangaroos.

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R. I. T. PRINCE

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Wildl. Res. Bull. West. Aust. 1984, No. 13

ISSN 0726 – 0725
ISBN 0 7309 0337 0

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EXPLOITATION OF KANGAROOS AND WALLABIES IN WESTERN AUSTRALIA

I. A Review to 1970, With Special Emphasis On The Red And Western Grey Kangaroos

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ABSTRACT

An overview is presented of developing knowledge of the occurrence, distribution and abundance of kangaroos and wallabies in Western Australia from the time of first European contact, and the European reaction to and subsequent impact on the populations of several species from the time of the first permanent settlement in the South West in 1829 up until the close of the 1960s decade is described.

This review includes: an assessment of the abundance of kangaroos in different parts of the State prior to closer settlement and the intensive development of the country by the European settlers; an examination of the attitude of the European settlers to exploitation of the kangaroos and wallabies in the first instance and the subsequent changes in patterns of exploitation and in attitudes flowing from the increasing alteration of the natural landscape; consideration of the changing impact of direct exploitation on the hunted kangaroo and wallaby populations with the passage of time; and a consideration of the possible interaction between continued commercial exploitation and other factors which most probably contributed to observed changes which occurred in the status of some of the exploited south-western species after the late 1920s. Findings are related to needs for continuing management of the Red and Western Grey Kangaroo populations within Western Australia.

The Western Grey Kangaroo was extremely abundant at various places throughout its range within the present agricultural areas of southern and south-western Western Australia at the time of first European settlement, and contrary to much popular belief the evidence also suggests that the present relatively high abundance of kangaroos (by Western Australian standards) within parts of the State's arid pastoral rangelands is not a phenomenon solely attributable to the advent of the pastoral industry. Circumstantial evidence does however suggest that the pastoral industry has favoured some general increase in the total abundance of the Red Kangaroo to date.

Exploitation for commercial trade has figured largely in the interaction between the State's kangaroos and wallabies and European man since the time of settlement, but the general attitude of the new landholders and users has always tended to the view that kangaroos and wallabies are almost worthless pests rather than being a valuable living resource. Past legislation bearing on the exploitation and management of this segment of the fauna reflected the dichotomy between practice and opinion as described, but had little real impact on the course of events that followed. It is only in recent times that the concept of wildlife conservation has come to the forefront of official opinion and that related legislation has exerted some positive controls on exploitation.

Quantitative analyses of the patterns of variation in past commercial exploitation of the Red and Western Grey Kangaroos and the Brush Wallaby have shown that harvesting of Red Kangaroos from pastoral rangelands in Western Australia can be managed as a sustainable operation capable of exerting effective and necessary control over the total numbers of kangaroos sharing the rangelands with the pastoral industry while simultaneously furthering the interests of wildlife conservation.

In contrast, populations of the Western Grey Kangaroo in south-western Western Australia have almost certainly been reduced in abundance since the 1930s. Further population reduction and fragmentation is inevitable in the face of continuing agricultural development in this area, but surplus kangaroos displaced by new farmland development projects will continue to be disposed of by farmers. Carcases of these may be passed through to the commercial trade as in past years along with the excess numbers produced by the residual kangaroo stocks remaining in areas of natural habitat interspersed with developed farmland. Conservation of the Western Grey Kangaroo will best be served by a programme aimed at maintaining local populations of the species in this changed and still changing environment. Management of numbers present on farms and within the general farming areas is necessary.

The transient, but at times substantial, exploitation of the Western Australian Brush Wallaby during the first thirty years of the 20th Century was not a simple case of excessive direct exploitation reducing the species' populations to a low level. The picture obtained reflects that end of the spectrum of human impact on wildlife populations where wholesale environmental changes have engulfed the major part of a species' population (and range) within a short time with the displaced animals being disposed of largely via commercial trade. The evidence to hand thus suggests that commercial exploitation did not primarily influence the change in status of this wallaby or of other south-western fauna species that were exploited in times past, but it seems most likely that heavy direct exploitation at critical times in the history of

such species could present a real conservation hazard. Commercial exploitation of wildlife is thus not without risk, but practical management of the still abundant and widespread populations of the State's larger kangaroos is required and is best served by allowing commercial disposal of excess stocks. Management incorporating this use is acceptable provided the risks are taken into account and adequate control is exercised by the responsible authorities.

1 GENERAL INTRODUCTION

Exploitation of kangaroos and wallabies for commercial trade was a subject of considerable public debate in Australia during the 1960s and early 1970s (e.g. Australian Conservation Foundation 1967, 1970; Australia. Parliament. 1971; Australia. Department of Environment, Housing and Community Development 1977; Poole 1978), but much of this debate was clouded by the paucity of definitive information on the extent of commercial exploitation at that time and its real impact on the target kangaroo populations. Some unfortunate examples of past exploitation of other native fauna, e.g. the Koala (Phascolarctos cinereus) increased the misgivings of the concerned members of the public in regard to the possible course of continuing exploitation of the kangaroos whilst lack of readily available data on exploitation of kangaroos in most States in earlier times also prevented knowledge of exploitation that was then available from being considered in its proper context (see Ride 1970, Ch. 2 and Ch. 5 also).

Large scale commercial exploitation of kangaroos at the levels attained during the 1960s was apparently thought by some of the opponents of exploitation, e.g. Serventy (1971), to be a new phenomenon. On the other hand, representatives of farmers and pastoralists held to some extremely subjective opinions on the abundance of the different kangaroos and also the ability of the kangaroo populations to withstand unrestrained exploitation. In fact, the extreme views of both groups mentioned above in regard to exploitation of the kangaroos were incorrect. The commercial exploitation of kangaroos for the skin trade had its origins in the 19th century (e.g. Livanes 1971), and it was only the resurgence of the kangaroo trade in the 1960s and the change in emphasis of exploitation at this point following the substantial collapse of the kangaroo skin trade in the early 1950s (e.g. Doohan 1971) that focussed wider public attention on management and conservation of the kangaroos.

The major debate in the 1960s was centred in south-eastern Australia, viz. Victoria and New South Wales, but the setting of this debate and the matters raised were equally applicable to the Western Australian situation.

Knowledge of the biology and ecology of the Red Kangaroo (Macropus rufus; see Kirsch and Calaby 1977) available by the late 1960s (summarized by Frith and Calaby 1969) was sufficient to permit the development of a conservation orientated management policy for the species in Western Australia (Prince 1984). State management policy for the Western Grey Kangaroo (Macropus fuliginosus) was also reviewed in the early 1970s in light of more recent knowledge, but the history of prior exploitation of these two kangaroos in Western Australia remained hidden. Discussion on past patterns of abundance and distribution of the exploited kangaroos in comparison with their apparent status in Western Australia in the late 1960s was also based largely on personal opinions rather than independent records of observations.

In this paper I have attempted to document accumulated knowledge of kangaroo abundance, developing patterns of exploitation, and the human attitudes and actions affecting this situation in the State of Western Australia prior to 1970. The major segment of this work involved historical research. Information was sought mainly from published accounts of explorations, copies of private diaries and official records in the Western Australian State Archives (Battye Library), and from legislation and the associated reports of Parliamentary debates. The information obtained has provided the basis for analyses aimed at interpreting past patterns of exploitation, and these analyses have permitted the patterns of exploitation and changes in abundance of the different species of kangaroos and wallabies dealt with to be placed in their proper perspective. The findings are discussed in relation to ongoing management and exploitation of kangaroos in Western Australia.

II THE OCCURRENCE AND EARLY ABUNDANCE OF KANGAROOS IN DIFFERENT PARTS OF WESTERN AUSTRALIA : FIRST REPORTS AND KNOWLEDGE FROM EARLY EXPLORATION

A. INTRODUCTION

Public debate within the past 15 - 20 years concerning the possible impact of human exploitation on the kangaroo and wallaby populations of Australia has centred mainly on the subject of commercial exploitation and thus refers to a post-European settlement sequence of events. It is nevertheless apposite to remember that exploitation of kangaroos by man pre-dated European settlement in Australia and that the prior activities of Aboriginal man most probably had had a profound influence on the composition of the Australian flora and fauna present around the time of first European settlement (see Merrilees 1968), although even more radical changes in the Australian fauna have certainly occurred since (see Ride 1970). Some of these modern changes at least may be ascribed to European excesses (e.g. Marshall 1966).

The fact that human exploitation of the kangaroos and wallabies certainly changed following European settlement in Australia and that the occurrence of such changes is considered common knowledge does not however constitute an adequate assessment of the possible impact of single factors such as an apparently increased level of exploitation on different kangaroo and wallaby species at different times during the past 150 - 200 years in relation to the present status of these animals. This assessment requires more detailed information on both past and present kangaroo populations, the levels of exploitation imposed, and the effects on the populations concerned of additional contributory factors which could also have influenced their present situation.

In this section of the paper I briefly review the growth of knowledge of the Western Australian kangaroos and wallabies prior to the first European settlement and then document the increase in knowledge of abundance and distribution of some of these animals in the early years following settlement in, and then organized exploration of different parts of the State.

B. KNOWLEDGE OF OCCURRENCE, ABUNDANCE AND DISTRIBUTION

1. First Reports of Occurrence

Early European visitors to the southern parts of Western Australia reported the presence on islands of three of the smaller species of macropodids (see Alexander 1914; Frith and Calaby 1969, pp. 1-3), but the presence of the larger kangaroos in south-western Australia was not reported until much later visits by coastal explorers [e.g. Vancouver 1791; Riche 1792; Flinders 1802; King 1818 (see Alexander 1916)]. However, the kangaroos and wallabies were already well known to the Aboriginal inhabitants of Australia prior to permanent European settlement in Western Australia.

2. Reports Following First Settlement

The first European settlement in what is now the State of Western Australia was at Albany on King George Sound in 1826 (Garden 1977), and was followed soon after by founding of the Swan River Colony (Perth) in 1829 (Appleyard and Manford 1979, Chs. 4 & 5).

Exploratory forays made by some of the earliest colonists into the hinterland around King George Sound showed that kangaroos were then generally abundant in that area, e.g. Wilson (1829), Collie (1831, 1832). This assessment was soon supported by the reports of explorers seeking a suitable overland route between Albany and Perth, after 1829. These overland explorers also reported an abundance of kangaroos in the Kojonup area, and further southwards, as well as in other places along the way, e.g. Roe (1835a & 1835b), Hillman (1836).

In the early years following settlement at Perth, other explorers also ventured into the lower south-west corner of the State, and eastwards from Perth across the Darling Scarp. Some of these commented on the local abundance of kangaroos, e.g. Preston (1831), Bussell (1831a & 1831b), Ludlow (1834), and Shenton and Wells (1837), in the lower south-west; and Erskine (1830), Dale (1830), and Smith (1834), in the country to the east of Perth. Hillman (1835a & 1835b) also reported an abundance of kangaroos in the Hotham-Williams area. Further references can be found in the diary of George Fletcher Moore (1884; see also Alexander 1918).

None of the explorers above were recognised naturalists, but the descriptions given in their reports for the localities where kangaroos were considered to be abundant, and the notes they made on their observations of kangaroos leave no doubt that kangaroos were truly abundant in the south-west corner of the State in the years immediately following European settlement in Western Australia.

The impressions gained from the reports in diaries of these explorers are also confirmed by comments and reports made by experienced naturalists soon after (c. 1840s). Thus, James Drummond, the Colonial Botanist, noted in correspondence to Sir William Hooker at Kew Gardens (1839) that kangaroos were seen in hundreds on the sandy plains of the Guangan (Toodyay-Wongan Hills district) and around the Salt River (near Goomalling); while John Lort Stokes visited King George Sound in 'HMS Beagle' in November 1840 and reported on "the great abundance in which the kangaroo is found (in this neighbourhood). I am certain that there could scarcely have been less than a hundred in a herd". (Stokes 1846, Vol. 2, p. 231).

Figure 1. Western Australia - Localities Map. Areas of the State designated as the **Kimberley, North West, South West,** and **Eucla** refer to 'Land Divisions' as defined by State Legislation. The boundaries are indicated '---' plus a date. **1887** indicates the boundary defined by the 'Land Regulations, 1887', **1933** the boundary defined by the 'Land Act, 1933'. For further details of Regions defined within Western Australia see Figures in Ch. 1 of Gentilli (Ed.) (1979). 'Western Landscapes'. (UWA Press : Nedlands).

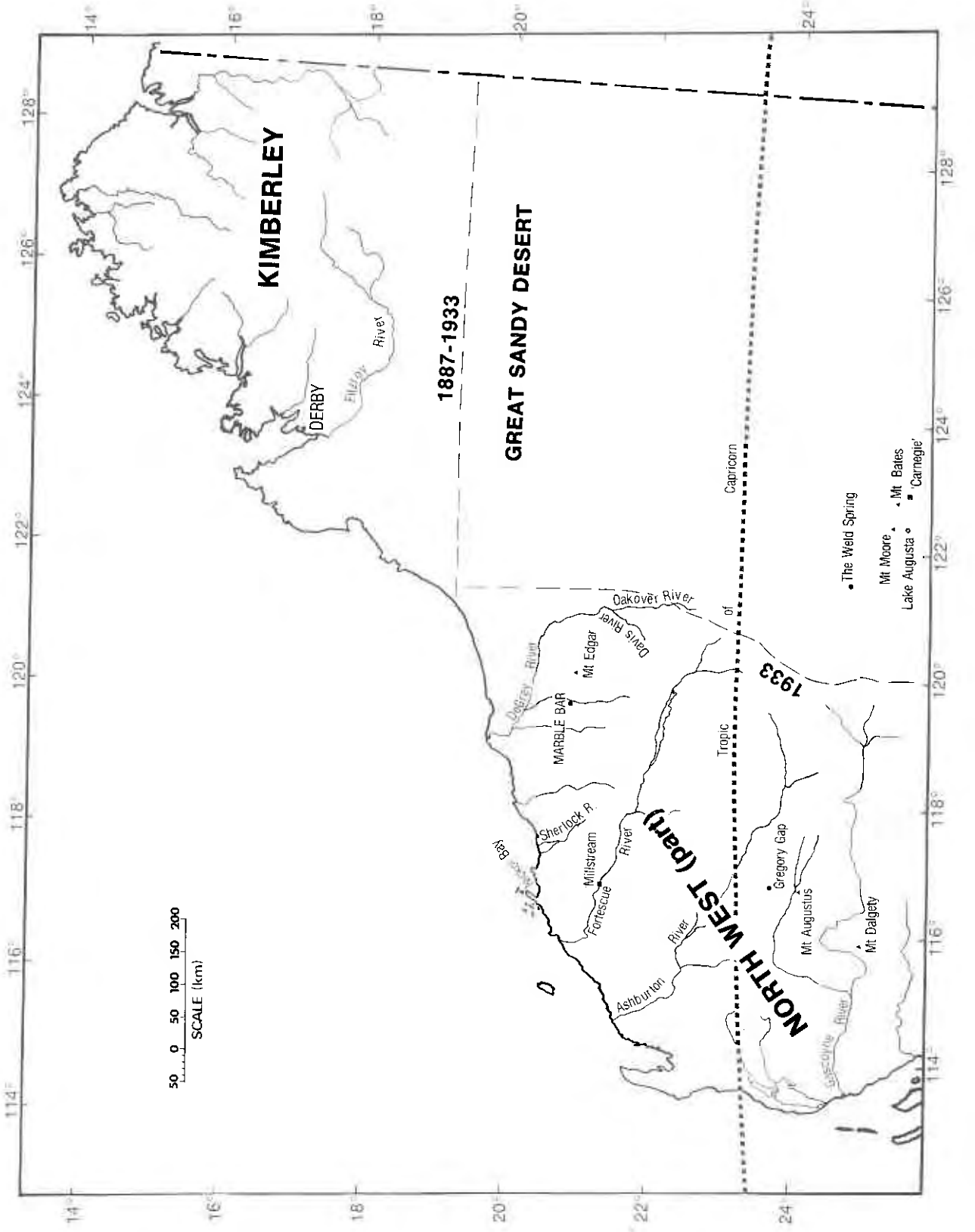


Figure 1a. Western Australia - Northern Half.

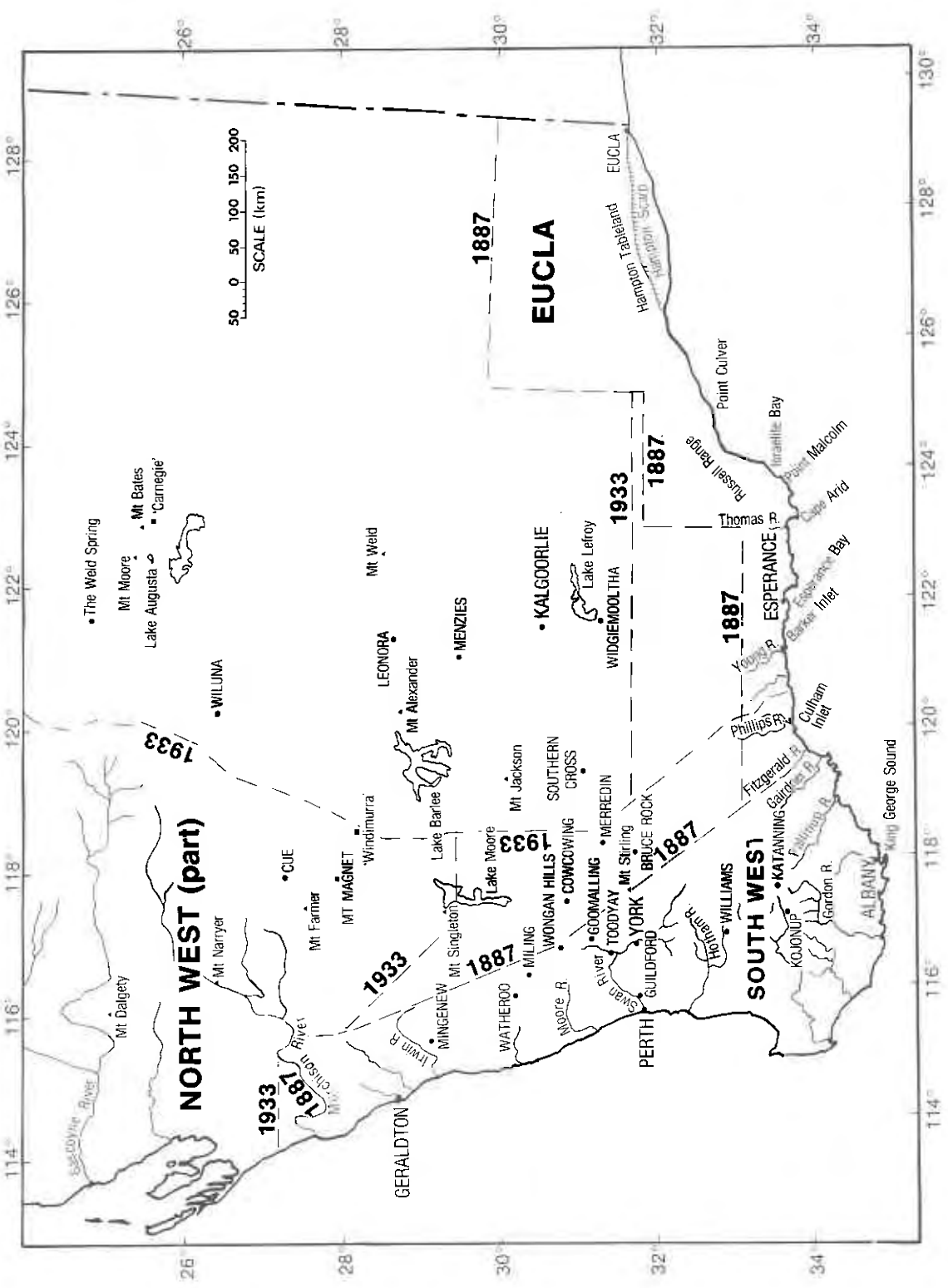


Figure 1b. Western Australia - Southern Half.

The most comprehensive synopsis of kangaroo abundance about the time of settlement is given by John Gilbert, who collected material in Western Australia for John Gould between March 1839 and February 1840, and again between July 1842 and December 1843. In a letter to Gould from Perth dated March 27, 1843, he wrote as follows "The large Grey Kangaroo is tolerably abundant over the whole Colony of Australia, from King George's Sound, South, to forty Miles North of Moore's River, North the furthest point I have been. It does not appear to confine itself to any peculiar description of Country, being as often seen in Gum Forests among the Hills as on the open Plains and clear grassy Hills; (but) It is certainly more numerous in the open Spots of Country, where it is not so liable to sudden surprise. In travelling along the Road, from Guildford to York, two to four or five may occasionally be met with, but further in the Interior, particularly Gwangan Plains, herds of thirty to Fifty may often be met with, but further South, beyond Kojonup they are more numerous, In fact I have never seen in any part of Australia, so large a Herd as I once met with on the Garden (sic = Gordon) Plains in 1840. There could not have been less than 500 Kangaroos, speaking in the utmost moderation; Several others of the Party, in their astonishment considered them even a greater number than I have stated". (Wagstaffe and Rutherford 1955; cf. the similar rendition in Gould 1973, p. 8).

The Western Grey Kangaroo (Macropus fuliginosus; then referred to colloquially as 'kangaroo' or 'common kangaroo') was abundant in the south-west corner of Western Australia in the years immediately following settlement, and apart generally from the smaller species of macropods in this area, was the only kangaroo known to the early settlers until exploration was extended much further afield. This work gained momentum in the later 1840s, and continued into the early part of the 20th century.

3. Results of Further Exploration and the Expansion of Settlement

Extension of exploration outside the first, and still the most fully, occupied south-western corner of the State was generally directed to discovery of additional grazing land (see Gregory and Gregory 1884, pp. 1-2; and others). It is important that this point is emphasised, because the reports now available were in the main written by non-naturalists searching for new grazing land. This fact, and the limited number of exploration reports, poses difficulties in assessing the status of kangaroo populations outside the lower south-west around the time of European settlement. Sufficient information is however available to allow for a limited appreciation of the kangaroo populations in the different areas being traversed. For convenience, these new areas may be dealt with under three general heads, viz. the south coast and the Eucla Land Division; the Eastern Goldfields and the north-eastern pastoral areas; and areas to the north of Perth, and further into the North West and Murchison pastoral areas (see Fig. 1 for localities mentioned in this text).

The tracks followed by the explorers travelling further away from Perth initially took them through areas occupied primarily by the Western Grey Kangaroo. Eyre's journey along the southern coast from Adelaide to Albany in 1841 (Eyre 1845) also took him through Western Grey habitat. We can, therefore, start by building on the previous information regarding the status of this species.

Eyre's push westward along the south coast into Western Australia was commenced from a camp site near the Head of the (Great Australian) Bight, just to the east of the line of cliffs extending westward to near the W.A. - S.A. border. Kangaroos (certainly Western Greys) were numerous in this area (p. 286; January 10), and remain so. However, the narrative contains no further mention of kangaroos until March 27 (p. 351), when Eyre was more than 160 km west of the border and forced to travel along the beach front. This next comment is included in a general discussion regarding habitat use by the wildlife, and the ability of the Aborigines to live in areas apparently inhospitable to European eyes. It seems likely that Eyre would not have been surprised if kangaroos were found in the woodlands below the Hampton Scarp, although he apparently saw no more kangaroos or wallabies until April 1 (p. 368, et seq., to p. 397), when camped at water more than 70 km further westward. The 'wallabies' seen and shot in this area cannot be positively identified from the text.

John Forrest (1875) camped at this same site in June 1870, and thence continued eastward to Eucla. Unlike Eyre, however, Forrest traversed the plain above the Hampton Scarp in this sector. Nevertheless, Forrest's party procured two small kangaroos "(the first we have shot since leaving Israelite Bay)" within two days travel from this campsite (p. 110, June 26), and Forrest later summarized his observations made over the remainder of this sector in a letter written at Eucla on July 7, 1870 (p. 117; "very little game exists along the route, a few kangaroos were seen, but no emus - an almost certain sign, I believe, of the scarcity of water.)"

The two accounts given by Eyre and Forrest thus provide a consistent picture, despite their journeys being separated by nearly 30 years, their tracks not coinciding, and their published reports appearing generally to omit specific daily references to all fauna they may have seen. This latter feature of these two reports appears characteristic of most exploration journals, and is worth re-emphasis here.

The tracks followed by Eyre and John Forrest were also similar further westward, from Point Culver to Culham Inlet. Eyre camped for six days near Point Malcolm, and found kangaroos to be reasonably abundant in that area, and towards Cape Arid and the Russell Range (Eyre 1845, Vol. 2, Ch. 3, to p. 53). Roe (1848-9) also travelled out as far east as the Russell Range, and noted that kangaroos were again met with within 20 miles (32 km) of these ranges on his westward journey. John Forrest's party shot a kangaroo

near Point Malcolm (J. Forrest 1875, p. 93), and Alexander Forrest's (1872) party shot three kangaroos (two at Thomas River) on their way from west of the Russell Range to Esperance Bay. These observations are again consistent, and suggestive of an abundant kangaroo population in the above area. Eyre's comments also suggest that he may have seen and shot at least one other species, apart from the Western Grey.

Eyre also reported (Vol. 2, p. 73) an abundance of kangaroos near Rossiter Bay (to the east of Cape le Grand). Earlier, Riche, and other members of D'Entrecasteaux's expedition reported seeing numbers of kangaroos in the vicinity of Esperance Bay (late 1792; see Alexander 1916). The Dempsters had already settled at Esperance prior to the Forrest's expeditions (Rintoul 1964, pp. 26-7).

Further westward, kangaroos were noted in abundance around Barker's Inlet (Gage River, Roe 1848-9; J. Forrest 1875, p. 87), the Young River (A. Forrest 1872) and Phillips River areas (Roe 1848-9, p. 182, 'kangaroos were very numerous on the open downs'; A. Forrest 1872), and generally within the present Fitzgerald River National Park (Eyre 1845, Vol. 2, pp. 99-100; Roe 1848-9). Roe also noted that the area south of the Gairdner River inlet (Gordon Inlet) was abounding in kangaroos; and, when returning to Perth, that country between the Pallinup River and Kojonup 'teemed with kangaroos' (p. 211). Gregory (1849, p. 235) also reported that kangaroos swarmed in the open forests around the Beaufort River near Kojonup.

Explorers travelling eastward from Perth into the area now known as the Eastern Goldfields found kangaroos in abundance in the general Kalgoorlie - Widgiemooltha - Lake Lefroy area, including areas further eastward in the vicinity of the north-eastern section of Lake Lefroy, e.g. Hunt (1864, 1866), A. Forrest (1872). It is clear from these reports that Western Greys were seen, as well as animals of at least one other species. Hunt noted in his reports seeing 'red kangaroos' in numbers "in the neighbourhood of the ironstone hills" (1864), and later that "these animals ... locate themselves on the most sterile ranges and hills" (1866, p. 140); but he also recorded shooting "a fine kangaroo of fawn colour, ... - the first I have seen of this species", and seeing numerous kangaroos "of various species - red, fawn and the ordinary grey" on another occasion. Hunt's identifications seem to be confused in regard to distinction between true Red Kangaroos (Macropus rufus) and Euros (M. robustus), but he apparently encountered both species. Alexander Forrest's report (1872) corroborates Hunt's observations on kangaroo abundance in this area, but adds nothing further to the picture regarding species abundance.

In his reports, Hunt also noted that kangaroos were scarce between Mt Stirling and the area above. In this respect, his observations support those made by Dempster (1861), Lefroy (1863), and Clarkson et al. (1864) regarding the general scarcity of kangaroos once they had passed eastward of the present Bruce Rock - Merredin district. Unlike Hunt, however, the latter three parties travelled further north-eastward, into the Southern Cross - Mt Jackson area.

Although the first European visitor to Mt Jackson, A. C. Gregory (in 1846) made no comment on the fauna (Gregory and Gregory 1884, p. 4), the reports of each of the above three later parties, e.g. Dempster, Lefroy, and Clarkson et al. make mention of either seeking to shoot a 'red' kangaroo among hills, or of having seen 'red' or 'dark red' kangaroos in these situations. The comments made make it clear that these observers were familiar with the Western Grey, but had not previously seen a Red Kangaroo. The animals being referred to in this instance were almost certainly male Euros. Apparently, neither these nor any other kangaroos were particularly abundant in this area but Lefroy (1863) suggests that Tammar wallabies (Macropus eugenii) may have been abundant in the scrub to the south of Southern Cross.

The country immediately to the north of the Southern Cross - Mt Jackson area was explored by John Forrest in 1869. Forrest's party traversed the area extending eastwards from the northern end of Lake Moore to Lake Barlee, and thence through the Leonora district to east of Mt Weld.

Generally, John Forrest's comments on the fauna are not comprehensive. Most seem to be simply a record of animals killed (mostly by the Aboriginal members of the party) and eaten, rather than attempts to provide an account of the diversity and abundance of the fauna. Thus, records of kangaroos being killed may not only provide evidence of the presence of particular species, but also imply a reasonable abundance, when the apparent difficulty in shooting kangaroos while travelling, and the lack of a positive incentive to hunt while food rations held out, is taken into account. Forrest records taking two 'red' kangaroos, one at Two Springs near Mt Alexander and the other near Mt Malcolm, and four 'rock' kangaroos to the south of Mt Leonora (J. Forrest 1875, pp. 44-52). He also recorded later shooting another three 'rock' kangaroos while proceeding to climb Mt Singleton (p. 63), and a kangaroo (p. 66) in the vicinity of Cooroo (sic = Coordoo) Springs to the south-east of the present town of Miling. The term 'rock kangaroo' may have been used by Forrest at this time to describe the Euro, but it is possible that he could have been referring to a rock wallaby (Petrogale sp.; see below). The 'kangaroo' noted in the latter instance certainly would have referred to the common Western Grey. The previous references confirm that two other species were also taken by Forrest's party within the area now occupied by the pastoral industry.

Assessment of the abundance of kangaroos elsewhere to the north of Perth and into the present pastoral areas of Western Australia south of the Great Sandy Desert in the period immediately following European settlement in the State has to depend on relatively few reports. The major reports throwing light on this matter are those of Robert Austin (1855), the Gregory brothers (1884, and others) and John Forrest (1875); but, of these, only Robert Austin's journal

appears to have been compiled by a person having had a deep interest in observing and reporting on the fauna. John Forrest's reporting style has already been discussed in relation to two earlier expeditions. The lack of comment on the fauna by A. C. Gregory when in the Mt Jackson area (Gregory and Gregory 1884, p. 4) has also been noted.

Similarly, the Gregorys' reports on other expeditions to the north (e.g. in 1848, Gregory and Gregory 1884, pp. 13-30; and several others) also omit any references to fauna. However, the context of the remarks on fauna included by the Gregorys in their published journals suggests that they generally omitted making specific comments on wildlife unless something out of the ordinary took their immediate attention. Thus, the comments made later in the report of their 1846 expedition (Gregory and Gregory 1884, pp. 9-10) that "several kangaroos were seen on the sandy downs" upstream along the Irwin River to the vicinity of the present town of Mingenew, and that the next day on their journey south they "halted for half-an-hour and shot a kangaroo, which provided a welcome addition to the commissariat", can be regarded as indicative of reasonable abundance of kangaroos in the type of country described, and through which they were then travelling. One of their party was also able to procure "a kangaroo and ten cockatoos" during a short excursion several days later in the Watheroo district. The area traversed is predominantly Western Grey habitat.

Robert Austin travelled north-eastward from Goomalling towards Lake Moore before proceeding into the Murchison district in 1854. It is clear from his report (e.g. Austin 1855, p. 33) that Western Greys were then extremely abundant in the Goomalling and Wongan Hills districts, and further northward towards Lake Moore. In this respect, his observations are generally consistent with the earlier reports by James Drummond (1839) and John Gilbert (1843, in Wagstaffe and Rutherford 1955). Austin also recorded seeing and shooting 'mourarings' or rock kangaroos around Cowcowing and Waddering (p. 11); and later, in the Murchison, of having shot several of the numerous rock kangaroos "among the huge blocks of granite on the eastern side" of Mt Farmer (p. 49), where Red Kangaroos were also numerous on the plains to the westward.

Unfortunately, the apparently interchangeable use by Austin of the Aboriginal name 'mouraring' and the descriptive name 'rock' kangaroo for animals he saw and shot but did not collect as specimens does not resolve the question as to what species he was referring, nor does it help us in deciding what species John Forrest called 'rock' kangaroos and 'red' kangaroos. The initial description given by Austin in his report strongly suggests reference to a Rock Wallaby, but the much larger Euro which similarly frequents rocky areas is closer in size to the Western Grey Kangaroo of the south-west, and might, on this account, be expected to have been more likely to be referred to as a 'kangaroo'. However, as Frith and Calaby (1969, p. 18) point out there is no clear-cut distinction between the animals that may collectively be called 'kangaroos' and individually described as either 'kangaroos' or 'wallabies'. We also have no way of deciding how Austin and John Forrest may have applied these descriptions, and further uncertainty arises because the small colonies of Euros still found in the Toodyay district and the relict populations of the Brush-tailed Rock Wallaby (Petrogale penicillata ssp. lateralis) in the Mt Caroline - Mt Stirling area inhabit a part of the State already known to the settlers prior to Austin's trip.

John Forrest's use of the description "red kangaroo" may also be questioned here (cf. Hunt 1864; etc., above), but there can be no doubt that Austin knew the Red Kangaroo by the time his party reached Mt Farmer. He had earlier collected the first Western Australian specimen of this species at Recruit Flats, just near the present Windimurra station homestead (Austin 1855, p. 42). Even so, two earlier references in the report (p. 16) to 'red' kangaroos' dung and tracks may be in error. These observations appear quite likely to have been attributable to Euros. We therefore need to make some personal judgement in interpreting the earliest reports of the presence and abundance of different species in the present pastoral areas of Western Australia.

From Recruit Flats, Austin travelled north-westward into the Mt Magnet - Cue area and thence across to the Murchison River. It is clear that Red Kangaroos were abundant in a number of places in this area, but they were also extremely wary and hard to approach (pp. 42 & 49). Habitat for the Reds included "stony plains covered with scrub" and "plains". Austin also noted that they fed "on leaves of the nut or native peach (= Santalum spp.) trees that are very numerous where these kangaroos are found". Earlier (in 1852, p. 296), Augustus (A. C.) Gregory had apparently seen Red Kangaroos, e.g. "a species of Kangaroo new to me remarkable for its large size, red colour, the great length of the legs and the shortness of the foot" on the lower Murchison, and also noted that "Its food appears to consist of the leaves of a species of Sandalwood and Samphire bush".

F.T. Gregory further explored areas on the Murchison and Gascoyne Rivers in 1858, but in keeping with previous reports, the fauna notes included are not comprehensive. Apart from bird notes, the report includes only one mention of kangaroos, this being the finding of a "few skins of the red kangaroo" in a riverside Aboriginal camp on the Gascoyne River near Beelu Island (c. NNW of Mt Dalgety; Gregory and Gregory 1884, p. 41).

John Forrest also travelled along the upper Murchison River in 1874 before proceeding eastward across to the overland telegraph line between Darwin and Adelaide, but apart from one mention of having seen "several kangaroos" around a campsite c. 14 km (about 9 miles) down river from Elizabeth Spring south of Mt Narryer (J. Forrest 1875, p. 164), his report adds nothing more to the previous knowledge of kangaroos in this part of Western Australia. However, after passing

through the Wiluna district, Forrest's party found kangaroos to be particularly abundant from the vicinity of Weld Spring across to Mt Moore - Lake Augusta, and further eastward towards Mt Bates and Carnegie.

The Pilbara region was principally explored by F.T. Gregory. Commencing at Nickol Bay, Gregory's party undertook two excursions. The first of these commenced on May 25, 1861. During the following eight weeks, the party completed a return journey southwards as far as Gregory Gap (approximately 40 km north of Mt Augustus, which F.T. Gregory had ascended during his previous expedition into the Gascoyne in 1858 and named after his brother). No mention of kangaroos is made in the account of this first trip, but three days after commencing the second trip which eventually took the party eastward through the Marble Bar - Mt Edgar district to the Oakover River, and southward as far as the Davis River before turning and following the De Grey down to the coast, Gregory reports (Gregory and Gregory 1884, August 1, pp. 74-5) when near the Sherlock River - "We had seen more kangaroos on these plains than on any other portion of our route; one that was shot resembled the Osphranter, and was in very good order, the fur much thicker and softer than the common kangaroo of the western coast, and of a pale mouse colour. It weighed about forty-five pounds": but the identity of this latter kangaroo is uncertain. It may have been a Red Kangaroo. On the other hand, the description could possibly apply to a female Euro. It is obvious that Gregory knew the Western Grey, but one cannot be certain of his concept of "the Osphranter" in this context. Both the Red Kangaroo and the Euro (Wallaroo) were included in the genus Osphranter about this time (see Gould 1973). The lack of connection between this description, and Gregory's previous mention of skins "of the red kangaroo" being seen on the Gascoyne also does not help. More importantly, however, the above quote was referring to an area the party had previously traversed around July 16 when on the return leg of their trip to the south. There is only one other comment on kangaroos made in this narrative (p. 85, September 24), nearly eight weeks afterwards when the party was on the lower reaches of the De Grey River, in or near the Ord Ranges, viz. "kangaroos were numerous among these hills, but we did not succeed in shooting any. They appear to be similar to those seen on the plains near the Sherlock". Whatever the species, it seems certain from the context of the remarks that kangaroos were present in greater than usual abundance in the two areas mentioned, rather than being absent elsewhere. The first comment also reinforces a conclusion previously touched on, i.e. that lack of comment on kangaroos in such exploration journals is not necessarily indicative of scarcity.

Although Ernest Giles passed westward through the area to the south of Menzies in October 1875, and in May 1876 travelled up the Murchison River and across the Gascoyne to the upper reaches of the Ashburton before returning eastward across the desert, his journals (Giles 1889) make no comment on kangaroos within the present pastoral areas of the North West and Pilbara regions of Western Australia. Pastoral settlement had progressed into the Murchison by this time (Giles 1889, Vol. 2, pp. 263-4), and further exploration in this area was undertaken by the pioneer pastoralists. Information from these sources is not readily available.

Organised exploring parties continued to probe the interior of Western Australia well into the 20th Century (see Western Australia. An Atlas of Human Endeavour. 1829 - 1979. (1979, p. 42)), but their efforts were largely concentrated in the deserts to the north and east of the area of concern in this review. Consideration of these latter reports can therefore be omitted at this point.

C. SUMMARY

It suffices to say here that there is ample evidence supporting the view that Western Grey Kangaroos were extremely abundant at various places throughout their range within the present agricultural areas of southern and south-western Western Australia at the time of settlement. In contrast, little information is available on the pre-European abundance of Red Kangaroos and Euros in Western Australia. The few relevant reports are also not contemporaneous. Nevertheless, there is sufficient evidence to suggest that areas of relatively high kangaroo abundance did exist within the rangeland areas of the State prior to the advent of the modern pastoral industry.

The question of the initial relative species abundance within mixed and abundant kangaroo populations in the present pastoral areas of the State in earlier times is still subject to uncertainty because of problems related to actual species identifications in the source reports. However, in those cases where Euros and Red Kangaroos appear to have been referred to in reports along with habitat notes (e.g. Austin 1855; Hunt 1864, 1866; etc.) the species - habitat associations reported appear valid on the basis of my knowledge (see also Frith and Calaby 1969). Thus, major species - habitat shifts do not appear to have occurred in most of these areas over the past 100 years or so. Hence, it follows that species composition within the locally abundant kangaroo populations of the pastoral zone, first commented on by explorers who were not always specific about the types of animals encountered in particular areas, may have been similar to that presently found in those same areas. It also follows from this analysis that the present relatively high abundance of kangaroos within parts of the arid rangelands of Australia is not a phenomenon solely attributable to the advent of the pastoral industry, although the pastoral industry may generally have favoured some increase in the total abundance to date. Denny (1980) has also reached a similar conclusion.

III THE EUROPEAN ATTITUDE : EXPLOITATION AND LEGISLATION

A. INTRODUCTION

The early European settlers' perceptions of Australia were strongly affected by their own cultural traditions and reactions to a strange land. This story has been told and retold many times and need not be repeated in detail here. These new settlers did however differ from the Aboriginal inhabitants of the continent in two important respects: firstly, they had a fundamentally different view of the relationship between man and the natural environment, and secondly, they had a written language. Thus, while assuming the right of dominance over this 'new' land and all it contained, the settlers proceeded to occupy the land, often in accordance with their own individual precepts but generally under the umbrella of organized civil government. The evolution of official attitudes regarding exploitation of the kangaroos and wallabies can therefore be traced by examination of the relevant legislation. In Western Australia, this record begins in 1853.

B. THE LEGISLATION

1. The Kangaroo Ordinance

The subsistence requirements of the early European settlers forced them to adopt a strictly utilitarian view of kangaroos and wallabies, similar to that of the Aborigines. Their limited additional exploitation at first produced minor local conflicts, but this was soon intensified by the depasturing of increasing numbers of domestic livestock, the slow increase in the European population and, more importantly at that time, the rapid development of a commercial export trade in kangaroo skins. From the first recorded shipment of 320 skins from Western Australia in 1843 (Garden 1977, pp. 78-9), this trade had grown to 29 506 skins by 1851 (Western Australia. Blue Book. 1851), although the total European population of the State at this point numbered less than 6 000 (Bolton and Hutchison 1979, p. 3).

The attendant risk to the small European community of greater conflict with the Aboriginal population arising from this increased hunting pressure induced passage of the first piece of Western Australian legislation dealing specifically with the native fauna. Thus, 'The Kangaroo Ordinance, 1853' was passed into law by the Legislative Council of Western Australia on April 13, 1853. This ordinance became effective from July 1, 1853. Its preamble read as follows:

"Whereas the practice of hunting and killing kangaroos in the remote districts of Western Australia has of late been carried on to a considerable extent by nomadic hunters, and whereas such a practice is calculated not only to deprive the aboriginal natives of their natural means of support, without affording them in return any of the facilities for obtaining employment and food which they enjoy in the settled districts, but has also led to serious quarrels between such hunters and the Aborigines - For remedy thereof, be it enacted".

Further, this ordinance exempted "owners, legal occupiers, or lessees of any country land, or their servants, (and) the aboriginal natives" from any restrictions on "hunting and killing Kangaroos for their own consumption, or for the use of their establishments", but imposed an export duty of one shilling (1/- = 10¢) per kangaroo skin being exported from the colony. In contemporary terms, this export duty was essentially punitive.

In summary, the above legislation plainly shows that the kangaroos were then considered a legitimate and valuable local resource, and that this use was to be accorded the highest priority. The measure taken was aimed simply and directly at resolution of some problems arising from existing exploitation patterns. Protection of kangaroos per se was not then at issue. Finally, this legislation would I think have applied principally, if not solely, to exploitation of the Western Grey Kangaroo because this species was the only large kangaroo generally known to the European inhabitants of the south-west of Western Australia in the early 1850s (II B. 3.).

2. The Game Acts

Succeeding legislation dealing with fauna was generally wider in scope than 'The Kangaroo Ordinance, 1853'. Thus, the first of the State's 'Game Acts' (passed in 1874, prior to the repeal of 'The Kangaroo Ordinance, 1853' in July 1878 (42 Victoria, No. 9)), and succeeding Acts of the same title, considered that importations of exotic 'game' species which could possibly provide more acceptable or traditional quarry for the hunter and sportsman were beneficial. The 'Game Act, 1874' also considered that such imports should be protected from indiscriminate hunting, and that other designated native species which might be hunted should be protected during their "breeding season" as well. While the main thrust of this legislation was directed towards regulation and encouragement of hunting pursuits in the traditional English mould, the principal of stock maintenance as a pre-requisie for continued exploitation was recognized.

Practical administrative action however required knowledge of the biology of the native species being considered as worthy of protection. Lack of this necessary knowledge was soon apparent, and 'The Game Act, 1874, Amendment Act, 1878' varied the provision of protection "during the breeding season" to the administratively practical expedient of protection from exploitation to be specified by Proclamation of a "close season" as required. But no kangaroos or wallabies were designated "Native Game" until 1892, when both "Kangaroo" and "Tamar" (sic = Tammar, Macropus eugenii) were included in the "Native Game" schedule. "Seal" was the only other native mammal listed at this time. Measures aimed at protection from hunting were also revised in 1892 - the power to proclaim "reserve(s) for native game" was added to the existing provision for "Close Season(s)", but discretionary power permitting the issue of licenses to allow the taking of any "birds or animals" within any reserves that might be declared was also added.

Reading of the Parliamentary Debates relating to passage of 'The Game Act, 1892' makes it clear that there was genuine concern that then existing measures aimed at regulation of hunting pressure were inadequate, and that generally excessive exploitation of kangaroos and seals that was believed to have occurred should be stopped. However, the opinions of Members regarding the status of both the different species of kangaroos and their populations in different parts of the State varied considerably, although there was apparently general consensus that exploitation for food purposes should have priority over purely commercial hunting for skins, and that this former use ought not be subject to any constraint. Thus, the general opinion in the early 1890s regarding kangaroos (now including a group of species) was similar to that expressed earlier on passage of 'The Kangaroo Ordinance, 1853', except for the fact that commercial exploitation was also seen as a desirable method of destroying and utilizing animals that might otherwise compete for food with the now numerous and much more desirable pastoral livestock populations. The opinions of both Sir John and, particularly, Alexander Forrest, and some other Members also, in relation to the relatively low value that they accorded to either kangaroos and/or kangaroo hunters, in comparison with domestic livestock and persons engaged in more 'respectable' pursuits, were indeed sharp.

Interestingly enough, these debates on 'The Game Act, 1892' also make it clear that the community was then prepared to regard the presence of wildlife in some areas, such as Perth Water on the Swan River, much more highly than direct consumptive use via hunting.

Further official action aimed at control of exploitation of kangaroos did not however follow immediately after passage of 'The Game Act, 1892'. In fact, the first Proclamation for legal preservation of "kangaroos" in accordance with this Act was not published until October 13, 1899. The area covered by this Proclamation (see Fig. 2a) clearly suggests that the action being taken was meant to apply to the Western Grey Kangaroo, although both this notice and the parent Act are not specific in their definition of 'kangaroo', and the preceding debate on the Bill for this Act clearly shows that the word was used in reference to several species. Incidentally, 'wallaby' was nevertheless distinguished from 'Tammar' in the debates, with 'wallaby' being omitted from the final list of declared "Native Game", apparently because of its propensity as a garden pest. The distinction being made in this latter instance may have been between the Tammar (Macropus eugenii) and the Brush Wallaby (M. irma).

The first series of Proclamations (1899, 1900) establishing a 'Kangaroo Reserve' in southern Western Australia apparently caused confusion in the minds of many country people, despite a specific provision allowing general destruction of kangaroos within the reserve "for purposes of human food" only, as had been agreed previously. A specific 'Act to Allow Kangaroos to be taken for Food during a Close Season and on Native Game Reserves' subsequently passed in November 1900 detailed this exemption from provisions of the 'Game Act'. The succeeding Proclamation of the 'Kangaroo Reserve' on March 15, 1901 (Fig. 2b) further clarified the original intention to prohibit direct commercial exploitation without restricting the use of kangaroos for food, but imposed no restrictions on the subsequent commercial disposal of skins of kangaroos ostensibly taken for food purposes. As the Chief Inspector of Fisheries later pointed out (Gale 1905, p. 7), the intentions of the foregoing legislation were no doubt desirable, but there was no way of enforcing its observance and probably little hope of his readily obtaining a position where this would be practicable. The effect on kangaroo exploitation appeared minimal.

Further amendment of the 'Game Act' in 1907 repealed the specific powers of the 'Kangaroos for Food' Act of 1900, and incorporated similar provisions within the 'Game Act': but Section 2. (4.) of the 'Game Act Amendment Act, 1907' specifically prohibited the issue of licenses authorizing the killing, etc. of native game on native game reserves. This prohibition is puzzling, but the general context of Section 2 suggests that the constraint may have been intended to apply only to taking for sale or barter. Even so, the 'Kangaroo Reserve' Proclamation of March 13, 1908 (Fig. 2b) omitted specific general approval of the taking of kangaroos for food within the reserve, in contrast with the previous Proclamations of this type. Another two separate Proclamations published on the same date clarified this issue in regard to the taking of kangaroos for sale or barter, and also provided for the issue of licenses to "Bona fide" settlers to take kangaroos on reserves for food only, presumably under cover of Section 7 of 'The Game Act, 1892'.

Thus, despite the apparent confusion engendered and the ineffectual nature of the legislation in limiting hunting, the distinction between the purely commercial and subsistence levels of exploitation was maintained in regard to the legal 'Reserve', and priority remained with the latter use as in previous times.

Existing and proposed 'Game' legislation was reviewed in 1911 by a Select Committee of the Western Australian Legislative Council, and the "Laws relating to Imported and Native Game" were consolidated and amended by passage of the 'Game Act, 1912'. Legal conditions relating to the exploitation of kangaroos and wallabies in Western Australia during the next 40 years were largely determined by this Act (including some later amendments in 1913).

All kangaroos and wallabies were classed as "Native Game" by virtue of their inclusion within the group "All Marsupials excepting Native Cats" in "The Second Schedule" of the 'Game Act, 1912-13'. Priority recognition was once again given to the value of kangaroos as a human food resource, with Section 12a. authorizing the Minister responsible to grant special licenses to allow kangaroos to be taken for this purpose alone. These licensees were also exempted from compliance with other provisions of the Act in obtaining their requirements (Section 12a. (3.)).

The responsible Minister was also empowered to authorise property holders to destroy "Game" species on their property in cases where damage or injury was likely to arise (Section 21.).

Apart from the two special provisions above, hunting of "Game" species on a non-commercial basis was also permitted without license in areas exempt from cover under other specific provisions of the Act; that is, outside of Proclaimed "Reserves" and "Close Season" areas (see Section 6a.).

Licensing of persons engaged in direct commercial exploitation, and in trade in "Native Game", was also continued, as previously advised by Proclamation on March 13, 1908 (see Section 10. of the Act); but a new provision allowing imposition of Royalties on marsupial skins taken for trade was added (Section 23a.). The power to constrain the taking of particular "Game" species was incorporated under Section 6. . The power to declare "Close Season(s)" and "Native Game" Reserves by Proclamation remained as before. Administration of licensing, etc. was facilitated by the Regulation making powers under Section 24. .

Further 'Kangaroo Reserve' Proclamations were made during the currency of the 'Game Act, 1912-13' (see Fig. 2), the first of these being June 27, 1913 (Fig. 2b). These later Proclamations continued to make non-specific reference to 'Kangaroos', and continued in the same form as the preceding Proclamations until August 1, 1924, when the new 'Reserve' Proclamation was restricted to "Grey Kangaroos" (=Western Grey; Fig. 2c). From late 1929, however, subsequent notices generally exempted particular areas for a specified period from the cover of the general Grey Kangaroo Reserve proclaimed on August 1, 1924. The first of these later variations, e.g. the Proclamation of November 15, 1929, was made towards the end of the first major phase of agricultural development in south-western Western Australia (Fig. 3), and further changes that followed were generally made in response to increasing agricultural development.

The 'Game Acts' were not however the only legislation impinging on exploitation of kangaroos and wallabies in Western Australia during the period to the 1930s discussed above. Separate legislation also recognised animals as potential, or actual, agricultural pests. Among the first such legislation (see Tomlinson 1979) was 'The Destructive Birds and Animals Act, 1893'. This Act was directed specifically at exotic species. The deleterious impact of sparrows and similar exotic birds introduced elsewhere in Australia was noted in the Preamble, and the importation to and keeping of such exotic pest species within the State was prohibited. The distinction made here in regard to some exotic species stands favourable comparison with the sentiments expressed in the opening lines of the Preamble to 'The Game Act, 1892', e.g.

"Whereas it is expedient for the benefit of the Colony that encouragement should be given to persons to import any Bird or Animal not previously existing therein, and that Protection should be given to such Birds or Animals and their progeny ... ".

Doubt about the desirability of nurturing some exotic animals was expressed at one point during the Parliamentary debates on the Game Bill of 1891-2. The considered 'pest' or 'nuisance' value of some of the native fauna was also discussed during these debates. Nevertheless, it is clear that attitudes in regard to non-domesticated animals during the 1890s were essentially simplistic in outlook. Species were effectively assigned to either 'good' or 'bad' categories depending on their perceived utility value, and generally without particular reference to their origin. Exotic species were also classed without reference to their potential impact on native fauna. It should, of course, be remembered that 'ecology' as a science was then unknown.

Agricultural development expanded within Western Australia from 1905 onwards (Burvill 1979; and Fig. 3), and the later invasion by the rabbit (Tomlinson 1979) and problems with crop production on small cleared areas within a vast expanse of kangaroo habitat (e.g. Haddleton 1952) heightened awareness of pest problems. Further legislation directed at agricultural pest problems followed, eventually leading to passage of the 'Vermin Act, 1918'. This Act, with its subsequent amendments, had a major effect on the general approach to exploitation of kangaroos and wallabies over the remainder of the period under review; that is, from c. 1920 to 1970.

3. The Fauna Protection Act

The first official step towards the modern concept of wildlife conservation in Western Australia was taken when the 'Fauna Protection Act, 1950' succeeded the 'Game Act, 1912-13', coming into effect on July 1, 1952. All wild vertebrate animals in the State were then included in the definition of "fauna" (Section 6.), and, in direct contrast with the approach in the various 'Game Acts', all "fauna" was "protected" unless subject to a specific exclusion declared by Proclamation (Section 14.).

The possibility of a direct conflict between provisions of the 'Vermin Act, 1918-1946', and those of the new fauna legislation was foreseen at the time this legislation was considered, and the matter resolved by allowing the 'Vermin Act, 1918-1946' (and its successors) to prevail in cases where inconsistency might arise (see 'Fauna Protection Act, 1950', Section 5., and Section 17.(2)(e)). Thus, latent power to decide the primary approach to management of native animals that might also be regarded as agricultural pests in some instances that had previously existed under provisions of the 'Game Act' was, at this point, taken from the responsible fauna authority, and passed to those responsible for decisions made under cover of the 'Vermin Act'. However, in those instances where no action was taken by those empowered to do so under the 'Vermin Act', the fauna authority retained residual power. This constraint on the power of the fauna authority remained until June 1, 1968, when the 'Fauna Conservation Act, 1950-1967' became operative.

The effect of formally transferring the first option of making primary decisions affecting native fauna out of the hands of the fauna authority and placing this with the vested interest group having power under cover of the 'Vermin Act' from 1952 through 1968 could have been disastrous. The new arrangement of powers spelt out in the 'Fauna Protection Act, 1950' did not however result in any major shift in the existing patterns of exploitation of the large kangaroos, viz. Red, Euro and Western Grey; nor did it materially affect the status of the small wallabies of the south-west. The reasons for this are set out below.

Rural landholders in Western Australia had certainly had their way in 1952 in regard to obtaining legally unfettered power to act in whatever way they might consider desirable against fauna that might be declared agricultural pests: but none of the kangaroos or wallabies, apart from the Western Grey, had been accorded any formal legal protection during the currency of the 'Game Acts'. Even then, the formal legal protection of the Western Grey Kangaroo as spelt out in the 'Grey Kangaroo Reserve' Proclamations was generally of little consequence from the conservation viewpoint. Together, the numerous exclusions from the cover that might have been provided by this measure in its original form and, more importantly, the lack of any effective enforcement capacity, combined to render ineffectual whatever protection from exploitation that might at first have been considered desirable.

The net result of the above was that the three kangaroos, plus the smaller wallabies while they remained abundant, had all been exploited without effective legal constraint before introduction of the 'Fauna Protection Act', and the authority to continue in this manner was written into the 'Fauna Protection Act' if rural landholders as a group wished to formally consider any particular fauna an agricultural pest (declared "Vermin" under the 'Vermin Act'). The kangaroos remained reasonably abundant and were already considered such pests, so nothing changed in this respect. The result, as far as the new 'Fauna Protection Act' applied was that the former 'Grey Kangaroo Reserve' area was re-defined by Proclamation of areas in which Grey Kangaroos were to be "not protected" (Fig. 2d). Three Proclamations of this sort were gazetted over the period June 13 to August 1, 1952. Later, variations within this newly defined "protected" area were made by "Open Season" notices, e.g. the Proclamation of an "Open Season" on May 22, 1953; but, in effect, hunting of the kangaroos could be continued as before.

On the other hand, populations of the smaller wallaby species such as the Quokka (Setonix brachyurus), Tammar and Brush Wallaby were, by the 1950s, severely reduced in abundance, and the extensive commercial exploitation of the 1920s and 1930s had long since given way to general concern for conservation of these wallabies. Certainly, some pre-existing "Vermin" declarations for one or other of these species remained in force at this point, and were not cancelled for many years. However, these declarations were of little practical consequence while they endured, so the smaller macropods of the South West to all intents received the complete legal protection provided by the 'Fauna Protection Act' (and its successors) from mid- 1952 onwards.

Apart from the signal change in emphasis of this new legislation and the differences discussed above, the general provisions of the 'Fauna Protection Act' with regard to licensing and royalties applicable to trade in fauna and the distinction made between subsistence and commercial exploitation of kangaroos remained similar to those under the 'Game Act, 1912-13'. These provisions also remained substantially the same to 1970.

C. SUMMARY AND CONCLUSIONS

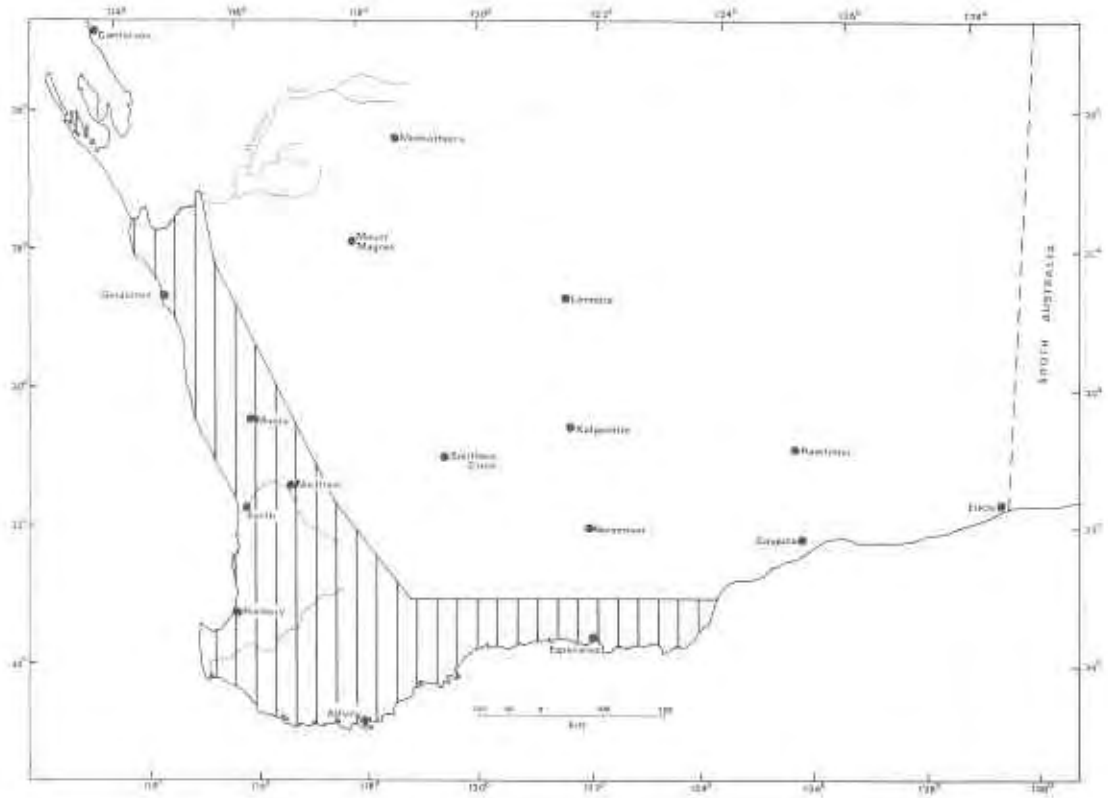
The legislation discussed above shows that the prevailing European attitude to exploitation of kangaroos and wallabies in Western Australia for most of the period from 1829 - 1970 was essentially utilitarian. These animals were first seen as a valuable resource, both for food and then for commerce; but up to the late 1960s, priority was consistently accorded to subsistence exploitation for food. In later years, however, the view that kangaroos were primarily agricultural and pastoral pests predominated. It is only in very recent times that the conservation of kangaroos as wildlife has achieved particular prominence in debate (e.g. Anon. 1967, 1970; Australia. Parliament. 1971; Australia. Department of Environment, Housing and Community Development 1977; Poole 1978).

Because the kangaroos were first viewed as a common property resource and then more as pests, the relevant legislative decisions were concentrated on exploitation related issues. Thus, 'The Kangaroo Ordinance, 1853' was directed at resolution of problems arising from conflicts in exploitation, while later fauna legislation at first sought to exercise some control over the primary reasons for exploitation, and also over participation in trade, e.g. the 'Game Act'. This latter also provided a source of revenue.

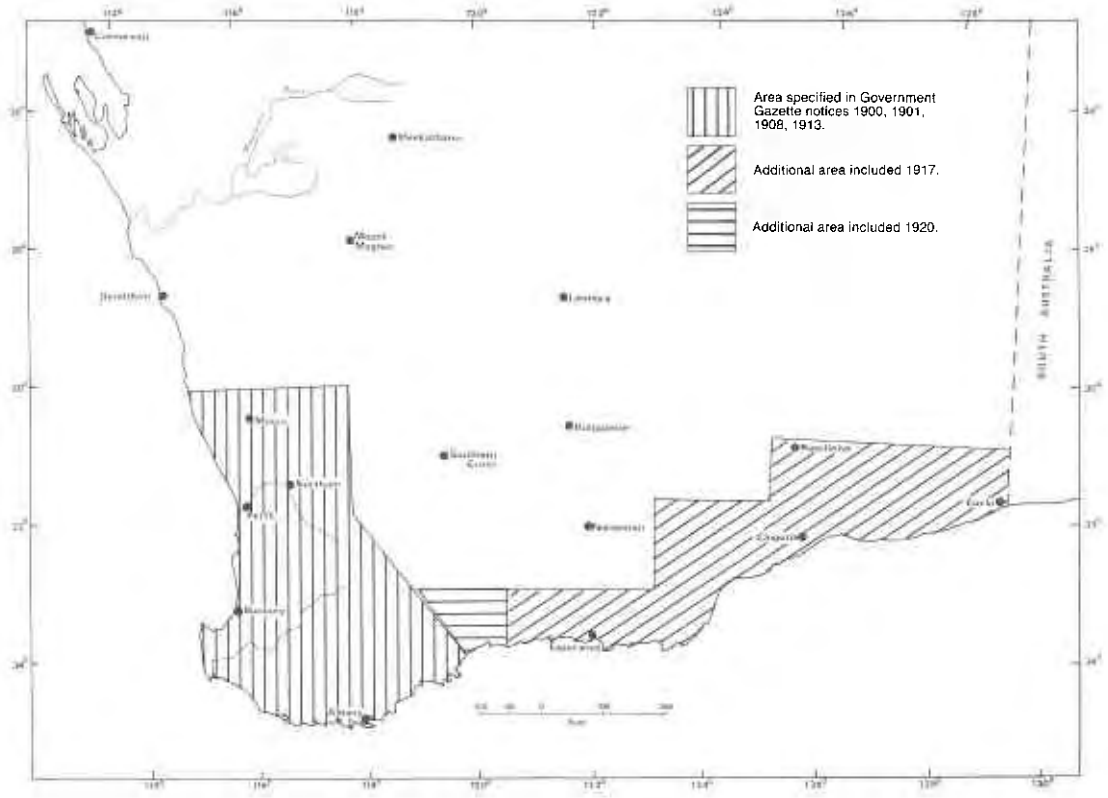
Apart from the general provisions of the relevant statutes (i.e. Acts, Regulations, etc.) there does not however appear to have been any consistent integrated administrative policy approach to kangaroo exploitation during this review period.

The foregoing summary of the development of legislation affecting exploitation of the Western Australian kangaroos and wallabies has shown that this process took place against a backdrop of ongoing exploitation of these animals. In the main, no practically effective action to direct or constrain such exploitation as occurred prior to 1950 flowed from these deliberations. The official attitude to determination of harvest levels for the different species of kangaroos and wallabies entering the commercial trade prior to the 1950s appears to have been to leave this to

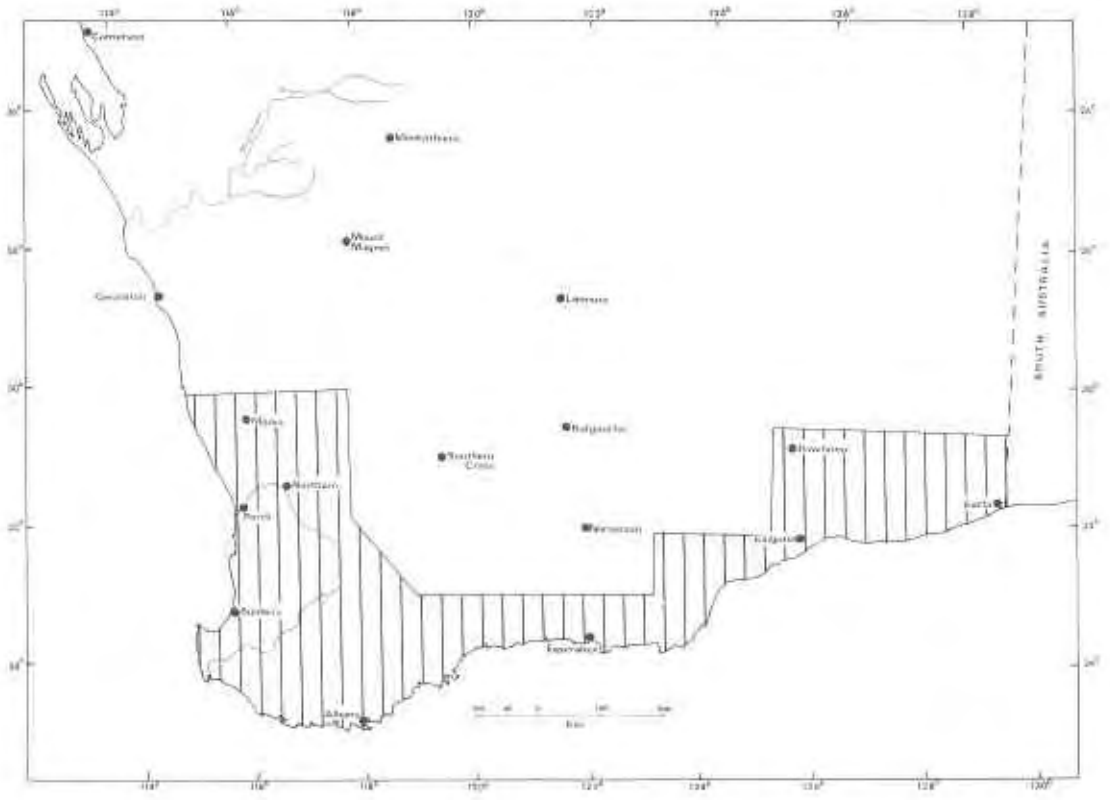
Figure 2. Area of Southern and south-western Western Australia in which a Need for Restraint on Exploitation of the (Western Grey) Kangaroo was given general Statutory Recognition : 1899 - 1970.



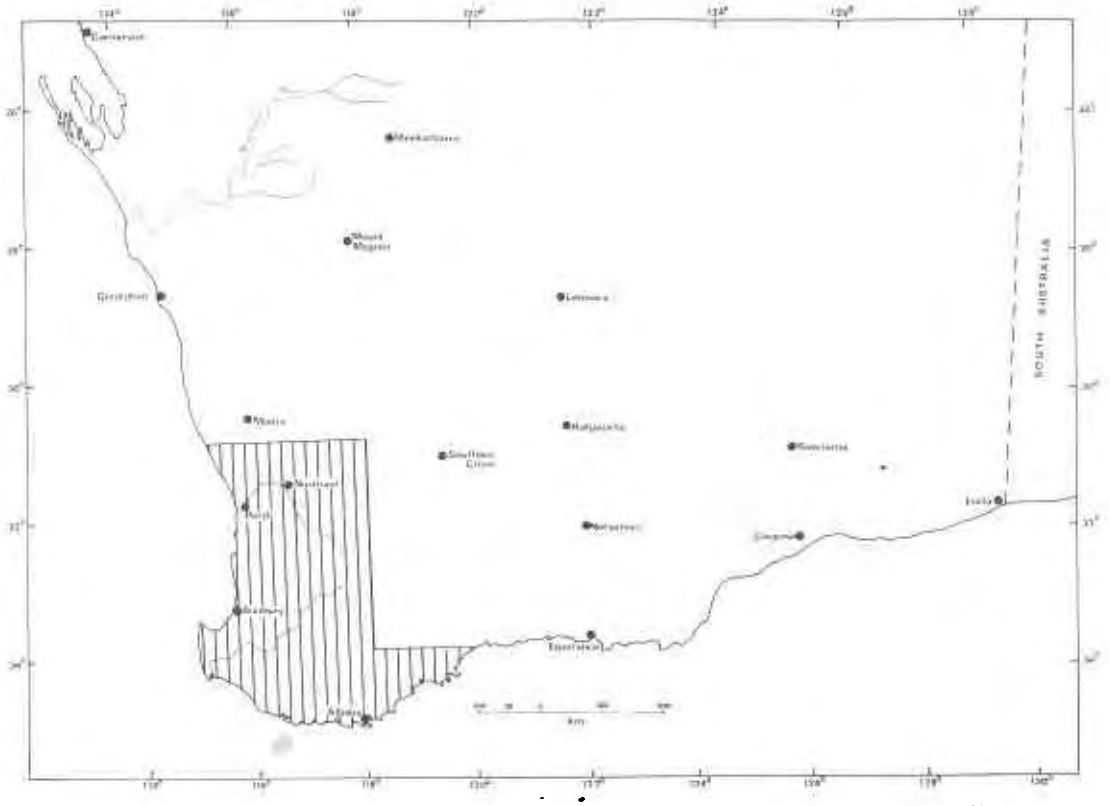
2a. 'Grey Kangaroo Reserve' - Area specified pursuant to the 'Game Act' in Government Gazette Notices: 1899.



2b. 'Grey Kangaroo Reserve' - Areas specified pursuant to the 'Game Act' in Government Gazette Notices: 1900-1920.



2c. Consolidated 'Grey Kangaroo Reserve' - Area specified pursuant to the 'Game Act' in Government Gazette Notice: 1924.



2d. Area in which (Western) Grey Kangaroos were generally "protected" under provisions of the 'Fauna Protection Act, 1950'. See Government Gazette Notice: 13 June 1952.

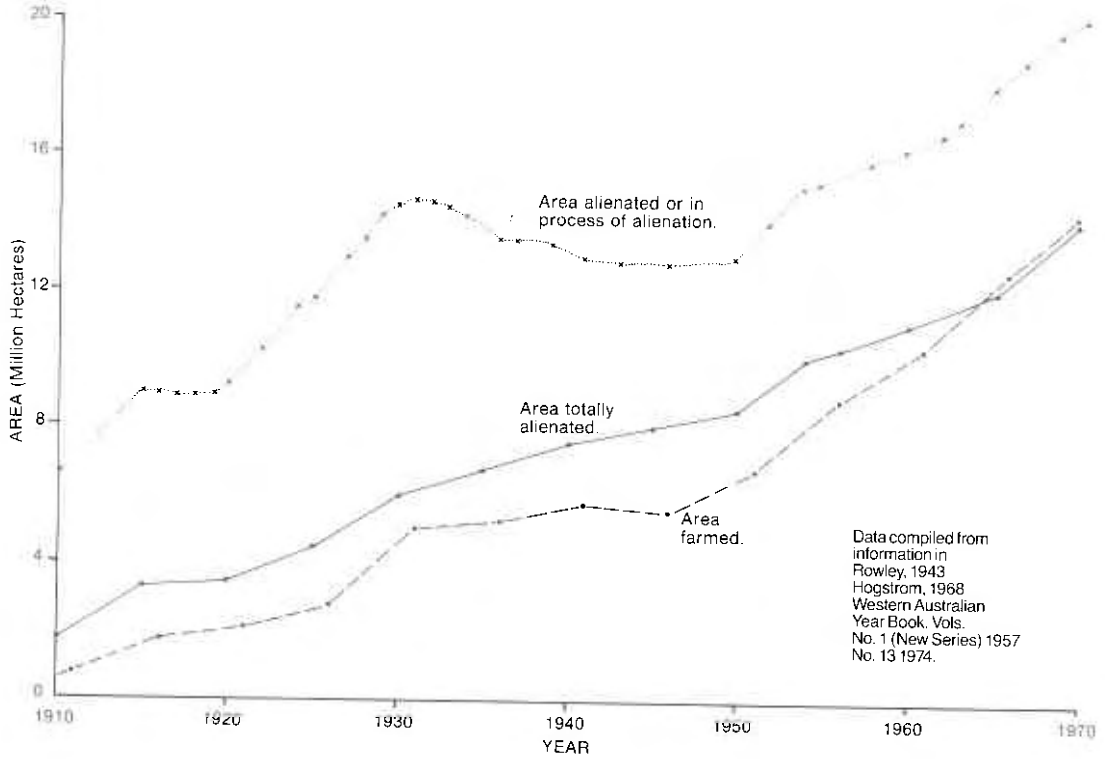


Figure 3. Progress of Disposal and Development of Agriculturally suitable land in south-western Western Australia: 1910-1970.

the balance between vulnerability of the species to exploitation and the commercial incentive to exploit. From 1950 the official view apparently favoured attempts to increase the prevailing levels of exploitation of both the Red Kangaroo, and the Euro in particular, above this limit.

The early official approach to management of the fauna obviously did not form part of an entirely successful conservation strategy where the fate of the smaller wallabies was concerned prior to the 1950s, whereas it was apparently of little real consequence in the case of the kangaroos. The major contribution of the fauna legislation to knowledge of the kangaroos and wallabies in Western Australia during this review period therefore arises solely from the provisions which permitted some documentation of exploitation.

In view of the multitude of exemptions from formal licensing provisions of the 'Game Acts', the separate authorities to exploit kangaroos later conferred by the 'Vermin Act', and the general omission of formal requirements for most persons exploiting kangaroos and wallabies to report numbers taken, the present value of the early fauna legislation arises solely from the provisions for collection of royalties on skins traded: but this provision was of course directed at revenue gathering (see Game Act Amendment Bill 1913, Parliamentary Debates).

IV COMMERCIAL TRADE AND THE EXPLOITATION OF THE KANGAROOS AND WALLABIES OF WESTERN AUSTRALIA : 1829 - 1970

A. INTRODUCTION

Exploitation of the kangaroos and wallabies by man commenced with the Aborigines and clearly has a long history. The tribes in the south-west of Western Australia were provided by these animals with both a valuable food source (see Meagher 1974, for a summary of numerous reports) and clothing, e.g. King (1827, Vol. 2, Ch. 3) for an early report on the use of kangaroo skin cloaks by the Aboriginal population in the vicinity of King George's Sound, and many others (e.g. Berndt and Berndt 1977, p. 118; Bignell 1971, p. 11; Bunbury 1930, pp. 84-5; Haddleton 1952, p. 32; Hassell 1975, Ch.2; William 1947, p. 30) which show that wearing of these cloaks was common practice in south-western Western Australia. Undoubtedly, the exploitation of the kangaroos and wallabies was of great importance in the lives of the Aboriginal people.

The early European settlers in Western Australia were also quick to adopt a similar mode of exploitation. These settlers had limited numbers of economically valuable domestic livestock (see Moore 1884, pp. 91-152, passim; and Bunbury 1930, p. 31). They also experienced great difficulties in obtaining adequate food supplies from other sources. The ready alternative source of meat offered by the native kangaroos was regarded as a common property resource, of which these settlers were only too pleased to avail themselves whenever they could. The use of the skins for domestic purposes also provided an added benefit. Even so, the impact of this early subsistence hunting by the European settlers probably did not add much to that due to the resident Aboriginal population. However, besides subsistence hunting, the Europeans soon extended their exploitation to commercial trade, both in meat and skins (see Stokes 1849, quoted by Bolton and Hutchison 1979, p. 7; Moore 1884; Garden 1977; Bignell 1971; Hassell 1975; Rintoul 1964; Stephens 1962).

Limited local trade was shortly expanded following the advent of an export trade in skins in 1843-4 (Garden 1977, pp. 78-9; and Western Australian Blue Books 1843, 1844) which greatly increased the impact of exploitation on some of the local kangaroo stocks. The resulting conflict between the Aboriginal and European populations provided the incentive for passage of 'The Kangaroo Ordinance, 1853' (see III B. 1.), but the net impact of the total exploitation pressure to this point probably had little if any lasting effect on the prospective abundance of the south-western species.

Both commercial and non-commercial exploitation continued throughout the remainder of the review period, but commercial exploitation is the only component of the total direct exploitation for which there is any comprehensive documentation. Our knowledge of the impact of exploitation must therefore depend on the information obtainable from the commercial records.

B. THE TRADE DATA

1. Data Sources

The trade data discussed below were compiled from three main sources: the royalty statistics for the period 1914 - 1938, which are undoubtedly the best detailed commercial harvest data available (from State Archives); the various other official statistics relating to the trade in kangaroo skins from 1843 onwards (Western Australia. Blue Books, and the Statistical Registers); and the private records of a major skin trader at the time in regard to the numbers and species traded from 1938 to 1953 (Private company records made available by Mr H.A. Mofflin plus personal discussions). Comprehensive royalty data covering this last period were not available.

Official statistics from 1953 up until the middle 1960s also presented only a sketchy record of kangaroo exploitation, due to the combined effects of collapse of the commercial skin trade and changes in royalty regulations and other legislation during this period. Estimates of the commercial harvests taken and total levels of exploitation during these years are a composite of information obtained from several different sets of official records.

2. External Trade (Exports)

Prior to the late 1840s, the official export trade records (see Western Australia. Blue Books) present only estimates of the quantities of kangaroo skins exported, due to deficiencies in data collection. The estimated cash value of these exports is generally given, but the number of skins traded is omitted. However, it is clear that kangaroo skins were first exported from Western Australia during 1843 (Western Australia. Blue Book. 1843, p. 170), and that a greater number were exported in 1844. The exports from the port of Albany during 1843-4 accounted for 320 skins, and this trade had expanded by 1847 to in excess of 8 000 (see Garden 1977, pp. 78-9). The Western Australian Blue Book for 1849 (p. 168) also shows that this trade then accounted for 12 387 kangaroo skins.

It is not clear from the official records whether any kangaroo skins were exported during 1850, due to sole listing of the inclusive category "Hydes (sic) and Skins", but John Lort Stokes was apparently informed that 16 000 kangaroo skins were obtained in the Albany district about 1848-9 (quoted by Bolton and Hutchison 1979, p. 7). 29 506 kangaroo skins are also listed as a sub-category under the heading "Hides and Skins" in 1851, along with 459 seal skins and 1 300 hides. Smaller numbers within the inclusive sub-category "Skins" are listed in the 1852 and 1853 Blue Books (9 710 and 12 629), and these numbers dropped sharply after 1853, the year when the export levy was first imposed by way of 'The Kangaroo Ordinance' (see III B. 1.).

Subsequent exports of relatively small numbers of "Skins" in 1855 and 1856, and the export of small numbers of "Kangaroo skins" separately listed during the 1857 - 1864 period suggest that the unspecified skins included in the sub-category "Skins" in the records around this period were mainly kangaroo skins. The kangaroo skins being traded at this time would have been Western Greys (see III B. 2. & 3.).

The separate category "Skins" predominates in the Blue Book listings from 1864 to 1884, although "Sheepskins" or "Seal and Sheep" are specified over the three years 1870 - 1872. Monetary values are also the only indicators of the volume of this skin export trade given in these official summary records. More precise information may have been contained within the source data utilized in their preparation, but a search for this has not been attempted. Nevertheless, the figures that are available generally suggest that the export trade in kangaroo skins was not again of major significance in Western Australia prior to the mid- 1880s.

From 1885 however the sub-category groupings of the specific "Skins" listings in the Blue Books were again altered; at first to the inclusive "Sheep and Kangaroo", and thence to "Kangaroo and Sheep" in 1890. The monetary value of the total "Skin" exports rose sharply during this period. "Kangaroo" was once again listed separately in 1892, when 402 "Bales" of skins worth £27 599 ($55 198) were exported from the State. This pattern suggests that commercial exploitation of kangaroos for the export skin trade expanded significantly from about 1885. Parliamentary debate on the "Game Bill" in 1891-2 supports this conclusion. Thus, Mr F. H. Piesse, M.L.A. for Williams, stated on 15 December 1891 that about a "million and a half of kangaroos" had been destroyed in the southern districts of the State from May 1887 to the time of debate, and that there had "been a general slaughter for the last four or five years". An average kill of up to 300 000 (Western Grey) kangaroos per annum during this period is suggested.

The 1892 export figures also suggest the harvest of a substantial number of kangaroos. Top (?) market prices being received about this time were apparently in the region of 3 to 4 shillings (3-4/- = 30-40¢) per skin for Western Grey Kangaroos, and 2/- to 2/6d (20-25¢) per pound (weight; 1 lb ≃ 0.45 kg) for skins of the northern species (presumably Red Kangaroos; see Game Bill, Parliamentary Debates 1891-2). The average weight of the dried skins being traded would probably have been around 1¼ lbs (0.57 kg), so the exports for 1892 could at least have amounted to between 135 000 and 235 000 kangaroo skins.

"Kangaroo" skins continued to be listed separately in the official trade records for the remainder of the period 1893 - 1902, with the quantities involved being indicated by the numbers of "Bales" exported and their "(monetary) value". The term "Bale" appears to have been loosely used in this trade, and is not defined in the official statistics. However, dry kangaroo skins were packed in 'bales' for shipment in later years, and my perusal of trade records available suggests that the largest 'bales' shipped as sea cargo in the late 1930s contained up to 1 000 or more dried skins (also noted in File F.D. 14/27, AN 108/4, Acc. No. 477, Battye Library), while the smallest contained around 500 skins. The 'bales' prepared for road transport later during the 1950s were generally smaller. These averaged around 500 skins and 300 kg per 'bale'. Shipping was of course the only available transport during the late 19th Century, but handling technology may have advanced by the 1930s. I am therefore inclined to think that the smaller sized 'bales' would have been the more common in the 1890s. A further estimate of perhaps 200 000 kangaroo skins or more being exported in 1892 is suggested on this basis. Further improvemen in these estimates of the numbers of kangaroo skins being traded in 1892 is not possible without access to better source records. However, it is obvious that comparatively large numbers of kangaroos were being commercially exploited in Western Australia in the late 1880s - early 1890s period. It is likely that the bulk of the trade at this time comprised Western Grey Kangaroos.

The value of kangaroo skin exports from Western Australia slumped to less than one-quarter of the 1895 figure during 1896 and did not recover appreciably until the end of 1898. During this period, less than 100 "packages" of skins were exported per annum, whereas the quantities exported during the three preceding years (1893 - 1895) ranged from 157 to 203 "Bales" per annum, and in the four years afterwards (1899 - 1902), from 297 to 426 "Bales" per annum. Both changes in the skin market and in the kangaroo stocks may have influenced this pattern of trade. Up to 1890, and in the immediately preceding years, South Australia was the major recipient of Western Australian kangaroo skins, but during the next three years (1891 - 1893) direct shipments to the United Kingdom predominated. From this point onwards, New South Wales became the main destination for the Western Australian kangaroo skins. The period from 1886 to 1900 was however marked by recurrent drought years, and included two years of intense, state-wide drought in 1891 and 1894 (see Gibbs and Maher 1967, Figs. 11 & 14).

Further changes were made in the sub-categories listed in the official records of the skin trade post- 1902. The total numbers of all skins traded were listed in 1903, along with their monetary values, but any kangaroo skins and the like have been lumped in the "Skins and Hides" sub-category "Other" skins. This latter is exclusive of the "Rabbit and Hare" and "Sheep and Wool" sub-categories, but would of course include skins of possums and any other marsupial species traded. Lumping of kangaroo skins, etc., in the sub-category "Other" continued in the Western Australian Statistical Registers from 1903 until the end of the Year 1918-19 (the Statistical Trade Year was altered from the Calendar Year to the Year ending 30 June from 1 July 1914), but only monetary

values were listed during this period. Separate listing of "Kangaroo", "Opossum" and "Wallaby" skins within the sub-category "Other Furred Skins" in this series of official export trade statistics commenced in 1919-20 when quantities were again listed, this time in pounds weight. New South Wales remained the major destination for the skins traded from 1903 at least until 1914, with the exception of the 1908-10 period, during which the United Kingdom again became an important direct trader. Interstate trade also predominated after 1914, but separate State data are not listed.

Commercial exploitation of kangaroos and other fauna obviously continued to be most important during the 1903-13 period, with the total monetary value of "Other" skin exports from Western Australia averaging £54 110 ($108 220) per annum over these 11 years (maximum £98 529 in 1910; minimum £31 867 in 1911). Observed year to year variations in the volume of external trade may in part reflect shipping and trading factors rather than direct variations in annual harvest levels, but where mixed species bags of different unit values are lumped together and not harvested consistently and where there is some indication of consistent patterning in the assignment of exports to different markets, the information content of such limited data may be greater than appears likely at first glance. This appears to be the case with the data referred to above.

Thus, the 1903 data show that 856 599 unspecified "Other" skins were exported, with 506 308 skins going direct to the United Kingdom, and 287 020 to New South Wales at average unit values of approximately 8½ pence (8½d; = 7¢) and 2/- (20¢) respectively. Species data are, of course, not given, but the N.S.W. market data are consistent with previous data identifying this State then as the major recipient of Western Australian kangaroo skins. The United Kingdom obviously took lower priced skins, presumably including those of a range of small wallabies and various other species. This interpretation of the pattern of trade is also consistent with comments made by the Chief Inspector of Fisheries, Mr C.F. Gale, regarding administration of the 'Game Act' in his annual report for 1904 (Gale 1905, p. 7). He noted that at 2/- per skin, an estimated 340 000 kangaroo skins were exported from Western Australia between 1 January 1901 and 30 June 1902, with approximately 253 000 skins being shipped from ports within the then proclaimed 'Grey Kangaroo Reserve' (Fig. 2b). On this basis, he concluded that approximately half-a-million (Western Grey) kangaroos could easily have been taken from the South-Western Division of the State (Fig. 1; and 'Land Act, 1933') during the years 1901, 2, 3, and 4. Apparently, appreciable numbers of Red Kangaroos were also being taken at this time. Some further information on this topic can be gleaned from comments made by The Hon. J. M. Drew, MLC for Central Province, during debate on amendments to the 'Game Act' in 1907. He noted that "last year (1906) 80 000 skins were exported from Geraldton alone, and in the previous year (1905) 40 000 skins" (Game Act Amendment Bill, Parliamentary Debates, 13 December 1907).

Noting that subsequent detailed evidence (below) shows that commercial harvests of Red Kangaroos and Euros were generally much more variable than those of Western Greys, the full royalty statistics from 1914 onwards nevertheless showed that the kangaroo skins passed through Geraldton generally comprised 35-45% of the combined State total for Western Greys, Reds and Euros until 1921, and not less than 25% until the late 1920s, by which time trade in Euros was no longer being recorded and most Red Kangaroo skins were being dealt with at Fremantle. Thus, Drew's figures for 1905 and 1906 suggest average total State harvests of about 100 000 and 200 000 kangaroos respectively, although even greater numbers may have been taken (perhaps up to 300 000; estimated means for these two years c. 150 - 240 000 p.a.).

Evidence given during November-December 1911 to the Select Committee of the Western Australian Legislative Council enquiring in regard to the proposed new State Game laws also provides further information on the extent of the Western Australian skin trade during the 1903-13 period. Mr C.F. Gale, who had at this point just relinquished the position of Chief Inspector of Fisheries (see previous reference above) told the Committee that Wills and Company had paid £30 000 for possum skins during 1909, and noted that a "Close Season" for the taking of possums from 1st December 1910, to 31 August 1912, was then in force. He also recounted that one man in the Kimberley had previously told him that a bag of over 100 000 (= Agile or Sandy Wallabies, Macropus agilis) had been taken in one year, although these animals would have been worth no more than 1/- (10¢) each to the shooter.

More comprehensive evidence was given by Mr William Flett Loutit, accountant for Messrs. Henry Wills and Co. He suggested that on average a total of "a couple of hundred thousand (kangaroos) a year" would have been usual, although he doubted that his company was getting "200 000 a year at present, because the price is very low." He also stated that nearly all of these skins went to America (= U.S.A.) to be made into leathergoods (Report of the Select Committee ... on the Game Bill 1912, p. 18). The external trade statistics show that this transfer was not via direct trade between Western Australia and the United States of America.

Further evidence given by Mr Loutit (Report, pp. 19-20) also suggests that the taking of around of 100 000 kangaroos per annum may have been usual in the south-west of Western Australia about this time. Top prices being paid in late 1911 were quoted as 2/9d (28¢) per pound weight (0.45 kg) for prime Western Grey skins averaging 1½ lbs (0.68 kg) dry weight, and 2/3d (22¢) per pound weight for similar Reds. These data suggest that current average prices for kangaroo skins could have been between 2/6d and 3/- (25-30¢) per skin.

Both this price estimate and the suggested numbers being traded in 1911 are consistent with the quoted value of the 1911 and 1912 skin exports, when trade in possum skins would have fallen to a minimum. The taking of large numbers of coast (= Agile or Sandy) wallabies in the Derby area and along the Fitzroy River (West Kimberley district; Fig. 1a) was also discussed by Mr Loutit. Prices received for these skins were estimated at 6d to 8d (5-7¢) each, but it was noted that the local pastoralists also paid an additional bounty of 4d (3¢) per skin. During 1911 at least, these wallaby skins were being shipped direct to Sydney.

In total, the information available concerning exploitation of kangaroos and related species in Western Australia during the 1903 - 1913 period suggests that total annual kangaroo harvests may have averaged 200 000 per annum or more, and that at least half of these were likely to have been Western Greys. In the main, these skins were apparently shipped to interstate agents in N.S.W., who were then responsible for despatch of these and other Australian kangaroo skins to overseas markets. Large numbers of various species of wallabies, including the Agile (or Sandy) Wallaby of the Kimberley were also being taken, but detailed information on this subject is generally lacking. However, the value of these wallaby skins may not generally have exceeded £5 000 ($10 000) per annum, considering their low market value. Possum skins were, on the other hand, comparatively valuable, but were not always available on the market because of the application of "Close Seasons". The information I have does not cover development of the market for possum skins, but the data to hand suggest that the skins marketed were, in the main, exported direct to the United Kingdom.

External trade data for the period to 1916 are summarized in Table 1.

The more detailed external trade statistics available from 1919-20 also show a pattern of market organization consistent with that suggested above in the earlier years of the 20th century. The estimated values per skin calculated from the remainder of the relevant export data and related to the actual numbers of possum skins presented for royalty payment in Western Australia from 1915 are comparable with the prices then being quoted for these skins on the local Western Australian market. The pattern of trade suggested in my analysis of the data for the earlier years of the 20th Century is thus supported.

External trade records for the period 1916 - 1970 are included in Appendix III for completeness.

3. Royalty Records and Related Data

The trade data discussed above ceased to be the best source of information on exploitation of the Western Australia's kangaroos and wallabies from the inception of royalty charges on 1st April 1914 ('Game Act, 1912-13' Regulations (1914)). From this point, the even more comprehensive royalty and private trade data obtained provide the best source of information on past exploitation. These data are listed in Table 2 and summarized in part in Figs. 4 - 6.

No further discussion regarding the quality of the above statistics is required here. They have been used as source data for the detailed analyses of exploitation patterns for three of the Western Australian kangaroo and wallaby species presented in Appendices I and II.

Table 1.

Export of Kangaroo and Wallaby Skins from Western Australia, 1840-1916.

(Compiled from Official Western Australian Trade Records in 'Blue Books' and 'The Statistical Register', with some supplementary information from other sources).

	Listing		Destinations				
YEAR	Trade Item	Quantity, etc.	Other Aust. States (1)	United Kingdom (2)	United States America (3)	Other Countries (4)	TOTALS (5)
1843	Kangaroo Skins	Value (estimated)		£4			£4
1843-4*	do	Number	*	*	*	*	320*
1844	do	Value (estimated)			uncertain		£20
1845	-	-	-	-	-	-	-
1846	-	-	-	-	-	-	-
1847*	Kangaroo Skins	Number	*	*	*	*	>8 000*
1848	-	-	-	-	-	-	-
1849	Kangaroo Skins	Number Value			uncertain		12 387 £400
1850	-	-	-	-	-	-	-
1851	Kangaroo Skins	Number			uncertain		29 506
1852	Skins	do			uncertain		9 710
1853	do	do			uncertain		12 629
1854	-	-	-	-	-	-	-
1855	Skins	Number			uncertain		1 750
1856	do	do			uncertain		250
1857	Kangaroo Skins	do	1 036				1 036
1858	do	do	1 305	175			1 480
1859	do	do	136			136	
1860	do	do	750			750	
1861	do	do	30			30	
1862	Skins	Value	£54	£13			£67
1863	Kangaroo Skins	Number Value	400 £30				400 £30
1864	-	-	-	-	-	-	-
1865	-	-	-	-	-	-	-

			(1)	(2)	(3)	(4)	(5)
1866	Skins	Value	£23	£183			£206
1867	do	do	£130	£3			£133
1868	do	do	£431	£5			£436
1869	do	do	£256	£5			£261
1870	(Sheepskins only	do	£195				£195)
1871	(Skins; Seal & Sheep only	do	£373	£123			£496)
1872	(Skins; Sheep only	do		£946			£946)
1873	Skins	do	£417	£93			£510
1874	do	do	£276	£260			£536
1875	do	do	£391	£5			£396
1876	do	do	£250	£350			£600
1877	do	do	£565	£5			£570
1878	do	do	£770	£56			£826
1879	do	do	£1 519	£76			£1 595
1880	do	do	£1 247	£1 700			£2 947
1881	do	do	£1 464	£1 046			£2 510
1882	do	do	£1 621	£348			£1 969
1883	do	do	£415	£235			£650
1884	do	do	£554	£135		£10	£699
1885	Skins (Sheep, &c.)	do	£1 163	£928		£168	£2 259
1886	Skins (Sheep & Kangaroo)	do	£6 192	£144		£15	£6 351
1887	Sheep and Kangaroo Skins	do	£14 586	£2 283		£90	£16 959
1888	Skins (Sheep, Seal & Kangaroo)	do	£35 198	£2 038	£7 890		£45 126
1889	Skins	do	£22 454	£3 341	£2 085	£457	£28 337
1890	Skins (Kangaroo & Sheep)	do	£17 039	£6 620		£548	£24 207
1891	Skins (Kangaroo & Sheep)	do	£8 285	£28 213	£1 390	£170	£38 058
1892	Kangaroo Skins	Bales Value	119 £4 183	283 £23 416			402 £27 599
	(cf. Sheepskins	Value	£153	£6 585		£370	£7 108)

			(1)	(2)	(3)	(4)	(5)
1893†	Kangaroo Skins	Bales	101	102			203
		Value	£2 252	£6 845			£9 097
	(cf. Sheepskins	Value	£494	£6 480		£429	£7 403)
1894	Kangaroo Skins	Packages	147	10			157
		Value	£4 731	£430			£5 161
	(cf. Sheepskins	Value	£395	£7 081		£1 335	£8 811)
1895	Kangaroo Skins	Packages	156	4			160
		Value	£5 527	£50			£5 577
	(cf. Sheepskins	Value	£286	£10 305		£597	£11 188)
1896†	Kangaroo Skins	Packages	62	1		2	65
		Value	£915	£5		£20	£940
	(cf. Sheepskins	Value	£3 361	£11 450		£1 070	£15 881)
1897†	Kangaroo Skins	Packages	86			1	87
		Value	£1 165			£39	£1 204
1898	do	Packages	95	1		1	97
		Value	£3 346	£12		£1	£3 359
1899	do	Bales	328	4		1	333
		Value	£16 044	£93		£18	£16 155
1900	do	Bales	279	18			297
		Value	£12 517	£782			£13 299
1901	do	Bales	302	3			305
		Value	£16 432	£117			£16 549
1902	do	Bales	426				426
		Value	£22 729				£22 729
1903	Skins & Hides (Other: = Not Rabbit or Sheep, etc.).	Number	296 003	560 308		288	856 599
		Value	£30 507	£20 122		£8	£50 637
1904	do	Value	£39 001	£3 256			£42 257
1905	do	do	£47 745	£9 325		£30	£57 100
1906	do	do	£52 142	£16 845	£473		£69 460
1907	do	do	£44 336	£15 893		£42	£60 271
1908	do	do	£20 945	£17 350		£25	£38 320
1909	do	do	£36 039	£36 955		£26	£73 020
1910	do	do	£35 234	£61 518		£1 777	£98 529
1911	do	do	£28 813	£2 992		£62	£31 867
1912	do	do	£30 169	£2 861		£115	£33 145
1913	do	do	£34 868	£5 686		£46	£40 600
1914#	do	do	£18 056	£2 721			£20 777

			(1)	(2)	(3)	(4)	(5)
1915#	Skins & Hides (Other: = Not Rabbit or Sheep, etc.).	Value	£21 240	£10 152			£31 392
1915-16	do	do	£23 419	£8 590			£32 009
1st Half 1916#	do	do	£9 363	£747			£10 110

Note : £1 = $2; values quoted to nearest £ this Table. Blank fields in Table = Nil unless otherwise indicated.

* = Data from Garden (1977). - = Insufficient detail in source records. † Skins listed under heading 'N.O.E.' in source could include significant numbers of kangaroos and wallabies. # These data taken from official list in File F.D. 160/23 (since destroyed).

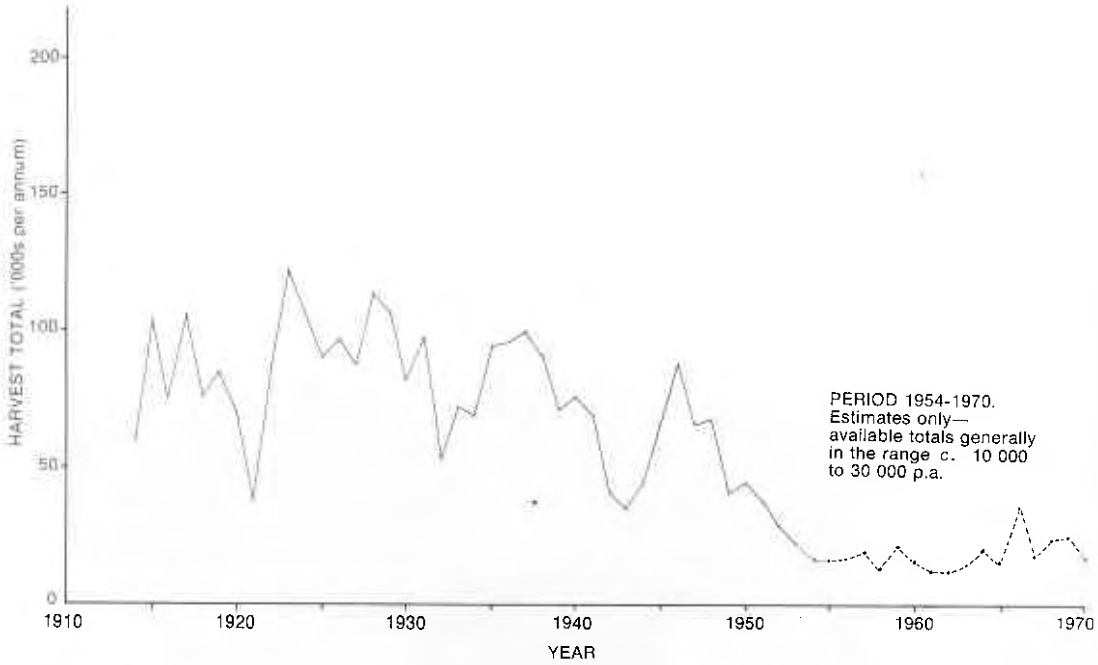


Figure 4. Variation in the Annual Commercial Trade (Harvest) of the Western Grey Kangaroo (Macropus fuliginosus) in Western Australia: 1910-1970.

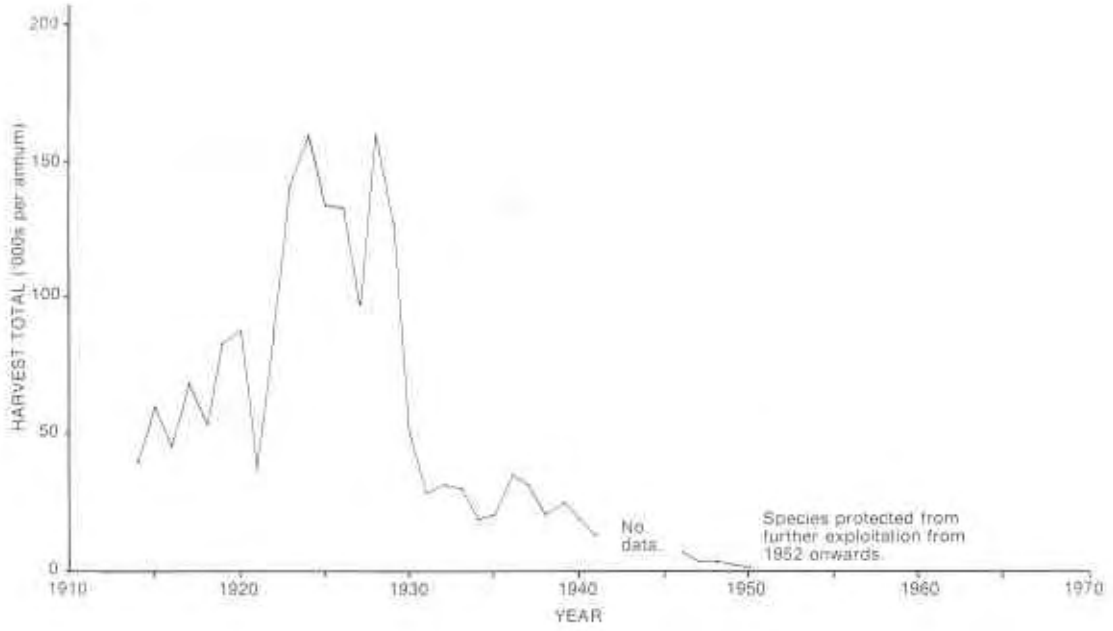


Figure 5. Variation in the Annual Commercial Trade (Harvest) of the Brush Wallaby (Macropus irma) in Western Australia: 1910-1970.

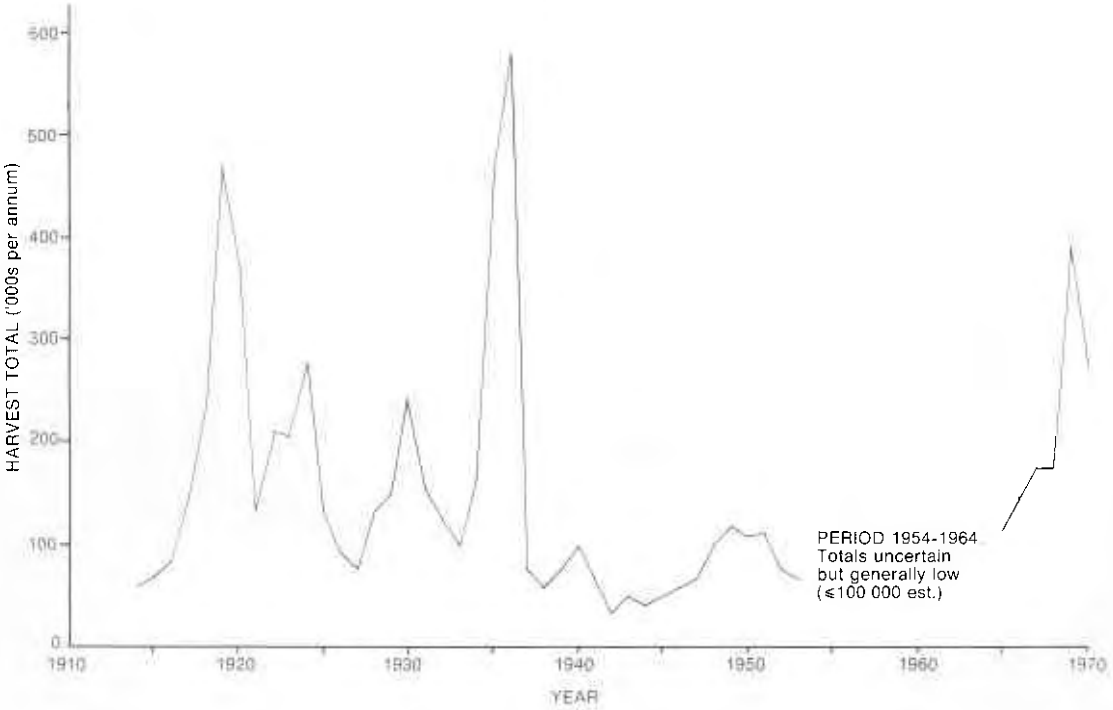


Figure 6. Variation in the Annual Commercial Trade (Harvest) of the Red Kangaroo (Macropus rufus) in Western Australia: 1910-1970.

Table 2.

Kangaroos and Wallabies Taken for Commercial Trade in Western Australia, 1914-1970.

(Compiled from Royalty Records and other Official Records in Western Australian Archives, and other Private Records).

Year	Red Kangaroo (1)	Western Grey Kangaroo (2)	Brush Wallaby (3)	Euro (4)	Other Spp. (5)
1914 (from April 1st - Dec 31 only)	55 286	50 256	33 500	12 790	14 254
1915	63 372	102 544	59 178	17 715	14 377
1916	80 475	76 220	45 507	22 752	8 463
1917	146 239	107 000	68 799	37 748	6 051
1918	230 000	75 000	53 000	38 000	14 000
1919	472 000	89 000	83 000	58 000	4 000
1920	372 124	67 902	87 916	92 091	13 738
1921	132 279	36 548	39 898	27 815	11 675
1922	208 231	86 565	87 452	42 345	19 468
1923	205 248	122 872	141 625	47 408	16 372
1924	274 105	105 088	159 461	13 088 (to May 1 only)	24 148
1925	135 000	87 300	135 200	NA	34 536
1926	95 370	97 056	133 353	NA	28 347
1927	76 440	86 542	98 725	NA	18 831
1928	131 286	113 847	160 130	NA	53 778
1929	151 442	106 499	126 643	NA	38 115
1930	236 611	80 459	50 791	NA	10 764
1931	154 184	96 418	28 681	NA	8 995
1932	124 065	53 735	32 408	NA	9 353
1933	102 735	72 537	29 039	NA	7 792
1934	161 426	68 376	18 752	NA	4 357
1935	461 872	93 000	19 500	NA	1 600
1936	579 823	95 000	33 500	NA	3 100
1937	71 705	98 975	29 833	NA	2 928
1938	58 905	89 612	19 938	NA	NA
1939	73 000	70 000	17 000	$\geq$22 400	NA
1940	99 636	76 073	17 991	$\geq$53 500	NA

	(1)	(2)	(3)	(4)	(5)
1941	64 945	69 734	12 700	≥17 600	NA
1942	32 000	40 348	NA	≥ 9 000	NA
1943	48 000	34 580	NA	≥ 7 600	NA
1944	42 000	44 349	NA	≥ 7 900	NA
1945	53 000	64 796	NA	≥16 000	NA
1946	56 670	89 209	6 704	≥15 600	NA
1947	69 753	65 431	3 694	≥13 300	NA
1948	99 598	66 061	3 359	≥13 600	NA
1949	116 788	40 356	1 609	≥ 9 400	NA
1950	105 067	44 288	1 262	≥ 7 900	NA
1951	108 000	38 317	NA	≥ 8 200	NA
1952	75 000	27 730	NA	≥ 3 900	NA
1953	65 000	22 979	NIL	≥ 2 900	NIL
1954	≥53 000	≥15 000	NIL	≥ 2 700	NIL
1955	≥34 400	≥15 400	NIL	≥ 2 000	NIL
1956	≥49 900	≥16 300	NIL	≥ 1 800	NIL
1957	≥26 800	≥18 800	NIL	≥ 1 000	NIL
1958	≥14 500	≥14 000	NIL	≥ 500	NIL
1959	≥40 000	≥21 200	NIL	≥ 1 500	NIL
1960	≥10 400	≥16 500	NIL	≥ 500	NIL
1961	≥17 200	≥11 700	NIL	≥ 400 (25 000) APB	NIL
1962	≥17 500	≥14 200	NIL	≥ 400 (20 000) APB	NIL
1963	≥49 000	≥15 200	NIL	≥ 300 (40 000) APB	NIL
1964	126 000	20 100	NIL	700	NIL
1965	127 000	15 500	NIL	NA	NIL
1966	150 000	37 000	NIL	NA	NIL
1967	175 000	17 500	NIL	NA	NIL
1968	175 000	24 000	NIL	NA	NIL
1969	400 000	25 000	NIL	NA	NIL
1970	275 000	17 000	NIL	NA	NIL

Note: ( ) APB indicates numbers reported killed in pest destruction drives organised by the Agriculture Protection Board, Western Australia.

V FACTORS INFLUENCING THE MODERN PATTERNS OF EXPLOITATION AND COMMERCIAL TRADE IN KANGAROOS AND WALLABIES IN WESTERN AUSTRALIA

A. EXPLOITATION OF KANGAROOS AND WALLABIES OF THE SOUTH WEST

It follows from previous discussion that exploitation of the Western Grey Kangaroo from the earliest years of European settlement in Western Australia commenced on a subsistence basis. This large animal was reasonably abundant, and provided meat which would otherwise have been unavailable from the settler's limited stocks of domestic animals.

Kangaroos also provided a cheap source of meat for many settlers undertaking agricultural development in the South West of the State well into the 20th Century and for many miners and prospectors elsewhere (see Parliamentary Debates on Game Bills, 21 December 1891, 13 December 1907, 19 December 1907, 28 August 1912, 16 December 1913; and Report of the Select Committee ... on the Game Bill 1912). Many of these people also sold skins of some of the kangaroos taken in order to generate needed cash income; but increasing agricultural development from about 1905 onwards (see Burvill 1979; and Fig. 3) also altered the interaction between man and the kangaroos and wallabies in the South West of the State. The change from predominantly pastoral to the more intensive agricultural pursuits inevitably altered the status of this part of the fauna from that of joint users of grazing lands to that of pests of croplands.

The immediate effect of the changing pattern of land use in the South West on exploitation of particular species is a matter of some conjecture. The available data certainly suggest that exploitation of the Western Grey Kangaroo immediately prior to 1914 may not have differed much from the pattern recorded during the 1920s and 1930s (see Fig. 4, and IV B. 2.). On the other hand, it is clear from reading old files that the Brush Wallaby was considered a major problem by many farmers during the earliest stages of extensive agricultural development. The available exploitation data also suggest a substantial and progressive increase in exploitation of this species up to the mid- to late- 1920s (see Fig. 5).

Exploitation data including such smaller wallabies as the Tammar and Quokka (Table 2, 'Other Spp.' group) suggest that these species were also subject to increasing levels of exploitation similar in pattern to that for the Brush Wallaby, albeit at a lower absolute level. Tammar would certainly have been abundant on land being cleared for cereal cropping. Thus, Mr John Maxwell Drummond noted the apparent early demise of Tammar on cultivated land in the Katanning and Goomalling districts in his evidence to the Select Committee on the Game Bill in 1911 (Report 1912, p. 7). Similar comment is also made by Haddleton (1952, pp. 96-7). In contrast, the Quokka was more of a problem for specialized agriculture, e.g. vegetables and fruit, and had also acquired the reputation as a silvicultural pest by the 1930s (Stewart 1936).

Thus, the combination of habitat conversion and the ensuing land use conflicts arising from increased agricultural development materially affected exploitation of at least four species of kangaroos and wallabies in the South West. Of course, the effects of this change in land use and the resultant increased local human population were not confined to these species alone.

B. EXPLOITATION OF THE KANGAROOS OF THE PASTORAL AREAS

The pattern of variation in commercial trade in Red Kangaroo skins from 1915 onwards clearly differs from the patterns of variation in trade in skins of both the Western Grey Kangaroo and Brush Wallaby (compare Fig. 6 with Figs. 4 & 5). This difference precludes any straightforward prediction of the possible pre- 1914 levels of exploitation of this species based on harvests documented in later years. There is however abundant evidence that kangaroos and wallabies were being exploited in the northern and north-western parts of the State well before 1914; e.g. F. W. P. Cammilleri recorded shooting kangaroos for skins in the Millstream area on the Fortescue River in 1891 (Cammilleri 1966), while comments made during the Parliamentary debates on the 'Game Bill' of 1891-2 also suggest that commercial kangaroo shooting was then an established pursuit in the North West pastoral areas. Further comments made in debates on the 'Killing of Kangaroos for Food Bill' in 1900, and the 'Game Act Amendment Bill' of 1907, and by Cleland (1909) are consistent with the above.

Examination of the skin trade statistics discussed previously (IV B. 2.) also suggests that exploitation of kangaroos in the North West could have accounted for quite large numbers in some years prior to 1914, although there is no information suggesting the exact numbers of either Red Kangaroos or Euros that may have been taken at any time during this early period. On the other hand, the taking of large numbers of Agile (or Sandy) Wallabies in the Kimberley district about this time has already been noted.

The actual pattern of development of European exploitation of kangaroos in the North West of Western Australia is also not well documented, but the same elements were certainly involved as in the South West, i.e. subsistence exploitation, commercial exploitation, and the concept of a pest destruction programme. The interrelationship between these elements may however have differed from that in the South West of the State because of the smaller numbers of people and the extremely large areas involved. For this reason, subsistence exploitation may not have been such a significant element as it apparently turned out to be in the South West, and the commonly held view among pastoralists that the kangaroos and wallabies of the North West were almost worthless pests may have developed very early in concert with an expansion of commercial exploitation. Even so, the kangaroos found in the North West were probably not immediately thought by the early pastoralists to pose major management problems. If my

judgement here is correct, this apparent lack of initially perceived conflict could probably be ascribed to the fact that the developing rangeland (= pastoral) areas were not, at the time the pastoralists arrived, being fully exploited by the kangaroos. Lack of reliable natural water sources throughout much of this part of the State would have imposed a major constraint on the potential size of the resident kangaroo populations, whatever the abundance and status of these populations in different areas at the advent of the pastoralists (cf. II B. 2. and II C.).

Progressive development of the pastoral industry later changed the pattern of exploitation of these rangeland areas and major changes in the rangeland environment and the perceived level of interaction between the kangaroos and domestic stock followed. In the shorter term these changes can be seen to have benefited some of the rangeland kangaroo populations, but they also heightened the level of conflict between the pastoralists and the fauna. Both Ealey (1967) and Newsome (1975) have discussed this topic in relation to considered changes in the abundance of the kangaroos and the consequences for conservation and management.

C. SUMMARY AND CONCLUSION

The foregoing discussion has pointed to the various common factors involved in development of the essentially European approach to exploitation of the Western Australian kangaroos and wallabies in different circumstances. The balance between consideration of kangaroos either as a valuable local resource or as almost worthless pests appears to have posed a dilemma during early development of agriculture in the South West, that, with the passage of time and improved economic standing of these landholders, and those now undertaking new farmland development, has swung heavily towards the latter view. In contrast, this dilemma does not appear to have confronted the pioneer pastoralists in the same manner, particularly because their original small but economically productive flocks could coexist with the kangaroos. The hardening of the pastoralists' low regard for kangaroos apparently resulted from an improvement in their own economic standing resulting from increases in their flocks, and in some situations at least, accompanying increases in the numbers of kangaroos present.

The general consensus of opinion of the landholders in Western Australia thus appears to have been conducive to exploitation of the native kangaroos and wallabies regardless of their status as species of wildlife. The previous review of the relevant legislation (Section III) has also suggested that official administrative policy in regard to commercial exploitation was not founded on any concept of rationalized wildlife management. Even so, the main and probably the only really significant factor contributing to extensive trade in kangaroo products in the past appears to have been commercial incentive. We should therefore examine the detailed harvest data more closely to see how they do relate to the situations and circumstances which favoured exploitation.

VI ANALYSIS OF PATTERNS OF VARIATION IN THE COMMERCIAL EXPLOITATION OF KANGAROOS AND WALLABIES IN WESTERN AUSTRALIA

A. BACKGROUND

It is clear from the preceding discussion that commercial trade has been a feature of European exploitation of the kangaroos and wallabies of Western Australia from the earliest years of settlement. Some of these species are presently subject to continuing exploitation (Prince 1984), and in the case of the Western Grey Kangaroo there is a record of its continuous involvement in commercial trade over a period of around 140 years. The Red Kangaroo has also been subject to continuing commercial exploitation for a period of at least 80 years. The apparent resilience of these two species in regard to continuing exploitation contrasts with the picture for the Brush Wallaby, and poses the question as to why this difference should be so.

It is of course very easy to jump to possibly erroneous conclusions regarding the role of commercial exploitation in the decline of a species that has diminished in abundance in circumstances where there is knowledge of previous apparently substantial exploitation. However the observed patterns in trade appear likely from previous discussion to reflect firstly the interaction between stocks of the target species and their potential exploiters, and secondly, any special circumstances that might affect either the numbers of the animals in the exploited stocks from time to time or the process of exploitation of the particular species being considered.

In general terms, the volume of trade in a commercially exploited species can be related to both economic and biological factors. Initially, the volume of trade supported by a particular exploited species may be related to the abundance and accessibility of the local stocks being exploited, with the primary incentive to exploit being economic advantage (although not always for direct monetary gain, as has been pointed out previously). As exploitation continues and expands, the resultant patterning of exploitation will eventually depend on the balance between the economic incentive to exploit and the biological factors affecting the productivity and accessibility of the species stocks. Development of the resulting harvest pattern can also be influenced by associated permanent environmental changes which affect the potential size of the exploited populations. Thus, exploitation patterns may vary. Declining exploitation patterns can in some instances reflect primary over-exploitation, but in other cases may simply track unrelated changes in market prices or population abundance, or reflect some combination of these factors. Quantitative explanations sought for variations in trade patterns should accordingly be defined by strings of variables relevant to the circumstances outlined above.

Detailed quantitative analyses of the historic patterns of variation in the annual commercial harvests of the Red Kangaroo, and of the Western Grey Kangaroo and Brush Wallaby are presented in Appendices I and II respectively.

The general results obtained from the above mentioned harvest pattern analyses are further discussed here in terms of the probable impact of exploitation on the target species from time to time in the historic context, and the resulting implications for future exploitation and management of the Red and Western Grey Kangaroos in Western Australia are considered.

B. DISCUSSION

1. General Resume

The harvest pattern analyses described in detail in Appendices I and II are believed to be the first attempt at a formal quantitative description of the variation in historic commercial kangaroo harvests, although Jarman and Johnson (1977) have presented a more general analysis of past exploitation of some other species in New South Wales.

Generally the harvest equations derived in this instance have accounted for between 70 and 80 percent of the total variability in the data sets examined. This is an excellent result considering the nature of the harvest and other data available and the input variables tested in the analyses. The deficiencies in the harvest records which effectively restricted the analyses to consideration of the harvests taken during the period from 1915 through to 1953 has not, I believe, presented any major problems in interpretation of the results because this period does adequately cover the most important time of change and economic development in Western Australia relative to concurrent changes in the apparent distribution and abundance of the exploited species and the observed changes in their exploitation.

The final equations derived in each case have also conformed with a priori expectations based on knowledge of the species' biology and ecology and the setting in which the exploitation occurred. There is therefore reasonable justification for saying that these equations adequately summarize knowledge of the modern, i.e. 20th Century, patterns of commercial exploitation of the nominated species of kangaroos and wallabies in Western Australia. Potential future harvests of the Red and Western Grey Kangaroos are predictable because of the generalized formulation of their respective harvest equations in terms of harvest independent variables relevant to continuing exploitation of these species. Useful comparisons between actual harvests taken in Western Australia beyond the mid- 1950s and those which would conform with the earlier patterns and trends in exploitation are thus possible.

The specific equations describing the historic patterns of variation in the harvests of the Red and Western Grey Kangaroos do nevertheless describe two different situations in respect to potential sustainability of commercial harvests in the future relative to present and previously observed harvest levels. These situations are further discussed below.

2. Future Harvest Potential and the Relationship to Previous Exploitation

Sustainable commercial harvesting of the Red Kangaroo in conformity with the observed historic harvest pattern is practicable. The available annual harvests can however be expected to vary widely depending on the incidence and severity of drought in the short-term. Long-term deterioration in the productive capacity of the pastoral rangelands could also depress the average available harvest. In contrast, continued harvesting of the Western Grey Kangaroo can be expected to occur because of pressures generated by ongoing agricultural development, but the available harvests will continue to decline until the balance between residual kangaroo habitat and developed farmland stabilizes. At this point a lower but potentially sustainable harvest should remain because of the presence of considerable areas of rangelands and other large tracts of vacant Crown (unallotted) land unsuited to agriculture elsewhere within the range of the Western Grey Kangaroo in Western Australia. On the other hand, the Brush Wallaby passed this limit prior to the 1950s and the commercial harvest once available disappeared when the residual wallaby population was reduced to very low numbers.

The picture presented above essentially relegates past commercial exploitation of the Western Australian kangaroos and wallabies to a minor role among the factors that may have determined the fate of the various species to date. This conclusion may indeed be correct, but the matter should not so lightly be dismissed. The Red Kangaroo harvest record shows that relatively heavy harvest pressure was, in the mid- 1930s (see Fyfe 1940, pp. 166-8), and again in the 1969 and early 1970s period (see Prince 1984), associated with apparently substantial reductions in kangaroo numbers. The Brush Wallaby and other south-western species had also declined to very low numbers by the late 1930s after a major episode of commercial exploitation extending to the early 1930s. Harvesting during these apparently critical periods in the record should therefore be subject to closer scrutiny to see if commercial exploitation at these times may have had a more deleterious impact on the target species than it appears to have had when the total harvest record is considered.

The most important feature of the Red Kangaroo harvest record in the context of the present discussion is the ability of the commercial trade in past years to have accommodated a two- to three-fold increase in the total harvest from one year to the next (see Fig. 6). Prior to the 1935 - 1936 event some considerable variations in harvest had apparently been supported by the exploited stocks with little lasting residual impact, but the post- 1936 harvests suggest that the highest recorded two-year harvest taken in Western Australia during 1935 and 1936 coincided with a lasting reduction in the Red Kangaroo stocks. The question that arises is whether a cause-effect link exists between these observations.

Results of the Red Kangaroo harvest pattern analysis (Appendix I) in fact suggest that the 1935 - 1936 harvest total was much higher than would normally have been the case because of substantial under-harvesting during 1932 - 1934. The relatively high Red Kangaroo harvests taken to the end of 1936 thus appear more likely to be symptomatic of events leading to the post- 1936 kangaroo stock reduction rather than the causal factor. The fact that apparent parallel changes in the pastoral livestock population also occurred during this period (Jennings et al. 1979, Fig. 1) supports this view. We are therefore left to consider whether the substantial harvest of kangaroos in 1935 - 1936 may have either ameliorated or exacerbated the impact of the coincident drought as far as the rangeland pastures and the kangaroo population were concerned.

The answer to this last question depends on knowledge of the effect on the rangeland plant communities of grazing pressure in combination with drought, and on the potential substitution of harvest mortality for natural mortality that would otherwise have occurred in response to the drought. Unfortunately, a definite answer cannot be given because of a lack of detailed contemporary information. There is however good reason to believe that substitution of harvest mortality for natural mortality will be incomplete at the best. Heavy exploitation pressure combined with drought might thus drive Red Kangaroo numbers down more quickly and also further in the short-term than the expected natural process of population reduction during drought. On the other hand, the incidental advance relief of heavy grazing pressure on the drought affected rangeland vegetation due to harvesting of the kangaroos could confer a long-term benefit on the pastoral ecosystem. The balance between these possibilities nevertheless appears likely to have depended on the continued grazing pressure being contributed by the remaining herbivore population, of which the kangaroos were only one part.

3. Commercial Exploitation and the Change in Status of the South-Western Species

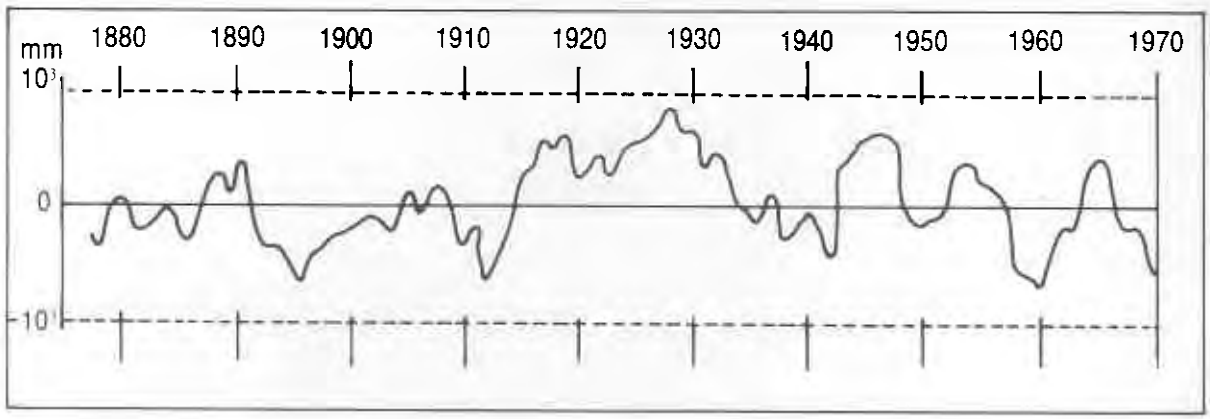
Assessment of the possible role of commercial exploitation as a causal factor relating to the decline of the smaller exploited south-western species, such as the Brush Wallaby in the 1930s, presents a number of alternative possibilities. These are discussed below.

Rainfall undoubtedly has had, and continues to have, a marked effect on productivity of Western Australian environments and their dependent fauna. A further period of declining abundance of some of the south-western fauna of the State has recently occurred during the droughty decade of the 1970s, and similar declines in abundance of fauna populations in Western Australia were apparently noted during earlier droughts, e.g. comments made by Mr A. R. Richardson, M.L.A. for DeGrey, in Parliamentary Debates on the 'Game Bill', 15 December 1891; and the Hon. C. A. Piesse, M.L.C. for South East Province, in 'Game Bill' debates, 28 August 1912. The Hon. J. Mitchell, M.L.A. for Northam, also suggested that disease was responsible for the apparent disappearance of possums from the present Eastern Wheatbelt area of the State in the late 1890s (Parliamentary Debates, 'Game Act Amendment Bill', 16 December 1913), but rainfall records show that the area was badly affected by drought about the period in question (see Gibbs and Maher 1967, Figs. 14-19 = the Annual Rainfall Maps for 1894 - 1899). The apparent disease noted by Mitchell may thus simply have been observed morbidity in animals dying from drought induced stress, as is commonly observed in the Rottnest Island Quokka population during late summer drought (Main et al. 1959). It is therefore not surprising that intense drought in the 1935 - 1938 period (Gibbs and Maher 1967, Figs. 55-58) was apparently associated with a decline in abundance of the south-western fauna.

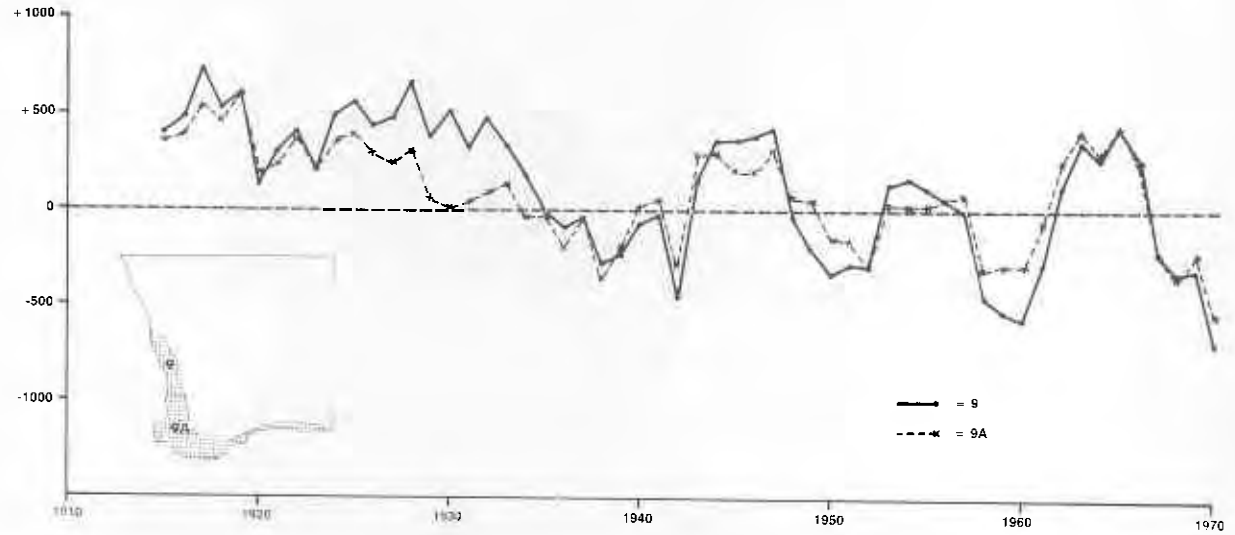
Nevertheless, circumstances associated with the 1930s decline of the south-western mammal fauna differed from those of previous times in three important respects: firstly, the drought followed what appears to have been the longest period of generally consistent high rainfall yet recorded in the South West of Western Australia (1915 - 1930; Fig. 7). Secondly, this drought halted what had to that time been a hitherto unprecedented burst of major environmental change (Fig. 3); and thirdly, major increases in populations of the Rabbit (Oryctolagus cuniculus), and perhaps more importantly, the European Red Fox (Vulpes vulpes), both of which had reached the State in earlier years (Tomlinson 1979), apparently occurred in the early 1930s. These latter increases in populations of the potential competitor, and additional predator, in the ecosystem are reputed to have adversely affected the medium-sized marsupials of the South West: but contemporary impressions concerning the natural abundance and the magnitude of normal fluctuations in the abundance of the fauna may have been distorted by the first mentioned differences. Apart from the above, there is also a general belief current in Western Australia that an unidentified epizootic may have affected the south-western fauna during the 1930s: but maybe the sequence of events that presumably was observed could have reflected the same combination of factors as suggested above in regard to the 1890s.

Lack of adequate documentation of the separate effects of each of the alleged factors in the apparently novel combination described above prohibits any definitive decision in regard to relationships, but it is possible to argue that the population declines of the smaller wallabies and some other marsupials in the South West during the 1930s were the inevitable results of habitat loss and deterioration following land clearing for agriculture and the grazing competition provided by the Rabbit, combined with the alleged effects of increased predation due to Foxes, and possibly other mortality due to disease. However, this scenario effectively relegates prolonged drought to a minor role, which is surely incorrect, and also leaves little room for an effective impact of prior commercial exploitation. My view is that the mid-1930s drought was an important factor, but that

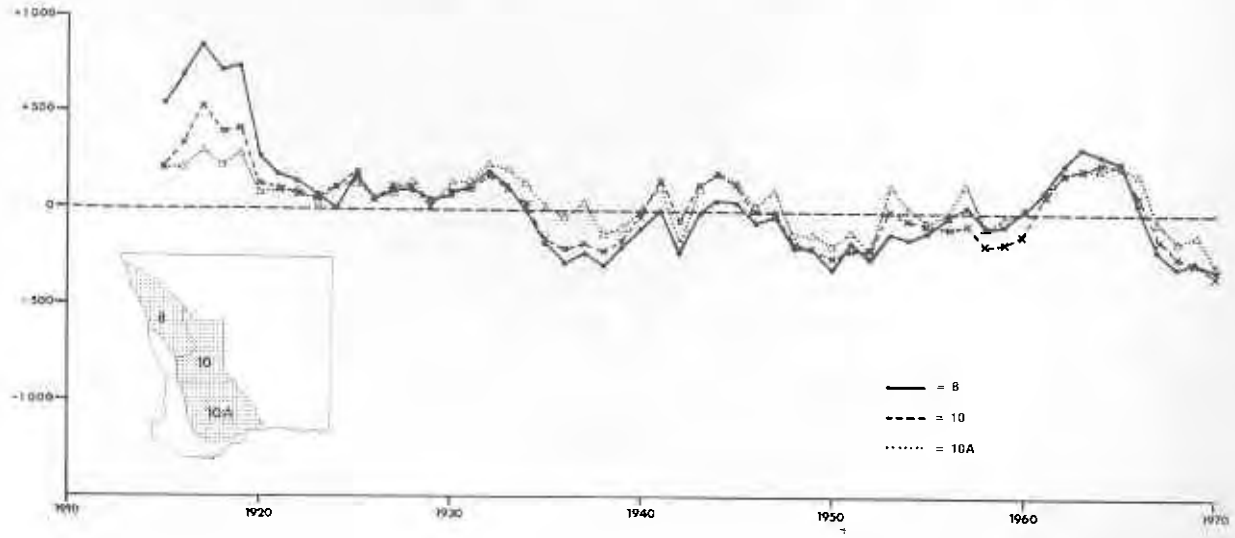
Figure 7. The Pattern of Long-Term Variation in Rainfall received in south-western Western Australia. Data plotted in each instance are 5 year running-means equivalent to the cumulative rainfall deviations from the mean in mm for the period commencing 2 years earlier and ending 2 years later than the particular year point. Mean annual rainfall for: Perth is 832 mm; District 9 is 858 mm; District 9A is 923 mm; District 8 is 401 mm; District 10 is 362 mm; District 10A is 440 mm.



7a. Perth Rainfall : c. 1875-1970. Reproduced with amendments by permission of the University of W.A. Press, Nedlands from Fig. 7.15, Chapter 7, 'The Atmosphere' by R.L. Southern in 'Environment and Science' (Ed. B.J. O'Brien), 1979.



7b. Rainfall in Districts 9 and 9A : 1910-1970. Inset showing location of Rainfall Districts 9 and 9A.



7c. Rainfall in Districts 8, 10 and 10A : 1910-1970. Inset showing location of Rainfall Districts 8, 10, and 10A.

its impact was also most probably intensified by the additonal Fox predation on the residual fauna populations made more vulnerable to other pressures by loss of prime habitat to agriculture, and possible reductions in potential numbers in these populations prior to the onset of the drought due to previous, and in part, continuing, unrestrained commercial exploitation.

If the explanation above represents the real situation, then it is possible that commercial exploitation indeed played only a secondary role in the events contributing to the observed decline of the south-western Western Australian fauna during the 1930s. Still, I think there is strong reason to believe that the declines in populations of the exploited species at this time may not have been so drastic in the absence of commercial exploitation. The same may also be said in regard to the presence of the Fox and Rabbit.

VII IMPLICATIONS FROM PAST EXPLOITATION PATTERNS FOR FUTURE MANAGEMENT OF THE EXPLOITED KANGAROOS IN WESTERN AUSTRALIA

A. INTRODUCTION

The analyses of past patterns of variation in commercial harvests of the Red and Western Grey Kangaroos and the Brush Wallaby in Western Australia discussed above have shown that there is a difference in these harvest patterns that can most readily be equated firstly with the degree of alteration and alienation of the habitat originally occupied by the species concerned, and secondly with the specific impact of the environmental changes that have occurred within the past 100 years. Management of the Red and Western Grey Kangaroos in the present is discussed below.

B. THE RED KANGAROO (AND EURO)

On balance, the changes to date in the rangeland habitat occupied by the Red Kangaroo and Euro have certainly not disadvantaged the species (cf. Ealey 1967; Newsome 1975) and may so far have conferred a net benefit. Continued harvesting of these species in conformity with past patterns of exploitation is thus possible. Deterioration of rangeland productivity appears to be the only immediate environmental factor that could lead to permanent depletion of the exploited kangaroo stocks (Newsome 1975) and thus, in the future, depress the potential average harvests.

Further exploitation of the Red Kangaroos (and Euros also) in Western Australia is in fact irreversibly linked with requirements for regulation of total grazing pressure on a major portion of the State's rangelands (Jennings et al. 1979, pp. 102-6 and 146-52). It is in this setting that we should therefore consider future exploitation and management of these species if we are to achieve the best available compromise between rangeland grazing management and wildlife conservation. The problem involved is essentially that of ensuring continued coexistence of the kangaroos and the pastoral industry while conserving productivity of the rangeland vegetation. From the viewpoint of wildlife conservation, the role of continuing commercial exploitation within this frame is of central importance.

Traditionally, the economically productive pastoral industry has always taken precedence in debate on rangeland management goals and practices and the kangaroos have generally been considered undesirable pests. From time to time in the past it has been argued that substantial reductions in kangaroo numbers ought to be made on the assumption that this course of action would solve rangeland management problems besetting the pastoral industry, but evidence supporting this simplistic link between the possible numbers of kangaroos and the fortunes of the pastoral industry is lacking. Meanwhile, commercial exploitation of the rangeland kangaroos continued under its own impetus until a collapse in the early 1950s, and then subsequently revived in the mid- 1960s. The interrelationship between continuing kangaroo exploitation and rangeland domestic livestock management and production therefore deserves further consideration in this context.

My further examination of yearly data on the number of small stock units (SSUs, Jennings et al. 1979) held by the pastoral industry within the range of the exploited stocks of both the Red Kangaroo and Euro in Western Australia (see Jennings et al. 1979, Figs. 1, 2 and 13; also Section VI and Appendices I and IV this paper) strongly suggested that the pastoral domestic livestock populations in this State had for the most part in past years been held near short-term environmental limits. Consequently, onset of drought generally had an immediate and detrimental impact on the pastoralists' livestock. In such circumstances, unfavourable economic shifts can readily compound the pastoral management problems associated with the frequent recurrence of drought, and it is these factors which in the past appear to have had the capacity to disrupt management of total rangeland grazing pressure in a way that can lead to disaster as far as conservation of the rangeland resource base is concerned.

Thus, the high peak kangaroo harvests taken during 1935-36 in fact closely followed the apparently depressed harvests of 1932 - 1934 (Fig. 6), which latter result appears attributable in part to the critical effects of economic recession on the kangaroo skin market. Simultaneously, this economic recession also contributed to an excessive increase in the rangeland domestic livestock population (Williams et al. 1973, p. 32; Williams 1978; Jennings et al. 1979), so that when the inevitable drought ensued, a major crisis was precipitated. In response to this drought, the kangaroo population was at once attacked with increased vigour, but the environmental damage had apparently already been done. Equivalent prior decisions made by both the pastoralists and the kangaroo shooters were dictated by adverse economic circumstances unrelated to prevailing rangeland conditions and resulted in each case in a major mismatch of stock management performance versus ecological need that was ultimately detrimental to all concerned.

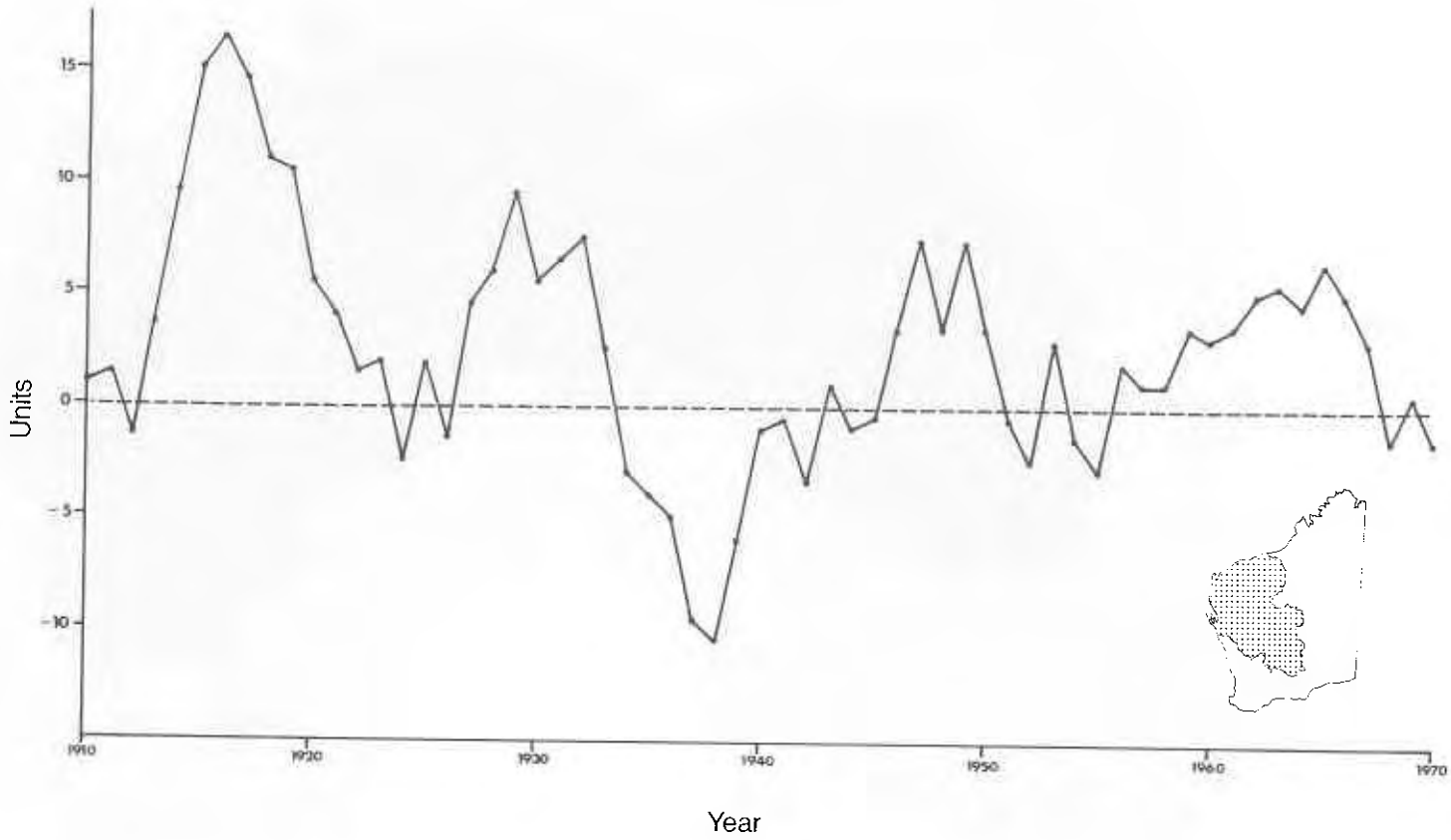


Figure 8. The Pattern of Long-term Variation in Rainfall Received in the Pastoral Areas of the North West of Western Australia from which Red Kangaroos were Harvested : 1910-1970. Inset showing Area within which the major portion of the Red Kangaroo Harvests were taken. Data plotted are 5 year running-means equivalent to the cumulative rainfall score (RNI) deviations from the expected annual average rainfall scores of 5.0 for the period commencing 2 years earlier and ending 2 years later than the particular year point.

Further evidence (e.g. Jennings et al. 1979, Fig. 1) shows that the total rangeland domestic livestock population increased during the 1950 - 1960s period, apparently in response to an improving rainfall regime (see Fig. 8) and some marginal increase in rangeland development, despite minimal exploitation of the kangaroo stocks at this time by both commercial exploitation and pest destruction programmes (refer Table 2). This information and the example discussed above suggests that the main feature shared by the rangeland domestic livestock and kangaroo populations is simply their occupation of the same geographical area.

Certainly, the trend of increase in the domestic livestock population continued after revival by the developing pet-meat trade of commercial exploitation of Red Kangaroos in the mid- 1960s (Jennings et al. 1979, Fig. 1). A further increase in the wool-cut per adult sheep, and some improvement in lamb marking percentage also appeared to accompany this continuing increase in the domestic livestock population (Jennings et al. 1979, Fig. 11). Even so, the reductions in both the domestic livestock population and the Red Kangaroo harvests following the 1969-70 drought still mirrored events previously observed in the 1930s period (see Jennings et al. 1979, p. 39, for comments on the domestic livestock population; Prince 1984, for details of the recent kangaroo harvests). Apart from the direct economic returns available, the major importance of commercial exploitation of the rangeland kangaroos therefore appears to lie in its contribution to regulation of the total rangeland grazing pressure. Kangaroo exploitation needs to be integrated within the context of this management to be effective, but the impact of management orientated exploitation on the rangeland kangaroo populations will depend to some extent on the level of integration of grazing management that is actually achieved.

Essentially, environmentally sound rangeland management requires effective general constraint of total grazing pressure below the short term environmental limits in times of plenty, and the ability to constrain the potential increases in grazing pressure if there is some gradual improvement of rangeland condition during a short period of favourable rainfall (see Jennings et al. 1979, pp. 146-7). History shows that intense drought will invariably recur, and it is only by the exercise of this necessary restraint in periods when memories of past drought are fading and economic pressures may be tending to suggest otherwise, that a repetitive cycle of environmental degradation will be avoided in the future. The prescriptions for correct management of both the kangaroo and domestic livestock populations are thus similar, but it must be emphasized that this similarity is a function of the rangeland environment itself, and not a reflection of any real or presumed interaction between these two groups of grazing animals.

Both the apparent kangaroo management problems encountered in Western Australia during the late 1950s - 1960 period, and the results of the rangeland kangaroo control programmes of the early 1960s further point to the fact that previous exploitation of these kangaroos for strictly commercial purposes did, for the most part, effectively limit the potential for increase in the State's rangeland kangaroo stocks. Where, in past years, commercial exploitation has apparently failed to perform adequately in its de facto role as the principal rangeland kangaroo management agent, effective alternative management measures have also generally not been implemented immediately and the alternatives that have been used have required considerable financial support without being directly productive. The real cost to the community is therefore greater where this action is required.

Continuing commercial exploitation of the rangeland kangaroos clearly is the preferable method of kangaroo population control. The case for favouring rangeland kangaroo management on the basis of exploitation of a renewable natural resource in a multiple use setting is thus strong. In addition to the continuing commercial exploitation having the potential to be economically self-sustaining, this approach also appears to offer the best conservation prospect in providing control over the numbers of kangaroos on the rangelands while also permitting the continued existence of the kangaroos throughout their natural range. The question of what kangaroo population could be necessary to support a viable commercial trade within the State remains, but on past evidence this would certainly be below the average carrying capacity of the pastoral rangeland environment in all but the most extreme drought conditions.

C. THE WESTERN GREY KANGAROO

We now turn to consideration of the major difference between the historic pattern of exploitation of the Western Grey Kangaroo and that for the Brush Wallaby, and the connection between this difference and the possible course of future exploitation of the Western Grey Kangaroo in Western Australia, this being the only south-western species still subject to direct exploitation pressure.

The pattern of trade and the more rapid decline in the abundance of the Brush Wallaby points to the fact that confrontation between developing agriculture and this species was relatively more direct than in the case of the Western Grey. The evidence suggests that this result was due to agricultural development within the most important part of the species' habitat during the first major period of agricultural expansion in Western Australia beginning in 1905. In comparison, the decline in harvests of the Western Grey is of more recent occurrence, although there is some remaining uncertainty regarding comparison between average harvests of this kangaroo in the 1920s and those of the 1890s. The difference between the Western Grey and the Brush Wallaby in the 1920s does however appear to be explained by the fact that a considerable proportion of the Western Grey Kangaroo harvest during the 1920s was probably still being taken in non-farm situations, although by far the largest portion of the total harvest continued to be taken within the area included in the 'Grey Kangaroo Reserve'. This

'Reserve' (Figs. 2a - 2d) included practically all of the area now developed for farming in south-western Western Australia, but it is only since the 1950s that the major part of this area has become fully developed farmland (see Figs. 3 & A II. 1; and Burvill 1979, Table 3.1).

Farmland development is continuing in south-western Western Australia at present, and includes both more intensive land development in the older settled areas and further alienation and clearing of large tracts of new land. Continued displacement of (Western Grey) kangaroos from these areas will generate similar pressure for continuing exploitation as in past years, and commercial disposal of the kangaroos being taken will be preferred in many cases. This wish to continue trade will no doubt prevail, but caution appears necessary in assessing the relevance of past exploitation levels as predictors of acceptable exploitation of this kangaroo in the future: the new land now being developed possibly comprises the less favourable parts of the species' range, and so will hold lesser numbers of kangaroos. Further, modern technology and the change in emphasis in the commercial trade could have increased harvest efficiency, and has probably tended towards more sustained hunting pressure being placed on the exploited populations in comparison with the previous seasonally biased dry skin trade. Future conservation policy for the Western Grey Kangaroo will need to recognise the lessons from past exploitation, and to also take note of the changed circumstances of the present.

VIII CONCLUSION

This review has pointed out how the early European exploitation of kangaroos and wallabies in Western Australia continued the established pattern of exploitation practised by the Aboriginal population; but the European settlers soon introduced new dimensions to this interaction. The most immediate change directly affecting exploitation of the fauna was introduction of the concept of commercial export (external trade) orientated exploitation. This factor greatly increased the local human impact on the existing kangaroo stocks, and thereby proved a further source of conflict between the Aboriginal and European populations present at that time. In the longer term, the most important of the changes wrought by the European settlers have been the development of land for agriculture, and the introduction of exotic livestock and feral animals such as the Fox and Rabbit. Continuing human population increase and economic expansion has, of course, been the driving force behind most of these changes.

Since the first kangaroos were taken for commercial purposes in Western Australia and skin exports commenced in 1843, commercial exploitation in this State has accounted for relatively large numbers of kangaroos and wallabies, and other fauna besides, and some species which were apparently subject to comparatively heavy commercial exploitation pressure in the past are now posing conservation problems. The natural tendency of concerned members of the public appraised of such past events, and some considered excessive exploitation of other species occurring elsewhere in more recent times, is to now single out unrestrained commercial exploitation as the factor responsible for transition of the status of an exploited wildlife species from abundance to that of scarcity posing problems in conservation. The real situation is by no means as simple as this.

Unrestrained commercial exploitation of the fur-bearing fauna of the South West of Western Australia prior to the 1950s certainly did not form any part of a comprehensive integrated public policy of wildlife management and conservation as far as I can judge. Some of the smaller animals which were heavily exploited prior to the mid-1930s also apparently suffered substantial and irreversible declines in abundance during the mid- to late- 1930s. The bulk of the evidence suggests however that commercial exploitation pressure was not a primary contributory factor associated with the 1930s decline in abundance of the medium-sized south-western mammals, because species without any history of commercial exploitation were apparently affected similarly to the species known to have been exploited. The changes in abundance and conservation status of members of this fauna should more correctly be viewed as further examples of the general environmental impact of increased human disurbance following European settlement. Even so, I do suggest that the impact of commercial exploitation on the species so affected probably amounted to more than the simple process of mopping-up of animals being permanently displaced by agricultural land development.

Presently only the large kangaroo species are subject to continuing commercial exploitation pressure in Western Australia, but except for the fact that rates of habitat loss or degradation, as the case may be, have been slower relative to the sizes of the original ranges of the species and that the species themselves have apparently been more resilient in the face of the combined new pressures, their situation is essentially little different from that affecting the smaller wallabies of the southern part of the State during the first thirty years of the 20th Century. As Newsome (1975) has suggested, the present contrast between the general abundance on rangelands of the larger kangaroos and the decline of other smaller species in previous times also probably differs only in degree and timing.

Persistence of abundant populations of the presently exploited larger kangaroos in Western Australia to date is not therefore a reflection of either the suitability of former administrative policies in regard to exploitation of these species, or of the actual exploitation practice. The circumstances now affecting the Western Grey Kangaroo and the Red Kangaroo differ, but the present abundance and widespread distribution of

each species does nevertheless provide a good foundation for long term conservation orientated management policy for each.

The Western Grey Kangaroo has generally sustained considerable commercial exploitation pressure from practically the earliest years of European settlement in Western Australia, but still appears to be as abundant in some remaining extensive areas of natural habitat as at the time of European settlement. On the other hand, large areas of former habitat are no longer available to the species, and further losses of habitat seem certain to occur in the future. The evidence therefore suggests that in total the Western Grey Kangaroo is now less abundant in the south-west of Western Australia than it was prior to the extensive agricultural development in this area, and that further population reduction and fragmentation is inevitable.

The best conservation policy for the Western Grey Kangaroo in this changing environment would be one based on the requirements for maintenance of local populations of the species throughout as wide an area as possible.

In contrast with the Western Grey Kangaroo, species populations of the Red Kangaroo, and the Euro in similar situations, probably are more abundant than they were prior to the advent of the pastoral industry in the rangeland areas of the State. Locally abundant kangaroo populations did exist within this area prior to development of the modern pastoral industry, but the artificial provision of reliable water sources throughout large areas of potentially suitable habitat that formerly would have been largely unexploited by kangaroos because of lack of natural waters has benefited these two species. Some of the structural changes in the rangeland vegetation wrought by the grazing of domestic livestock have also further benefited one or the other of these kangaroos to date.

Current commercial exploitation of the Red Kangaroo and Euro in the pastoral areas of Western Australia thus differs from that now affecting the Western Grey. Distributions of the former two species apparently remain similar to those found at the time of European settlement, and the centres of abundance of the exploited populations generally appear similar to the areas of original abundance of these species, despite some shifts in relative species abundance in particular areas, e.g. the increase in the Pilbara Euro populations relative to Red Kangaroos and Sheep (Ealey 1967). The habitat now occupied by the main Red Kangaroo and Euro populations has been markedly altered from its pristine condition by the cumulative effects of increased grazing pressure sustained since the beginning of the pastoral industry, but the animal dependent pastoral and kangaroo industries in Western Australia will continue in the foreseeable future to be limited to exploitation of the remaining natural rangeland vegetation.

Because of the practically complete occupation of the State's rangelands by the pastoral industry, the enforced coexistence of the kangaroos and domestic livestock will also need to remain a feature of this system. In this setting, exploitation of the rangeland kangaroo populations can be considered as part of the total natural-resource based human exploitation of the rangeland ecosystem.

Accumulated evidence shows that the present productive capacity of the State's rangelands has deteriorated markedly, and that the long term stability and productivity of these rangelands is in doubt (Jennings et al. 1979; Wilcox and McKinnon 1972); but it is the productive capacity of the rangelands which will ultimately determine the potential magnitude of the dependent animal-based exploitative industries in these areas. In the shorter term, the scope of these industries will be determined by their commercial viability. The consequences flowing from these facts require expansion to allow a better understanding of the situation under discussion.

Present indications are that greater constraint on total rangeland grazing pressure is needed to protect the rangelands from further degradation, but any consequent reductions in the domestic livestock and kangaroo populations will reduce the potential production of both the pastoral industry and the kangaroo trade, each of which is reliant on favourable economic returns for its continued operation. Two potential causes of future contraction of the rangeland animal industries are thus identified. Either factor could affect these industries in the near future, but adverse economic conditions are not necessarily related to rangeland condition and, on past experience, appear capable of compounding rangeland over-grazing problems while these animal enterprises continue to exist. An understanding of the relationship between economic circumstances and the requirements for sound rangeland management is therefore most important in considering future management of the dependent animal populations.

In general, ecologically sustainable rangeland management in arid areas requires constraint of grazing pressure below the short term environmental limits in good times, so that an immediate crisis does not occur as soon as the inevitable drought intervenes. Dependence of the kangaroo industry itself on removal of kangaroos from the field populations is consistent with this management objective, insofar as harvesting of these kangaroos has apparently depressed total numbers below the environmental limits. Further, relatively high average rates of offtake would also be expected to constrain kangaroo numbers well below the short term environmental limits, while simultaneously being of economic benefit to the kangaroo industry due to increased trade turnover. On the other hand, the history of the decline in the kangaroo trade in the 1950s and the coincident kangaroo management problems encountered in the North West pastoral areas in the 1950s suggests that commercial exploitation of the rangeland kangaroo stocks is required if effective rangeland grazing management is to be achieved, although attention to control over the numbers of rangeland kangaroos will not resolve any of the management problems caused by the presence of the domestic livestock populations.

A continuing economically successful kangaroo industry can thus provide what experience suggests is the only practical solution to management of the kangaroo component of the total rangeland grazing pressure, as well as providing productive employment for the persons involved in that industry. However this course of action does not eliminate problems.

Commitment to dependence on the kangaroo industry for management of rangeland kangaroo grazing pressure does require recognition of some potential conflict with the simpler desires of the pastoral industry. If the activities of the people involved in the kangaroo industry (which in the past has generally, albeit incidentally, made the major contribution to control of the size of the rangeland kangaroo populations) are integrated in a service role within the framework of official policy directed towards conservation and management of the rangeland kangaroo populations, then the interests of these people must reasonably be accommodated. The investment in the equipment necessary to realise the full value of the kangaroos taken requires some security if an adequate spread of available kangaroo management effort is to be provided and maintained on a self-supporting basis. Resolution of the conflict of some immediate interests of the pastoralists and those of the kangaroo industry aside, maintenance of the Red Kangaroo populations in the pastoral areas also poses a further conflict of direct interests because the best areas of Red Kangaroo habitat are also the best pastoral lands.

Recognizing from the above that compromises between the direct interests of the different parties involved are necessary, we should now consider the implications in relation to wildlife conservation needs of a management policy that is aimed at exerting control via a programme of continuing commercial exploitation over the total numbers of kangaroos inhabiting the pastoral rangelands while at the same time maintaining the kangaroos as part of the pastoral ecosystem.

The comparative scarcity of nature conservation reserves within the rangeland areas involved may be cause for general concern for nature conservation, but while such reserves may be an essential requirement for conservation of some wildlife, they nevertheless represent a minimum conservation solution. Maintenance of widespread and abundant populations of the particular native species concerned wherever possible is a much more desirable alternative to be aimed at. The resource base requirements for a continuing viable kangaroo industry are entirely consistent with this latter objective, so the desirable conservation alternative is readily achievable in this instance, and obviates a direct necessity for nature conservation reserves for the rangeland kangaroos themselves. Acquisition of suitable areas including prime Red Kangaroo habitat for nature conservation could in any case be extremely difficult.

Given the above situation, maintenance of a viable kangaroo industry sharing the rangelands with the pastoral industry does provide the best solution for both management and conservation of the State's rangeland kangaroos, and is a firm basis for formal kangaroo management policy.

Circumstances affecting future management of the Western Grey Kangaroo differ from those of the species largely confined to rangelands. Secure areas of natural habitat now available to the Western Grey over an important part of its range are restricted to small islands of bushland which are quite adequate to shelter a reasonable number of kangaroos and yet are far too small to wholly maintain a local viable population of kangaroos. This picture is particularly true for most Nature Reserves in the agricultural areas of south-western Western Australia.

Apart from the generally small size of these Nature Reserves in the South West (Kitchener et al. 1980, p. 126; K.J. Wallace, pers. comm. 1982), the habitats included also do not generally comprise a representative sampling of all the former habitats available, and seasonally important resources, e.g. water, needed by the kangaroos are not always present on the reserves. Thus, survival of Western Grey Kangaroos as part of the wildlife of these Nature Reserves in the future will be dependent on their continued presence in, and access to, some of the surrounding agricultural land. Attempting to confine these kangaroos within the Nature Reserves is not a viable alternative. Western Grey Kangaroos are only one of the many species in the biota of the different Nature Reserves, and as such are of no greater biological importance than any of these other species of flora and fauna. Needs for management within the Nature Reserves must therefore be assessed from the viewpoint of maintaining as great a range of species as possible. Relegation of these reserves to the role of kangaroo parks will in the main be incompatible with this wider long term nature conservation objective, but these reserves do potentially provide the only areas with long term security of tenure available to the Western Grey Kangaroo.

Because Western Grey Kangaroos are readily able to live in the situation described above it is still possible for a conservation programme for the Western Grey Kangaroo in the agricultural areas of south-western Western Australia to aim at ensuring the survival of local populations over as wide an area as possible, but management of these local populations will be needed to reduce the level of conflict between the needs of the farming community and the remaining kangaroos in sensitive areas. Elsewhere within the species' range, management requirements should be viewed as an extension of this particular approach, taking into account the different local situations.

Commercial disposal of the carcases of Western Grey Kangaroos taken in this instance could also be desired and may readily be permitted, but commercial exploitation of this species as part of long-term management is of secondary importance. The numbers of animals that may become available to the kangaroo trade from future management activities also appear to be limited in comparison with the prospects for further exploitation of the Red Kangaroo.

IX ACKNOWLEDGEMENTS

Having not previously attempted an historical research project, preparation of this paper was a new experience for me. Miss Margaret Medcalfe and her staff at the Battye Library (Western Australian Archives) were most helpful at the start of the project, and whenever their assistance was sought later.

Roslyn Roberts worked hard during the initial searching for, and sifting through, potential source references while temporarily employed as a Technical Assistant. Her invaluable assistance is gratefully acknowledged. Mary Colreavy also assisted in this work at a later date. Gary Martin helped in extracting trade statistics, and received valuable assistance from Mike Lyndon and Vida Corbett of the Australian Bureau of Statistics, Perth Office.

Mr H. A. (Dick) Mofflin was of great help in providing access to records of the business of H. E. Mofflin and Co., and also for his comments on the skin trade prior to the 1960s. My access to Elder's collection of the in-house journal 'Elders Weekly' was facilitated by Mr Gordon Hamilton of Elder Smith Goldsbrough Mort Ltd., Perth.

My colleagues, Norman Hall and Nick Caputi, provided helpful advice and assistance in using the SPSS programme package for analyses, and Angas Hopkins made some extremely helpful comments on the draft manuscript. Thelma Woodward typed most of the first drafts of this paper onto word processor files. Raelene Hick and Jill Pryde reset the final manuscript for printing.

To the above, and the many others who provided helpful comments and assistance, I extend my thanks.

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APPENDIX I

ANALYSIS OF PATTERN IN THE RED KANGAROO TRADE
- WESTERN AUSTRALIA -

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INTRODUCTION

The simple record of the numbers of skins of the Red Kangaroo traded in Western Australia from 1914 onwards (see Table 2), unembellished either with any further details of the precise origins of the skins being presented for sale, or on the amount of effort actually expended in their collection, seemed a most inauspicious starting point for an attempt at a quantitative explanation for the observed pattern of variation in these harvest data. However the exploitation record for the Red Kangaroo in Western Australia shows continuity of harvest over a long period, coupled with an apparent pattern of inherent cyclic variation in harvest levels and an apparent difference in the annual average harvest levels attainable within different parts of the record (see Fig. 6).

The pattern of variation described above suggested that the historic trade data could be considered as approximating a sustainable pattern of exploitation operating in a variable environment, and that the explanation for the observed trade pattern should be sought in terms of variations in the exploited kangaroo stocks and their productivity and factors related to the accessibility and vulnerability of these kangaroos to commercial exploitation, taking any special commercial factors into account along with the biological factors as required.

The results of analyses aimed at discovering the main factors contributing to the observed pattern of variation in the historic Red Kangaroo harvests taken in Western Australia are reported below.

BACKGROUND AND FORMULATION OF HYPOTHESIS

Pastoral development of the arid and semi-arid rangelands within the range of the Red Kangaroo has not generally reduced the area of habitat available to the species, and there is evidence that the grazing of domestic livestock has in some situations produced changes in the rangeland plant communities that have benefited this kangaroo, although the total impact of changes in the rangeland environment on the Red Kangaroo populations due to the advent of pastoralism is more complex (e.g. Newsome 1975, for review). Still, the single most important change in the rangeland environment that has affected utilization of the rangeland plant communities by the dependent herbivore populations to date has been the widespread artificial provision of reliable watering points in areas formerly lacking permanent waters: but these water points have only directly influenced the pattern of exploitation of the natural plant communities. The pattern of productivity of these existing plant communities is still dependent on rainfall patterns. We should therefore look to rainfall as the key to the productivity component of variation in the Western Australian Red Kangaroo harvests.

Further to the above, knowledge of the biology of the Red Kangaroo (e.g. Frith and Calaby 1969; Newsome 1971, 1975, 1977; for summaries) suggests firstly that vulnerability of the Red Kangaroo to exploitation generally increases in times of drought, and secondly, that if drought extends for long periods, then reproduction can eventually cease. Recurrent extended droughts are therefore likely to result in both intermittent recruitment to the exploited stocks and changes in the harvest rate per unit of effort from time to time. This situation does apply to the Western Australian Red Kangaroo stocks (Author, unpublished observations). I have also observed (unpublished data) that the majority of the Red Kangaroos taken in Western Australia in recent years has generally comprised sexually mature individuals (usually > 2 years of age). One may thus assume in the absence of convincing contrary evidence that this was most probably the case in earlier times also, although it is possible that the former dry skin trade might have taken relatively larger numbers of young kangaroos than the modern pet-meat and skin trade.

A reasonable explanation for the observed pattern in the harvests taken might thus be expected to be based on rainfall patterns and include factors relating to the above aspects of the biology of the species and the commercial harvesting of the kangaroos, as well as considering the purely commercial influence of market prices on the trade.

METHODS AND PROCEDURES

Selection of the Primary Test Variables

The minimum information provided by the harvest data initially posed problems in selection of suitable test variables to be considered in the proposed analyses. Regional variations in the expected annual rainfall and rainfall regimes within the area from which the historic Red Kangaroo harvests were most probably obtained could not be considered because of lack of comparable detail in the harvest data. There was also no direct information on the likely size of the total Red Kangaroo stocks (field population) being exploited. Suitable primary variables for testing in the analysis thus had to be selected. The variables tested and the bases for their selection are described below.

The Numbers of Kangaroos in the Exploited Stock

In view of the expected common dependence of the Red Kangaroo and domestic livestock populations on similar areas of rangeland habitat I considered that the published information on the pastoral livestock populations would provide the only

possible index of changes in the likely rangeland Red Kangaroo population. The total numbers of small stock units (SSUs; see Jennings et al. 1979, p. 29) sharing the rangelands with the Red Kangaroos within the general area from which the majority of the kangaroos most probably were taken (see Fig. 8) were calculated from the appropriate livestock summaries published annually by the Australian Bureau of Statistics (e.g. "Sheep, Lambing and Woolclip", and "Cattle and Pigs").

Rainfall

My choice of a suitable annual average rainfall index (RNI) for use in exploring the relationship between rainfall and the annual commercial kangaroo harvest was restricted to scoring rainfall patterns experienced within the general area of harvest origin in relation to the general expectation of rain in this area, i.e. summarizing rainfall effects in terms of variations about the usual rainfall patterns for the various regions probably contributing to the kangaroo harvest without bothering about particular differences between regions. The major series of Annual Rainfall Decile maps published by the Australian Bureau of Meteorology in Bulletin No. 48 (Gibbs and Maher 1967) provided a ready reference source for this purpose, supplemented from 1966 onwards by the information on similar maps included annually in issues of the Australian Monthly Rainfall Review series of publications (Bureau of Meteorology 1966, etc.).

The RNI score values used in the analyses were derived by inspection of the above maps, and then visually weighting the observed decile range data in relation to the area in which it was considered that the Red Kangaroos taken would most probably have been obtained (see above). This process was repeated non-consecutively several times for each year to check the first choice score. Year values used covered the range $10 \geq RNI > 0$, with minimum score intervals of 0.5 being interpolated where considered necessary. The method described is admittedly an extremely crude way of summarizing presumed rainfall effects, with the RNI scores being based on an original scale with irregular class intervals in terms of actual rainfall received, and falling within the range specified above. Nevertheless, the information content of this variable in the context of the Western Australian Red Kangaroo exploitation pattern was apparently more than adequate, judging from the results of the subsequent analyses.

Market Prices

Simple average cash values paid for skins being traded over a period of 40 years or more obviously would not have provided a uniform measure of the commercial incentive to hunt kangaroos. Unit annual average skin cash price estimates through the review period were compiled from market reports published in 'Elders Weekly' interpreted in light of separate information on the trade grading of skins presented for sale and the within year variation in the quantities sold. These annual average cash price estimates were then reduced to a common base index for use in analysis by reference to the average or standard wage rates for unskilled workers listed in the relevant section of the Western Australian Statistical Register. This wage level was judged to be the appropriate alternative otherwise generally available to persons choosing to shoot kangaroos professionally. Variations in the estimated annual kangaroo skin price index (PI) are shown in Fig. A I. 1.

Analysis

The primary data-block examined was that for the 1915 - 1953 period, supplemented where necessary during the course of analysis with more recent data from the 1965 - 1972 period to provide an additional check run (see harvest levels, Table 2; and Prince 1984, Table 1 also).

Harvest numbers (Red Kangaroos traded by year) were transformed to natural logarithms (Ln values) for use in analyses to both constrain the predicted harvest values ($\hat{Y}$ = Y hat) to true values ≥ 0, and to take into account the anticipated multiplicative effects of changing recruitment and vulnerability to harvest. The total numbers of small stock units (SSUs) were also converted to Ln values for use in the analyses.

The step-wise multiple regression technique of Nie et al. (1975; the SPSS programme package) was used in performing the required analysis.

THE HARVEST PATTERN ANALYSIS

Determination of the Variables Associated with the Major Component of the Harvest Variation

The simple correlation between the annual average unit skin price and the total Red Kangaroo harvest was not statistically 'significant', so the main analysis was commenced by focussing on the relationship between rainfall and harvest. In view of the anticipated contribution of immediate recruitment to the exploited stocks in influencing harvest levels if harvesting was having an appreciable effect on kangaroo numbers, the probable dependence in part of recruitment on the numbers of adult kangaroos in the population at the time when breeding to produce these recruits would previously have occurred, and the expected impact of drought on the interaction between the kangaroo shooters and the kangaroos and thus the residual numbers of adult kangaroos remaining at the end of each year, the first relationship examined was that between harvest levels (LNRED) and the rainfall regime experienced during the more recent segment of the lifespan of the hunted adult kangaroos, i.e. the combined rainfall scores for up to three years prior to the harvest year in question (LRNI 1 + LRNI 2 + LRNI 3; RNI = Rainfall score, L = lag, and 1 through 3 = years before the harvest record). The relationship between the two variables tested here was 'significant', but shed no light on the possible contributions due to rainfall in particular years on the observed pattern of harvest variation. Attention was therefore redirected to an examination of the contributions due to rainfall in separate years within strings of individual rainfall variables.

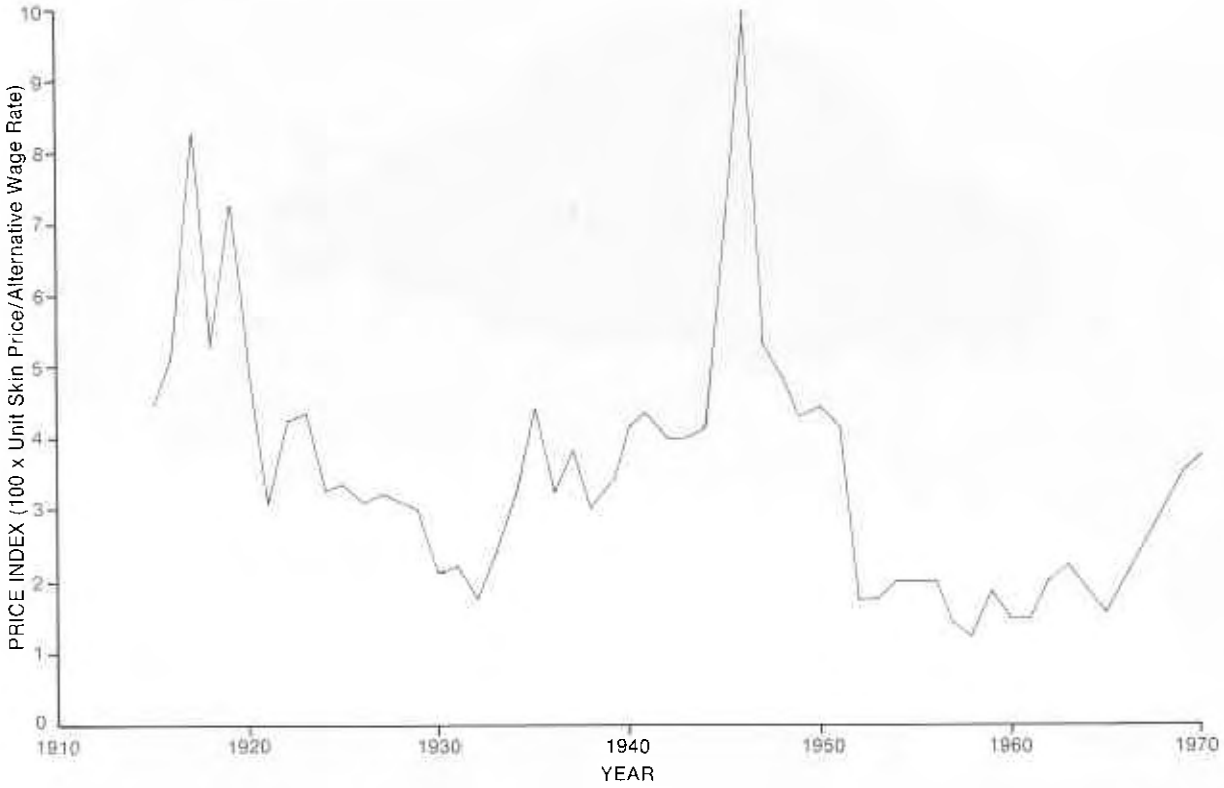

Figure A I.1. Pattern of Variation in the Relative Value of Red Kangaroo Skins in Western Australia: 1910-1970.

The rainfall variable string first examined included rainfall scores from the current year (RNI) up to eight years prior to the year of harvest (LRNI 1 - LRNI 8). This rainfall string was later extended to ten years prior to the harvest year in light of the results applicable to the Western Grey Kangaroo and Brush Wallaby data (Appendix II).

Regression analysis of harvest level on the RNI to LRNI 8 rainfall string showed 'significant' ($P < 0.05$) partial correlations between harvest and rainfall in years 2, 3, 5 and 6 prior to the year being considered. The partial correlation coefficient for the (harvest year - 4) year's rainfall (LRNI 4) was found 'not significant' ($P > 0.10$) with regard to the 1915-53 data block alone, but was 'significant' along with the coefficients for the other four rainfall variables mentioned above in relation to harvest levels when the combined 1915-53 + 1965-72 data-block was tested. Inclusion of the string of the five consecutive prior rainfall variables LRNI 2 - LRNI 6 noted above as one block in further analysis was thus indicated. A check of this result using the extended prior rainfall string of variables (to LRNI10) showed that the same pattern of 'significance' of partial correlation coefficients as above generally prevailed, with the notable difference being that the partial correlation coefficient for LRNI 9 was also generally 'significant'. Apart from this difference, no other rainfall variables above LRNI 6 approached 'significance'.

The clear separation of LRNI 9 from the other 'significant' rainfall variables suggested reinforcement of an underlying pattern of effects of rainfall on harvest levels in the shorter term, where the results generally showed LRNI 2 and 3, and LRNI 5 and 6, to be significant year-pairs. Inclusion of LRNI 9 in the chain also tended to re-emphasize the equivocal status of LRNI 4 mentioned before. LRNI 9 was however omitted from further inclusion in analysis because of its apparent cyclic relationship with variables already included up to LRNI 6, whereas LRNI 4 was retained because it could not clearly be eliminated as a possible bridge between the two year-pairs of 'significant' variables on either side, i.e. LRNI 2 and 3, and LRNI 5 and 6.

In total, between 40 and 50% of the variability in the annual numbers of Red Kangaroo skins traded could be attributed to the five consecutive rainfall variables LRNI 2 - 6, depending on the data set examined, e.g. 1915-53 data, $R^2 = 0.48$; 1915-53 + 1965-72 data, $R^2 = 0.43$. This general result was therefore consistent with the initial hypothesis that the annual harvest levels would probably depend to a large extent on immediate recruitment to the adult stocks of kangaroos being exploited and on factors affecting the numbers of kangaroos in the breeding stock.

Having discovered that variations in the annual commercial harvest could be meaningfully related to assumed variations in numbers of adult kangaroos and productivity of these stocks, the two questions that remained were, firstly, how could the observed harvests possibly be related to the potential numbers of kangaroos in the field, and secondly, how did these harvests relate to the anticipated changes in vulnerability to hunting and commercial factors such as skin prices.

Annual Red Kangaroo harvest totals were strongly correlated with the numbers of rangeland SSUs present at the end of the year prior to the harvest year (LNRED vs LNSSU 1; 1915-53, r^2 = 0.53; 1915-53 + 1965-72, r^2 = 0.49). A slightly higher, but similar proportion of the variability in the annual Red Kangaroo harvests is accounted for in this instance, in comparison with the combined prior rainfall variables previously discussed. The above correlation was also similar to the auto-correlation between the harvests in one year (LNRED 1) and the next (LNRED) found in the harvest data, e.g. 1915 - 1953 data, $P < 0.001$, $r^2 = 0.47$.

In view of the above result, both the previous years' kangaroo harvest and pastoral livestock data were tested separately with the selected string of five prior years rainfall variables (LRNI 2 - 6). In each case, the rainfall received two years prior to the harvest year (LRNI 2) was the only one of these individual rainfall variables appearing to have any appreciable influence on the proportion of harvest variability otherwise accounted for by either of the major variables LNRED 1 and LNSSU 1 respectively, e.g. 1915-53: (a) LNRED vs LNRED 1 + LRNI 2, R^2 = 0.53; partial correlation coefficient for LRNI 2 'significant', $P < 0.05$; (b) LNRED vs LNSSU 1 + LRNI 2, R^2 = 0.56; partial correlation coefficient for LRNI 2 'not significant', $0.05 < P \leq 0.10$.

The slight improvement in 'fit' to the variability in the harvest data apparently attributable to LRNI 2 noted above suggested that rainfall effects during the most recent year in which recruitment to the currently harvested kangaroo stocks could have been initiated were the most important of those attributable to previous rainfall. However, considering the previously found general similarity of the separate correlation coefficients for each of the five prior rainfall variables in question and the changes that could be produced in the order of stepwise reduction of this variable list by the multiple regression procedure when small changes were made in the numbers of years data input, this result might also have been due to chance. Accordingly, I decided that rather than reducing the possible contribution of apparent environmental effects on productivity and past history of the exploited kangaroo stocks by deleting individual rainfall year variables at this point, the alternative choice of attempting to summarize the rainfall pattern effects over the years 2 - 6 prior to the year of harvest should first be considered.

In view of the probable overriding importance of changes in rainfall in relation to rangeland productivity and past hunting of the exploited stocks, the rainfall scores for each of the five years selected were therefore combined to form a new variable which summed departures of rainfall totals in each of these years from the expected average score, taken to be 5.0 in each case (e.g. DRT 26 = LRNI 2 + LRNI 3 + ... + LRNI 6 - 25.0). This single new rainfall variable was found to account for the same proportion of the total variability in the Red Kangaroo harvest data as was previously accounted for collectively by the five separate prior year's rainfall variables. Thus, the initial explanatory value attached to the combination of separate rainfall year variables was conserved. A test of this new rainfall variable in combination with the rangeland livestock variable, LNSSU 1, produced a further improvement in 'fit' to the harvest data over that previously discussed, e.g. LNRED vs LNSSU 1 + DRT26, R^2 = 0.65; cf. LNRED vs LNSSU 1 + LRNI 2, R^2 = 0.56. The partial correlation coefficient for DRT 26 was also 'highly significant' ($P < 0.001$), in contrast with 'non significance' for LRNI 2. Both LNSSU 1 and DRT 26 were correlated (r = 0.54), and to some extent can be considered convergent, but they obviously do not provide completely over-lapping measures of the same system parameters.

Variables Associated with the Minor Component of the Harvest Variation

Equations fitted to the residual variation remaining after fitting of the LNSSU 1 + DRT 26 equation to the annual harvest data showed that the previous season's price index, LAGPI, was apparently a better indicator of the influence of market price on the numbers traded than was the current season's index, PI. The former variable was 'significant', i.e. $P < 0.05$, and accounted for about 12½% of the residual variability (r^2 = 0.125), but PI was 'not significant' ($P \simeq 0.06$). This result was considered reasonable on two counts. Firstly, because a shooter's decision to take kangaroo skins each season would be made prior to the opening of the new season's market, and secondly, because the records of the numbers of kangaroo skins being traded were compiled at the time of their disposal, rather than at the time when the kangaroos were shot. Because of the remoteness of the market from the harvest areas many of the Red Kangaroos taken at the end of one year would therefore have been included in the succeeding year's harvest total.

No other single variable which could account for further minor variation in the annual trade volume (apart from the above) was 'significantly' ($P < 0.05$) related on its own to the residual variation under discussion. The notable discrepancy from the expected result in this respect was the apparent lack of any definite response to rainfall that could be equated with the acknowledged short term changes in vulnerability of Red Kangaroos to exploitation during drought. The partial correlation coefficient of the current year's rainfall in relation to annual harvest was generally found to be negative in the initial runs testing the possible contributions of separate rainfall variables (discussed above) as would have been anticipated from the initial hypothesis, but the relationship did not approach 'significance'. The individual rainfall scores for the current year (RNI) and the previous year (LRNI 1) also failed to describe any further part of the residual variation when combined with the expected market price (LAGPI). Nevertheless, an obvious pattern of coincidence of the majority of peaks and troughs in the residual harvest variation with wet and dry years respectively, especially prior to 1940, remained (cf. Figs. 6 and 8).

In light of the result above, and the probable explanation for the closer relationship between LAGPI and harvest levels in comparison with PI, a new rainfall variable describing the change in rainfall between that received in the previous year and that received during the current harvest year, e.g. CHRNIØ1 = (LRNI 1 - RNI), was substituted for the two separate rainfall year variables and the residuals data retested. The partial correlation of this new variable with the residual harvest variation was 'significant' ($P < 0.05$).

This further residuals analysis also showed that the observed pattern of the annual harvests during the 1915 - 1953 period generally falling into two groups (see Fig. 6) carried through to the residuals, so that the partial correlation of a year of record variable (YEAR) with harvest was also 'significant'. However, the harvest pattern shown in the 1915 - 1953 data block relates firstly to a real decline in abundance of Red Kangaroos following the 1935-36 drought (e.g. Fyfe 1940, pp. 166-8), with a consequent reduction in the immediately available annual harvest thereafter: but this event was also closely followed by intervention of World War II, with its probable effects on marketing and available shooting effort, and then collapsing of the skin market over the last two years of record (1952 - 1953). Intervention of this particular sequence of events was therefore considered likely to have introduced a further source of possible constraint on realized harvests in the latter part of the record, apart from those factors which would typically have constrained the available harvests during this time. Besides this, the annual Red Kangaroo harvests in the late 1960s were again similar to those taken in the first half of the 1915 - 1953 period. Year of record was thus deleted from the list of variables considered to have a primary role in determining the size of the available annual Red Kangaroo harvest in Western Australia in modern times.

The Final Equation

Inclusion of the two further variables, LAGPI and CHRNIØ1, found to make an important contribution in explaining the residual variation in annual Red Kangaroo harvest levels after first extracting the component of variation accounted for by LNSSU 1 + DRT 26, in combination with these latter two variables finally accounted for between two-thirds and three-quarters of the total variability in annual Red Kangaroo harvests taken in Western Australia prior to the inception of formal management in the early 1970s (see Prince 1984), e.g. LNRED vs LNSSU 1 + DRT 26 + LAGPI + CHRNIØ1; 1915-53 + 1965-72 data-block, $R^2 = 0.67$, $P < 0.001$; 1915-53 data-block, $R^2 = 0.73$, $P < 0.001$. The equations derived are listed in Table A I. 1.

DISCUSSION

The harvest pattern analysis described above was predicated on the basis that the commercial harvesting of the Red Kangaroo varied both in response to changes in the abundance of the kangaroos and to factors affecting the commercial harvesting process as well as the process of exploitation itself placing constraints on the numbers of kangaroos inhabiting the Western Australian rangelands.

The results from this analysis have shown that the major part of the long-term harvest variation is generally ascribable to the effects of environmental variability on the kangaroo stocks. The factors relating to the harvesting and marketing of the kangaroos taken account for residual variability only. This result appears to represent a reasonable general summary of the relative amount of variability in the environment vis a vis the process of harvesting and marketing the kangaroos and the effects of these factors on the abundance of Red Kangaroos in Western Australia.

The continuity of the harvest supports the view that short-term fluctuations in market demand and harvest efficiency did not usually result in either a failure of the market or in a precipitate collapse of the hunted kangaroo population. Nevertheless, the available trade data do suggest that short-term fluctuations in the market price for skins did on some occasions affect the size of the harvest taken independent of the abundance of kangaroos at the time (cf. Figs. 6 and A I. 1). Heavy short-term exploitation pressure on other occasions also appears to have been associated with significant population reductions, e.g. the comparatively low average Red Kangaroo harvest level achieved post- 1936 relative to the 1920 - 1936 average (see Fig. 6), and harvesting during the 1969 - 1970 period appears to have produced the same result. 'Harvest efficiency' and 'market demand' thus appear to be potential critical factors in relation to continued commercial harvesting of the Red Kangaroo in Western Australia and the impact of this harvesting on the kangaroo stocks. Sustainable commercial harvesting of the Red Kangaroo in conformity with the observed historic harvest pattern does however appear practicable in the immediate future.

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Table A I. 1.

Equations Describing the Historic Pattern of Variation in Red Kangaroo Harvests Taken in Western Australia.

A. Harvest Equation [1915 - 1953] Data Set

LNRED = 1.967478*LNSSU1 + 0.03399*DRT26 - 0.0362641*CHRNI01 + 0.0116551*LAGPI - 4.633923 + [0.5*0.37266**2]

Variance of Estimates

Var LNRED = 9.30945 + 0.14*E + 0.00015*F + 0.00033*G + 0.00002*H + A*(-1.13999) + B*0.02276 + C*(-0.00652) + D*(-0.00647) + I*(-0.00281) + J*0.00084 + K*0.00073 + L*(-0.0001) + M*(-0.0002) + 0 + [0.5*0.37266**4/40]

Mean Arithmetic Estimates

REDNOS = Exp(LNRED)

95% Confidence Limits of Arithmetic Estimates

Lim REDNOS = Exp(LNRED ± 2.032*SQRT(Var LNRED))

B. Harvest Equation for [1915 - 1953 plus 1965 - 1972] Data Set

LNRED = 1.784298*LNSSU1 + 0.0415295*DRT26 - 0.0366646*CHRNI01 + 0.0067941*LAGPI - 2.902709 + [0.5*0.40652**2]

Variance of Estimates

Var LNRED = 9.87623 + 0.1504*E + 0.00016*F + 0.00031*G + 0.00002*H + A*(-1.21722) + B*0.02261 + C*(-0.00726) + D*(-0.00553) + I*(-0.00283) + J*0.00093 + K*0.00062 + L*(-0.00001) + M*(-0.00001) + 0 + [0.5*0.40652**4/48]

Mean Arithmetic Estimates

REDNOS = Exp(LNRED)

95% Confidence Limits of Arithmetic Estimates

Lim REDNOS = Exp(LNRED ± 2.018*SQRT(Var LNRED))

Key to the Variables and Form of the Equations

LNRED = Annual Total Harvest : LN (REDNOS)

LN = Logarithm to Base e

REDNOS = Annual Total Red Kangaroo Skins Traded

Note 1: The Value + [0.5*0.XXXX**2] added to the end of each harvest equation is a correction factor equivalent to 0.5*S**2. Calculation of the true arithmetic value of the predicted annual harvest is permitted by adding this correction to the value of the equation. Refer Baskerville, G.L. (1982). Use of Logarithmic regression in the estimation of plant biomass. Can. J. For., 2 : 49-53.

Variance . Covariance Multipliers Used in Calculating Variance Estimates

A	=	2*LNSSU1	H	=	LAGPI**2
B	=	2*DRT26	I	=	A*DRT26
C	=	2*CHRNI01	J	=	A*CHRNI01
D	=	2*LAGPI	K	=	A*LAGPI
E	=	LNSSU1**2	L	=	B*CHRNI01
F	=	DRT26**2	M	=	B*LAGPI
G	=	CHRNI01**2	N	=	C*LAGPI

LNSSU1 = Total Population (in thousands) of Small Stock Units (SSUs) present in Red Kangaroo Harvest Area at Beginning of the Harvest Year : LN (SSU1)

DRT26 = Deviation of Total Standardized Rainfall Received Over the Five Year Period from 2 Through 6 Years Prior to the Harvest Year from the Expected Total Average = 25.0

CHRNI01 = Difference Between Standardized Rainfall Received in Harvest Year and That Received in Previous Year

LAGPI = Standardized Average Unit Skin Price on Offer in Year Prior to Harvest Year

Note 2: Where DRT26 and CHRNI01 values calculated from the standardized annual rainfall data were = 0.0, a value of -0.1 was used in calculating the harvest equations quoted above.

Note 3: The value + [0.5*0.XXXX**4/NN] added to the end of the variance calculation is a correction factor equivalent to 0.5*S**4/(N+1). This correction removes the bias in the variance estimates about the logarithmic regressions and permits the correct arithmetic confidence limits to be calculated. Refer p. 153, Land, C.E. (1972). An Evaluation of Approximate Confidence Interval Estimation Methods for Lognormal Means. Technometrics, **14** : 145-58.

APPENDIX II

ANALYSIS OF PATTERNS IN THE WESTERN GREY KANGAROO AND BRUSH WALLABY TRADE
- WESTERN AUSTRALIA -

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INTRODUCTION

The Western Grey Kangaroo has been subject to commercial exploitation in Western Australia practically from the earliest years following European settlement (Section IV A. & B., this paper), but only the harvest record post- 1914 is sufficiently detailed to permit an attempt at a quantitative explanation for the pattern of variation in these harvest data.

The Western Australian skin trade during the first thirty years of the 20th Century also apparently encompassed exploitation of practically the whole of the fur-bearing fauna of the south-west of Western Australia and, apart from the large Western Grey Kangaroo, included exploitation of the smaller Brush Wallaby (Macropus irma), Tammar (M. eugenii) and Quokka (Setonix brachyurus). However 'Game Act' royalty regulations resulted in lumping of the Tammar and Quokka harvests in the one group "Other" for record purposes, and only the Brush Wallaby of these smaller species has a harvest record suitable for further detailed analysis (see Table 2).

The harvest pattern for the Western Grey Kangaroo (Fig. 4) differs from that for the Brush Wallaby (Fig. 5) and, while the former species is still subject to exploitation in Western Australia, exploitation of the Brush Wallaby was prohibited on commencement of the 'Fauna Protection Act, 1950' on 1 July 1952 (Proclamation of 13th June, 1952) as was further exploitation of the Tammar and Quokka. The harvest pattern described by the Brush Wallaby data is similar to that shown by the royalty group "Other" (Table 2) so the Brush Wallaby harvests can be considered representative of the pattern of exploitation and response of the three wallaby species to changes occurring during the period when exploitation of all three was permitted. We are therefore presented with a comparison between exploitation of the Western Grey Kangaroo and exploitation of the smaller south-west Western Australian wallabies as typified by the endemic Brush Wallaby.

The results of analyses aimed at discovering the main factors contributing to the observed patterns of variation in the historic harvests of the above two species are reported here.

BACKGROUND AND FORMULATION OF HYPOTHESIS

In contrast with the effects of pastoral development of the arid and semi-arid rangelands within the range of the Red Kangaroo (see Appendix I), land utilization and development in the south-west of Western Australia has been responsible for the loss of significant areas of habitat formerly available to the fauna. This difference is obviously a factor which must be considered in any analysis of the patterns of variation in exploitation of the kangaroos and wallabies of the south-west.

Apart from the above difference, it is reasonable to expect that factors affecting both productivity of the available stocks and the process of exploitation of these stocks during the course of exploitation would also have had some impact on the observed patterns of harvest of the south-western species, although the observed pattern of exploitation of the Brush Wallaby (Fig. 5) clearly shows that the exploitation of this species was not sustainable. The apparent trend of a declining average annual harvest of the Western Grey Kangaroos available from the 1930s (Fig. 4) also suggests that harvesting of this species has proceeded to a presently non-sustainable point during the past 40 - 50 years.

Comparison of the observed harvest patterns for the Western Grey Kangaroo and Brush Wallaby post- 1914 (Figs. 4 & 5) with the ongoing process of alienation and development of agricultural land in the south-west (Fig. 3) and the specific impact of this land development (Fig. A II. 1) in relation to the major part of the original range of these two species in Western Australia (Fig. A II. 2) clearly suggests that a close link between the observed harvest pattern and subsequent decline of the Brush Wallaby and agricultural land development existed through the 1914 - 1930 period. The Brush Wallaby was indeed commonly regarded as an important pest on new farmland in the 1920s (see Section V A., this paper). On the other hand, a possible link between the pattern of agricultural land development and exploitation of the Western Grey Kangaroo is less clear. Nevertheless, the pause in agricultural development after 1930 (Fig. 3) coincided with a trend of declining harvest of the Western Grey Kangaroo (Fig. 4). The bulk of the Western Greys being taken then (and previously; see IV B. 2.) were being obtained within the area included in the 'Grey Kangaroo Reserve' (see Fig. 2 a-d). Many of these kangaroos were also certainly being taken from the land being developed for agriculture. Thus, the difference in the impact of agricultural land development in this instance appears to be in degree only in comparison with the case for the Brush Wallaby (and, by association, the case for the other two smaller wallabies).

In addition to the increased pest problems encountered by the pioneer farmers in the van of agricultural expansion from 1905 onwards and the long-term direct impact of land clearing on the local wildlife populations, it must be remembered that many of these people also had little ready cash, and most of what they did have was committed to development of their properties. Any kangaroo meat that could be obtained helped eke out their cash reserves, and if any money could also be earned from the sale of skins, this was an added bonus. The economic incentive to trade thus remained.

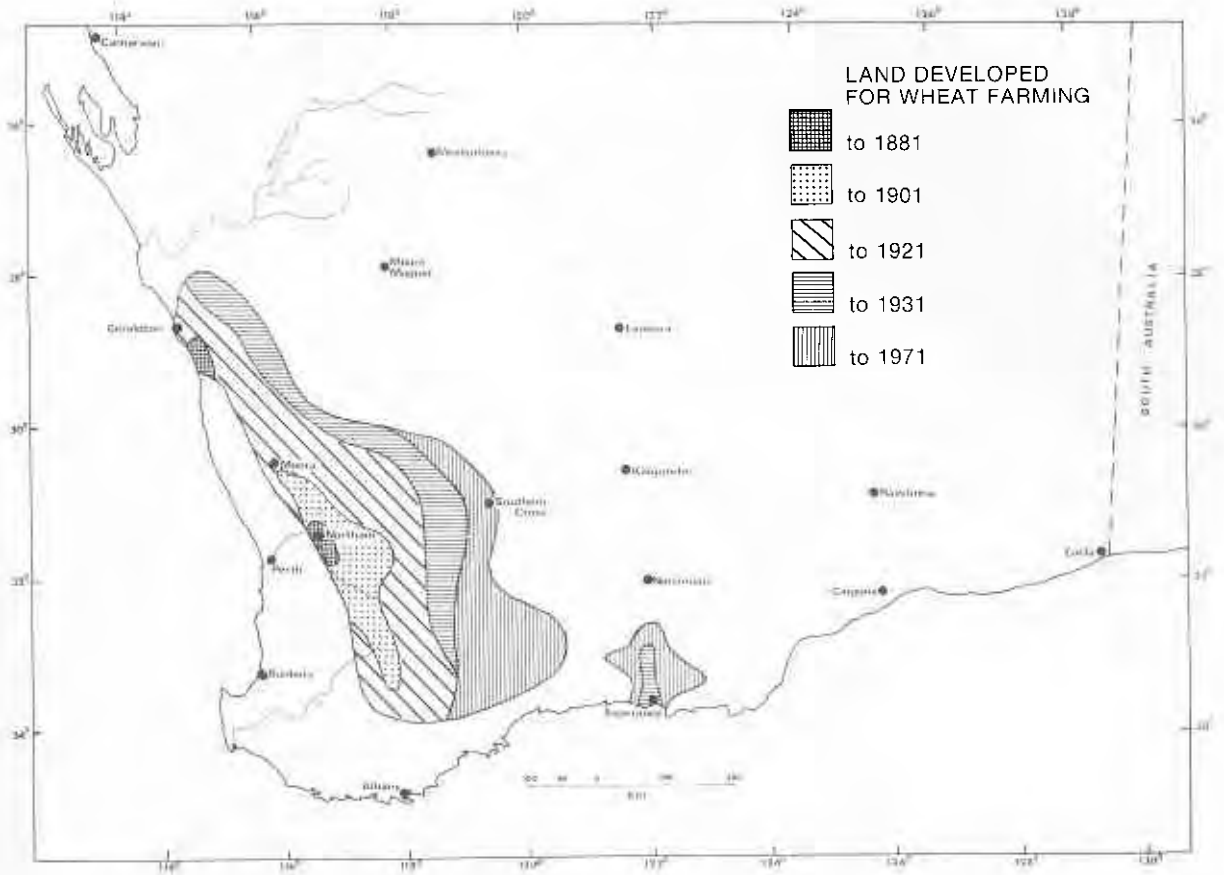

Figure A II.1. Pattern of Development of Wheat farming in south-western Western Australia: 1829-1971. Redrawn from "Western Australia. An Atlas of Human Endeavour 1829-1979." (Ed. N.T. Jarvis) p. 44. (Government Printer : Perth).

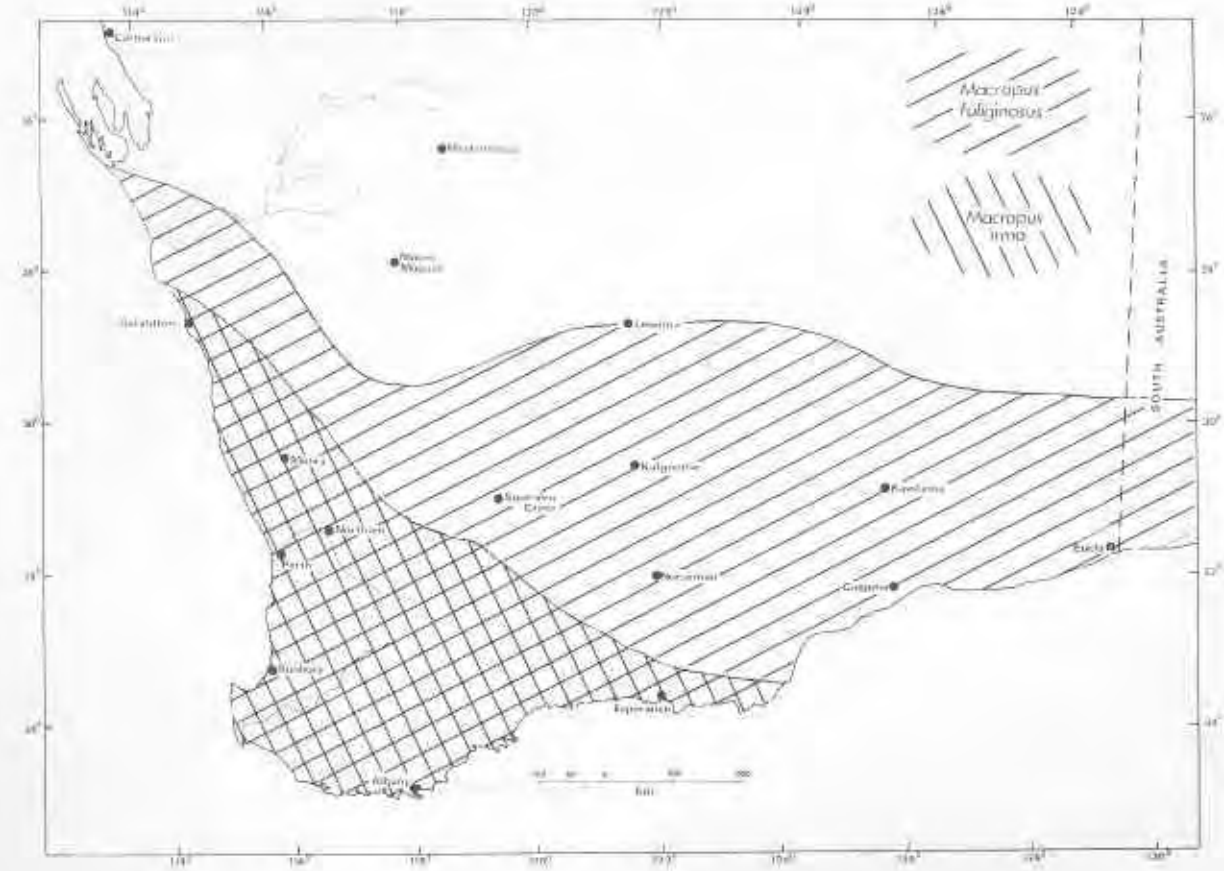

Figure A II.2. Distributions of the Western Grey Kangaroo (Macropus fuliginosus) and the Brush Wallaby (Macropus irma) in southern and south-western Western Australia.

The facts outlined above suggest that the analysis of the historic patterns of trade in Western Grey Kangaroos and the Brush Wallaby should concentrate on consideration of the following factors:-

a) the economic incentive to exploit;
b) the stock size and productivity of populations of each species;
c) their pest potential; and,
d) the effects of habitat alteration.

METHODS AND PROCEDURES

Analysis

The previously derived solution to the analysis of the pattern of variation in the historic Red Kangaroo harvests (Appendix I) was used as a guide in attempting the Western Grey Kangaroo and Brush Wallaby harvest pattern analyses. The step-wise multiple regression technique of Nie et al. (1975; the SPSS programme package) was again used to do these analyses.

Similarly, the main data-block examined was that for the 1915 - 1953 period (Table 2), and harvest numbers (the Western Grey Kangaroos and Brush Wallabies traded by year) were in each case transformed to natural logarithms (Ln values) for use in analyses to both constrain the predicted harvest values ($\hat{Y}$ = Y hat) to true values ≥ 0, and to take into account anticipated multiplicative effects of changing recruitment and vulnerability to harvest.

VARIABLES TESTED

Market Price

The evidence available from contemporary skin market reports suggested that well prepared and presented Western Grey Kangaroo skins may formerly have fetched slightly higher unit prices than Red Kangaroo skins, but more Western Greys were most probably taken and marketed by farmers and other non-professional hunters. The same standardized market price indicator, PI, as used in the Red Kangaroo analysis (Appendix I, Fig. A I. 1) was therefore used in the Western Grey analysis. The separate unit skin price data for the Brush Wallaby were used to calculate an equivalent market price indicator (PIBR) for this species.

Alienation of Habitat and the Related Pest Problem

A simple index of the extent of permanent loss of habitat is provided by the area of developed farmland (see Fig. 3), but I considered that the ongoing contribution to the potential harvests attributable to the process of farmland development and the consequent pest problem was more likely to reflect the proportional balance between the progressively increasing area of farmland actually developed and the changing boundary between this farmland and the remaining kangaroo and wallaby habitat. In concrete terms, new farmland development displaces the resident fauna, which in this instance could have been disposed of on a once only basis: but, in all probability, disposal of the long-lived displaced kangaroos and wallabies would have been expected to be spread over several years at least. Meanwhile, the residual displaced populations would have continued to produce further recruits which in turn would have tended to be forced back onto the farms, thus adding at first to the farmers' pest problems, and eventually to the commercial harvest.

Considering the fact that the early farmers' pest problems were mostly related to development of land for crop production and that cropping of new land was preceded by clearing, etc., a single variable summarizing the proportional change in the total area of developed farmland in the years preceding the harvest year under consideration was sought for testing in the analyses. The time interval to be covered by this variable would naturally have had to be relevant to the life-span of the animals being disposed of and the process of their disposal. The variable which most adequately encapsulated the above factor in the analyses was the Ln value of the ratio of the total area of farmland developed to the end of the year preceding the harvest year / the total area of farmland developed five years previously, e.g. LCHFLD 16 = Ln(Farmland Area in 'Harvest Year - 1' / Farmland Area in 'Harvest Year - 6').

Rainfall and Productivity

The expected effects of rainfall and rainfall pattern on the productivity of these kangaroo and wallaby stocks was explored using annual rainfall scores summarizing rainfall received in the south-west corner of Western Australia from which the major part at least of the harvests taken would have been obtained. These rainfall index scores (SWRN) were derived similarly to the RNI scores used in the Red Kangaroo analysis (see Appendix I; raw data from Gibbs and Maher 1967, and Bureau of Meteorology 1966, et seq.).

The Harvest Pattern Analyses

The initial test runs for the Western Grey Kangaroo and Brush Wallaby harvest pattern analyses concentrated on the relationship between harvest levels and rainfall, with the first nine rainfall variables, e.g. SWRN and LSWRN 1 to LSWRN 8, being included in these runs, although it was considered unlikely that the immediate rainfall pattern would have had the same potential to affect the vulnerability of these species to exploitation as does drought with respect to the Red Kangaroo. Surprisingly, in contrast with the initial Red Kangaroo analysis which suggested that rainfall seven years prior to the year of harvest was not significantly related to the harvest, the Western Grey Kangaroo analysis suggested that rainfall seven years prior to the harvest year (LSWRN 7) was the most important rainfall variable. In fact, this was the only one of these rainfall variables for which the partial correlation coefficient was 'significant' ($P < 0.05$). Next in apparent importance were LSWRN 8, LSWRN 3, and LSWRN 2, although partial correlation coefficients for each of these three variables were 'not significant' (in combination with LSWRN 7, P = 0.12 - 0.16 for these latter three variables). A check of this result by omitting the harvest records for the years 1951 - 1953 (at the onset of the later total collapse of the dry skin market) confirmed the view that LSWRN 7 was apparently the most important of these rainfall variables.

The separate result for the limited Brush Wallaby data suggested that SWRN and LSWRN 6 were the two most important rainfall variables (partial correlation coefficients 'significant', $P < 0.05$), with LSWRN 7 and LSWRN 2 next in importance ($P < 0.10$).

The above results suggested a probable separation in relation to the rainfall effects of the recruitment factor from that thought to reflect the adult kangaroo contribution to recruitment and harvest level, and that, on the whole, the adult Western Grey Kangaroo stocks contributing to the harvests might have been older in comparison with the Red Kangaroo. Support for this idea was gained from knowledge that the dry skins of Western Grey Kangaroos previously handled by the skin trade were generally heavier than those of Reds (average Western Grey skin $\geq$ 20 ounces ($1\frac{1}{4}$ lbs) = 570 g, vs 17-18 ounces = 480-510 g, Red).

Incidentally, these first results also suggested that variations in market price did have an important effect on trade in skins of the south-western species, in contrast with its minor role in influencing the Red Kangaroo Harvests. This observation was further supported by some additional information for the fifteen years 1920 - 1934 relating to the numbers of special licenses issued under the provisions of the 'Game Act' which permitted people to take kangaroos for food purposes. These licenses were issued free. They applied only to taking of the Western Grey Kangaroo, and the persons availing themselves of these licenses were permitted to also sell the skins of the kangaroos taken. The close correlation between prevailing skin prices and the numbers of these licenses issued annually is shown in Fig. A II. 3.

In view of the above, two further prior year's rainfall variables, LSWRN 9 and LSWRN 10, were added to the initial string of rainfall variables (SWRN to LSWRN 8) and tested in combination with the appropriate standardized average skin market price index for each of the two species being considered.

The new test runs for the Western Grey Kangaroo and Brush Wallaby showed that the market price variable was apparently the most important of the separate variables (initially, PI was taken in third in the stepwise multiple regression for the Grey, and PIBR first for the Brush). Apart from SWRN, LSWRN 1 and LSWRN 4, partial correlation coefficients for all other individual years' rainfall variables included at this level in combination with PI were 'significant' for the Western Grey Kangaroo. The partial correlation coefficients for SWRN, LSWRN 3, LSWRN 6, LSWRN 9 and LSWRN 10 were 'significant' in combination with PIBR for the Brush Wallaby. Partial correlation coefficients for LSWRN 7 and LSWRN 8 were also close to 'significance' for this species ($P = 0.06 - 0.08$).

The results of the second run analyses above were by no means as clearcut as those previously obtained in the case of the Red Kangaroo. However, the admittedly sketchy information available on life history and breeding patterns for the two south-western species suggested that their particular responses to rainfall patterns should be similar. Accordingly, the 'non significant' partial correlations of LSWRN 4 with harvest level in each case, and the general indication of an important contribution attributable to rainfall in the period two to three years prior to the year of harvest (LSWRN 2 and LSWRN 3 partial correlations 'significant' for the Western Grey, and LSWRN 3 'significant' for the Brush) were interpreted as pointers to the importance of recruitment to the annual harvest of each species and the separation of this contribution from that related presumably to the residual stocks of adult kangaroos and wallabies.

In keeping with the procedure adopted previously in analysis of the Red Kangaroo data, the consecutive but separate prior years' rainfall variables considered to be related to the same harvest factors were therefore combined to form two new single variables at this point. Rainfall index scores two and three years prior to the harvest year were combined to form the new variable SWRN 23, e.g. SWRN 23 = (LSWRN 2 + LSWRN 3), and another new variable SWRN 5T9 was substituted for the first five of the series of later prior years' rainfall variables, LSWRN5 to LSWRN 9, e.g. SWRN 5T9 = (LSWRN 5 + LSWRN 6 + ... + LSWRN 9).

Combination of the two new rainfall variables above with the relevant market price variable accounted for approximately two-thirds of the variability in the Western Grey Kangaroo harvests ($R^2 = 0.68$), and just under two-thirds of the variability in the Brush Wallaby harvests ($R^2 = 0.63$); but none of the three variables included at this point specifically addressed the question of the contribution that may have been made directly to the harvests by the process of farmland development and the consequent pest problem.

The combined equation incorporating the variable relating to the above effect plus the three variables previously discussed finally accounted for approximately three-quarters of the variability in the Western Grey Kangaroo harvests, e.g. LNWGK vs SWRN 23 + SWRN 5T9 + PI + LCHFLD 16, $R^2 = 0.76$.

The equivalent equation accounted for an even greater proportion of the variability in the Brush Wallaby harvests ($R^2 = 0.82$), but this equation was not sufficient to fully describe the pattern of declining harvest in relation to the first major phase of farmland development in Western Australia. A further part of the variability was 'significantly' related to the total area of farmland developed prior to the beginning of the harvest year, e.g. LNFMLD 1 = Ln (Farmland Area in 'Harvest Year - 1'). The final combined equation for the Brush Wallaby accounted for 85% of the variability in harvests of this species, e.g. LNBRH vs SWRN 23 + SWRN 5T9 + PIBR + LCHFLD 16 + LNFMLD 1, $R^2 = 0.85$.

The final harvest equations described above are listed in Table A II. 1.

39325—5

Table A II. 1.

Equations Describing the Historic Patterns of Variation in Western Grey Kangaroo and Brush Wallaby Harvests Taken in Western Australia.

A. Western Grey Kangaroo Harvests

Harvest Equation

LNWGK = 0.01787057*PI + 0.0476882*SWRN5T9 + 0.04040684*SWRN23 + 0.05075212*LCHFLD16 + 8.3598348 + [0.5*0.21592**2]

Variance of Estimates

Var LNWGK = 0.08415 + 0.00001*PI**2 + 0.00009*SWRN23**2 + 0.00004*SWRN5T9**2 + 0.0231*LCHFLD16**2 + 0 + 2*PI*SWRN5T9*0.00001 + 2*PI*LCHFLD16*0.00001 + 0 + 2*SWRN23*LCHFLD16*(-0.00008) + 2*LCHFLD16*SWRN5T9*(-0.00022) + 2*PI*(-0.00052) + 2*SWRN23*(-0.00119) + 2*SWRN5T9*(-0.00159) + 2*LCHFLD16*0.00137 + [0.5*0.21592**4/40]

Mean Arithmetic Estimates

WGKNOS = Exp(LNWGK)

95% Confidence Limits of Arithmetic Estimates

Lim WGKNOS = Exp(LNWGK ± 2.032*SQRT(Var LNWGK))

B. Brush Wallaby Harvests

Harvest Equation

LNBRH = 0.03986865*PIBR + 0.1041478*SWRN5T9 + 0.07729162*SWRN23 + 1.4621796*LCHFD16 - 0.8786998*LNFMLD1 + 18. 208967 + [0.5*0.54425**2]

Variance of Estimates

Var LNBRH = 33.61444 + 0.00016*PIBR**2 + 0.00078*SWRN23**2 + 0.00025*SWRN5T9**2 + 0.29594*LCHFLD16**2 + 0.13368*LNFMLD1**2 + 2*PIBR*SWRN23*0.00004 + 2*PIBR*SWRN5T9*(-0.00003) + 2*PIBR*LCHFLD16*0.00346 + 2*PIBR*LNFMLD1*0.00362 + 0 + 2*SWRN23*LCHFLD16*0.00242 + 2*SWRN23*LNFMLD1*0.00163 + 2*SWRN5T9*LCHFLD16*(-0.00253) + 2*SWRN5T9*LNFMLD1*(-0.00157) + 2*LCHFLD16*LNFMLD1*0.13419 + 2*PIBR*(-0.05863) + 2*SWRN23*(-0.03612) + 2*SWRN5T9*0.01716 + 2*LCHFLD16*(-2.13825) + 2*LNFMLD1*(-2.10656) + [0.5*0.544**4/33]

Mean Arithmetic Estimates

BRHNOS = Exp(LNBRH)

95% Confidence Limits of Arithmetic Estimates

Lim BRHNOS = Exp(LNBRH ± 2.056*SQRT(Var LNBRH))

Key to the Variables and Form of the Equations

LNWGK = Annual Total Harvest Grey Kangaroos : LN (WGKNOS)
LNBRH = Annual Total Harvest Brush Wallabies : LN (BRHNOS)

LN = Logarithm to Base e
WGKNOS = Annual Total Grey Kangaroo Skins Traded
BRHNOS = Annual Total Brush Wallaby Skins Traded

Note 1: The value + [0.5*0.XXXXX**2] added to the end of each harvest equation is a correction factor equivalent to 0.5*S**2. Calculation of the true arithmetic value of the predicted annual harvest is permitted by adding this correction to the value of the equation. Refer Baskerville, G.L. (1972). Use of Logarithmic Regression in the Estimation of Plant Biomass. Can. J. For., 2 : 49-53.

PI = Standardized Average Unit Kangaroo Skin Price on Offer During the Harvest Year

PIBR = Standardized Average Unit Wallaby Skin Price on Offer During the Harvest Year

SWRN5T9 = Total Standardized Rainfall Received Over the Five Year Period from 5 through 9 Years Prior to the Harvest Year

SWRN23 = Total Standardized Rainfall Received Over the Two Year Period 2 and 3 Years Prior to the Harvest Period

LCHFLD16 = Proportional Change in Area of Developed Farmland (FMLD) in the Grey Kangaroo and Brush Wallaby Harvest Area During the Five Years Between 1 and 6 Years Prior to the Harvest Year : LN (FMLD1/FMLD6)

LNFMLD1 = Area of Developed Farmland in the Grey Kangaroo and Brush Wallaby Harvest Area at the End of the Year Prior to the Harvest Year

Note 2: The value + [0.5*0.XXXX**4/NN] added to the end of the variance calculations is a correction factor equivalent to 0.5*S**4/(N+1). This correction removes the bias in the variance estimates about the logarithmic regressions and permits the correct arithmetic confidence limits to be calculated. Refer p. 153, Land, C.E. (1972). An Evaluation of Approximate Confidence Interval Estimation Methods for Lognormal Means. Technometrics, 14 : 145-58.

DISCUSSION

The harvest pattern analyses for the Western Grey Kangaroo and Brush Wallaby data were aimed at determining the relative contributions of environmental change and biological productivity factors in relation to the commercial incentive in describing the realized commercial harvest patterns. It was assumed that the recorded harvesting of the Brush Wallaby coincided with a period in which the species went from a situation of relative abundance to scarcity, and that harvesting of the Western Grey Kangaroo since the 1930s has also proceeded in concert with declining total abundance of this species in the South West of Western Australia.

The results from these analyses have pointed to the general similarity of the variables describing the major part of the variation in historic commercial harvests of these two south-western Western Australian species and the importance of agricultural land development in this context. Agricultural land development can in fact be identified as a major factor associated with the changing fate of the Brush Wallaby and smaller species such as the Tammar and probably the Quokka prior to the 1950s, and continues to influence exploitation of the Western Grey Kangaroo.

As in the case for the Red Kangaroo (Appendix I), recruitment to the existing stocks of these south-western species was apparently an important contributor to the short-term annual harvests, but the apparent contribution to the harvests attributable to the residual stocks of adult kangaroos and wallabies differed from that found for the Red Kangaroo. Market price was also of much greater importance in regard to trade in skins of the Western Grey Kangaroo and Brush Wallaby. These specific differences appear to be related to the circumstances in which exploitation generally occurred in the south-west of Western Australia, and are further discussed below.

The greater importance of the market price variable in explaining part of the variation in harvests of the Western Grey Kangaroo and Brush Wallaby appears in the first instance to be attributable to both the much less professional operation involved in harvesting of these species in comparison with the Red Kangaroo as well as the probable greater difficulty involved in shooting these animals. With competing demands on their limited time, farmers and members of their families might be expected to have been much more readily influenced by changing market prices in making their decisions to shoot kangaroos for skins than would the truly professional shooters (e.g. Fig. A II. 3). The even greater relative importance of

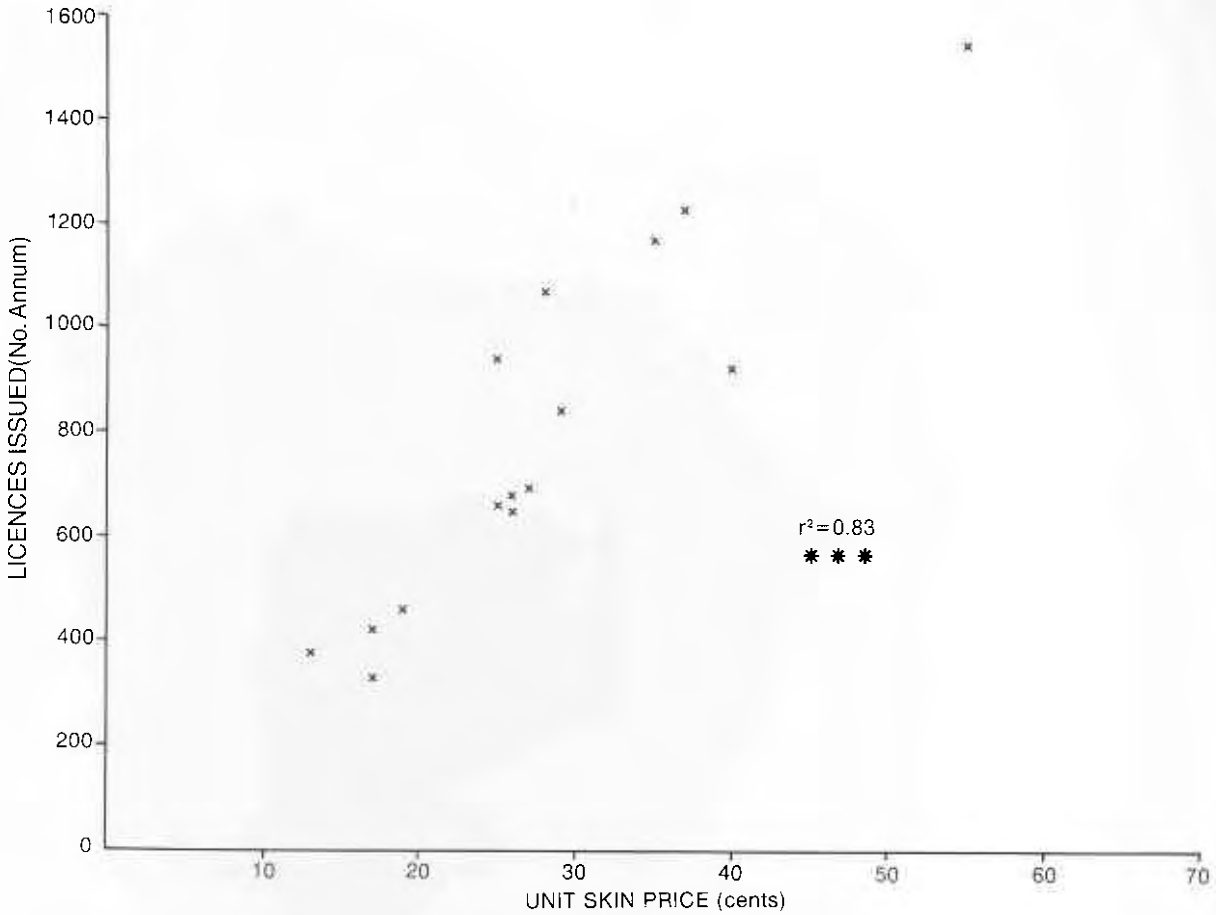

Figure A II.3. Relationship between the average skin price available and the number of licenses granted for taking Western Grey Kangaroos for food purposes within the 'Grey Kangaroo Reserve' in south-western Western Australia: 1920-1934.

market price in relation to the pattern of trade in Brush Wallaby skins (cf. the Western Grey Kangaroo) is probably due to the fact that the market prices on offer for these smaller skins during the early 1930s would have rendered most of them practically valueless to the vendor. In contrast, prices on offer for the kangaroo skins generally always offered some possible profit.

The more reliable winter seasonal rainfall pattern characteristic of the Mediterranean climate of the south-west of Western Australia (Gentilli 1972) also introduces a greater element of potential stability into the ongoing harvest and recruitment pattern for the south-western species, in contrast with the effects of the low and generally erratic rainfall which may fall either in the summer or winter period within the areas occupied by the Red Kangaroo. The expected increased stability in the potential harvest patterns for the Western Grey Kangaroo and Brush Wallaby could thus have allowed better resolution of the specific effect of varying market prices on the actual pattern of trade in skins of these species, as well as the effects of this basic stability in pattern being associated in this instance with the apparent clear break in the sequence between the prior rainfall variables thought to be related to stock recruitment (SWRN 23) and those related to the contribution of the residual adult stocks to the harvests (SWRN 5T9). The apparently equivocal status of LRNI 4 in regard to the Red Kangaroo analysis nevertheless suggests that this possible difference between the different harvest pattern analyses is not of major importance and thus should not be dwelt on in the absence of additional support.

The further extension in time of the 'significant' part of the prior rainfall record that I have previously identified with the contribution of the residual adult stocks to the observed pattern of harvest variability does however in the case of the south-western species appear to reflect a real difference between the commercial harvesting of these species and harvesting of the Red Kangaroo. The average age of the Red Kangaroos being harvested seems likely to have been less than that for the Western Grey Kangaroos. I consider this difference real, and that it reflects the fact that an appreciable component of the continuing harvests of the south-western kangaroos and

wallabies to date has comprised the non-renewable harvest of otherwise less accessible adult animals that have progressively been being displaced by agricultural land development.

By implication, past commercial disposal of kangaroos and wallabies taken in the south-west of Western Australia has exerted substantial pressure on the local populations being affected by agricultural land development. The smaller species have long since passed the point where harvesting could be sustained, and the Western Grey Kangaroo is the only species still being the subject of commercial trade. Exploitation of this kangaroo is permitted for the relief of property damage in the context of continuing agricultural development, and harvesting in conformity with the established post-1930s harvest trend (see Fig. 4) is still possible. The harvest levels presently being supported are unlikely to sustainable in the long-term, however.

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APPENDIX III

EXPORTS OF KANGAROO AND WALLABY SKINS FROM WESTERN AUSTRALIA : 1916-1970

APPENDIX III.

EXPORTS OF KANGAROO AND WALLABY SKINS FROM WESTERN AUSTRALIA : 1916-1970.

(Compiled from official Western Australian Trade Records in 'The Statistical Register.')

	Listing		Destinations				
YEAR	Trade Item	Quantity, etc.	Other Aust. States (1)	United Kingdom (2)	United States America (3)	Other Countries (4)	TOTALS (5)
1915-16	Skins (Other: = not Rabbit, Sheep, etc.).	Value	£23 419	£8 590			£32 009
1916-17	do	do	£33 282	£162			£33 444
1917-18	do	do	£80 493			£4	£80 497
1918-19	Other Furred Skins	do	£47 030	£1 782			£48 812
1919-20	Kangaroo Skins	Weight (lbs)	563 955	51 280			615 235
		Value	£138 885	£8 227			£147 112
	Wallaby	Weight (lbs)	1 098	993			2 091
		Value	£279	£132			£411
1920-21	Kangaroo Skins	Weight (lbs)	172 069	31 003			203 072
		Value	£27 430	£4 879			£32 309
	Wallaby	Weight (lbs)	1 769	6 326			8 095
		Value	£84	£1 281			£1 365
1921-22	Kangaroo Skins	Weight (lbs)	224 101	10 784		485	235 370
		Value	£28 830	£1 252		£63	£30 145
	Wallaby	Weight (lbs)	3 153	4 130		40	7 323
		Value	£359	£567		£3	£929
1922-23	Kangaroo Skins	Weight (lbs)	438 438	12 452			450 890
		Value	£76 169	£1 922			£78 091
	Wallaby	Weight (lbs)	30 392	9 284		179	39 855
		Value	£5 288	£953		£50	£6 291
1923-24	Kangaroo Skins	Weight (lbs)	274 403	70 875	6 915		352 193
		Value	£45 409	£13 532	£1 163		£60 104
	Wallaby	Weight (lbs)	11 248	35 932			47 180
		Value	£1 078	£6 294			£7 372
1924-25	Kangaroo Skins	Weight (lbs)	443 443	52 311		2 849	498 603
		Value	£59 667	£10 006		£44	£70 117
	Wallaby	Weight (lbs)	5 113	37 872			42 985
		Value	£412	£6 610			£7 022
1925-26	Kangaroo Skins	Weight (lbs)	229 064	40 393		305	269 762
		Value	£31 119	£7 136		£52	£38 307
	Wal	Weight (lbs)	331	32 884			33 215
		Value	£80	£5 363			£9 063

			(1)	(2)	(3)	(4)	(5)
1926-27	Kangaroo Skins	Weight (lbs)	214 669	42 551		214	257 434
		Value	£27 705	£5 842		£39	£33 586
	Wallaby	Weight (lbs)	2	27 176			27 178
		Value	£1	£5 363			£5 364
1927-28	Kangaroo Skins	Weight (lbs)	210 636	44 460	387	518	256 001
		Value	£28 261	£8 505	£141	£61	£36 968
	Wallaby	Weight (lbs)		10 491			10 491
		Value		£1 921			£1 921
1928-29	Kangaroo Skins	Weight (lbs)	370 261	48 500		1 450	420 211
		Value	£53 061	£10 130		£321	£63 512
	Wallaby	Weight (lbs)	1 456	25 087			26 543
		Value	£436	£10 800			£11 236
1929-30	Kangaroo Skins	Weight (lbs)	352 192	39 184			391 376
		Value	£40 789	£5 811			£46 600
	Wallaby	Weight (lbs)	374	22 613		134	23 121
		Value	£22	£4 486		£10	£4 518
1930-31	Kangaroo Skins	Weight (lbs)	304 103	17 405		368	321 876
		Value	£30 691	£775		£17	£31 483
	Wallaby	Weight (lbs)		2 890		250	3 140
		Value		£243		£13	£256
1931-32	Kangaroo Skins	Weight (lbs)	209 058	10 903		145	220 106
		Value	£22 249	£921		£33	£23 203
	Wallaby	Weight (lbs)		1 761		537	2 298
		Value		£109		£67	£176
1932-33	Kangaroo Skins	Weight (lbs)	202 993	14 716		947	218 656
		Value	£20 193	£1 055		£88	£21 333
1933-34	do	Weight (lbs)	230 585	5 463		124	236 172
		Value	£29 034	£250		£21	£29 305
1934-35	do	Weight (lbs)	343 944	1 823	9 847	1 307	356 921
		Value	£52 811	£188	£1 593	£99	£54 691
1935-36	Kangaroo & Wallaby Skins	Weight (lbs)	691 087	381	111 561	584	803 613
		Value	£93 725	£30	£17 517	£77	£111 349
1936-37	do	Weight (lbs)	448 131	1 569	51 707	18	501 425
		Value	£52 839	£228	£7 554	£3	£60 624
1937-38	Kangaroo Skins	Weight (lbs)	183 569	124	38 154	319	222 166
		Value	£29 049	£27	£7 983	£37	£37 096
1938-39	do	Weight (lbs)	191 096		32 311		223 407
		Value	£27 947		£5 260		£33 207
1939-40	do	Weight (lbs)	213 546		26 317		239 863
		Value	£34 265		£4 601		£38 866
1940-41	do	Weight (lbs)	181 945		76 240		258 185
		Value	£32 462		£15 444		£47 906
1941-42	do	Weight (lbs)	104 894		32 021		136 915
		Value	£21 530		£7 268		£28 798
1942-43	do	Weight (lbs)	63 314		12 739		76 053
		Value	£13 631		£3 035		£16 666

			(1)	(2)	(3)	(4)	(5)
1943-44	Kangaroo Skins	Weight (lbs)	85 014		24 951		109 965
		Value	£19 116		£5 612		£24 728
1944-45	do	Weight (lbs)	89 400		83 251		172 651
		Value	£23 647		£23 705		£47 352
1945-46	do	Weight (lbs)	101 672		33 875	10 000	145 547
		Value	£34 237		£13 188	£5 609	£53 034
1946-47	do	Number	97 696		120 998	6 314	225 008
		Weight (lbs)	119 423		161 869	7 849	289 141
		Value	£40 296		£65 720	£2 422	£108 448
1947-48	do	Number	109 012	304	102 304		211 620
		Weight (lbs)	136 565	152	131 824		268 541
		Value	£39 310	£22	£47 244		£86 576
1948-49	do	Number	126 599	2 442	66 548		195 589
		Weight (lbs)	162 124	2 899	83 811		248 834
		Value	£41 744	£839	£31 680		£74 263
1949-50	do	Number	108 992	4 000	55 150		168 142
		Weight (lbs)	131 914	3 920	70 406		206 240
		Value	£31 478	£1 357	£18 028		£50 863
1950-51	do	Number	128 487		87 516		216 003
		Weight (lbs)	154 097		112 587		266 684
		Value	£56 988		£46 195		£103 183
1951-52	do	Number	53 414		113 466		166 880
		Weight (lbs)	67 251		139 736		206 987
		Value	£23 163		£67 895		£91 058
1952-53	do	Number	59 657		6 500	400	66 557
		Weight (lbs)	77 426		8 565	1 275	87 266
		Value	£16 717		£2 277	338	£19 332
1953-54	do	Number	64 622			NA	NA
		Weight (lbs)	85 530			824	86 354
		Value	£22 404			£275	£22 679
1954-55	Kangaroo & Wallaby Skins	Number	77 041		NA	NA	NA
		Weight (lbs)	95 422		32 239	3 013	130 674
		Value	£26 818		£11 620	£698	£39 136
1955-56	Kangaroo Skins	Number	68 650		NA	NA	NA
		Weight (lbs)	88 691		13 418	10 193	112 302
		Value	£25 349		£4 328	£2 655	£32 332
1956-57	Kangaroo & Wallaby Skins	Number	99 660			NA	NA
		Weight (lbs)	(126 230)			354	(126 584)
		Value	£32 656			£100	£32 756
1957-58	do	Number	24 241		NA		NA
		Weight (lbs)	34 260		4 657		38 917
		Value	£5 528		£868		£6 396
1958-59	do	Number	30 961	NA			NA
		Weight (lbs)	44 590	100			44 690
		Value	£7 569	£11			£7 580
1959-60	do	Number	48 334		NA	NA	NA
		Weight (lbs)	61 270		30	1 263	63 013
		Value	£15 886		£3	£310	£16 199
1960-61	do	Number	19 810			NA	NA
		Weight (lbs)	30 085			1 528	31 613
		Value	£8 225			£369	£8 594

			(1)	(2)	(3)	(4)	(5)
1961-62	Kangaroo & Wallaby Skins	Number	4 095				4 095
		Weight (lbs)	5 274				5 274
		Value	£1 314				£1 314
1962-63	do	Number	2 182	1 909	18 664		22 755
		Value	£1 908	£1 964	£17 802		£21 674
1963-64	do	Number	125 734	3 000	2 782	2 350	133 866
		Value	$76 160	$1 810	$3 764	$2 540	$84 274
1964-65	do	Number	11 001	10 001	80 190		101 192
		Value	$6 238	$7 748	$84 998		$98 984
1965-66					No Data		
1966-67	Fur Skins, Undressed	Value	$17 000		$149 000 (inclusive)		$166 000
1967-68	Kangaroo & Wallaby Skins	Number	63 095	8 490	108 974	1 600	182 159
		Weight (lbs)	111 016	NA	NA	NA	NA
		Value	$56 000	$9 000	$144 000	$2 000	$211 000
1968-69	do	Number	89 270	2 500	9 058	13 492	114 320
		Weight (lbs)	387 124†	NA	NA	NA	NA
		Value	$150 000	$5 000	$15 000	$25 000	$195 000
1969-70	do	Number	257 479	NA	NA	NA	NA
		Weight (lbs)	1 008 896†	NA	NA	NA	NA
		Value	$540 000	$9 000	$72 000	$45 000	$666 000

Note : £1 = $2; 1 pound (lb) = 0.454 kg. Blank fields in Table = Nil unless otherwise indicated. NA = Data not available. † These weights apparently refer to fresh cured skins; previous weight data for dry skins.

Note also that wallabies in south-western Western Australia were protected from exploitation from mid-1952. Skins of these animals would therefore be excluded from the quoted trade figures where otherwise suggested.

APPENDIX IV

LISTING OF PRIMARY DATA FOR INDEPENDENT VARIABLES USED IN DERIVATION OF EQUATIONS GIVEN IN APPENDIX I, TABLE A I. 1., AND APPENDIX II, TABLE A II. 1.

APPENDIX IV

LISTING OF PRIMARY DATA FOR INDEPENDENT VARIABLES USED IN DERIVATION OF EQUATIONS GIVEN IN APPENDIX I, TABLE A I. 1., AND APPENDIX II, TABLE A II. 1.

(Data Sources and Variable Names, etc., as Described in Appendices I and II)

A. Data Relevant to Derivation of the Red Kangaroo Harvest Equations, Table A I. 1.

Year	RNI	SSUs	PI
1900	8.0	-	-
1901	4.0	-	-
1902	5.0	-	-
1903	7.0	-	-
1904	8.0	-	-
1905	5.0	-	-
1906	5.0	-	-
1907	7.0	-	-
1908	6.5	2 233	-
1909	9.0	2 586	-
1910	4.5	2 822	-
1911	2.5	2 946	-
1912	3.5	2 532	-
1913	7.0	2 363	-
1914	6.0	2 379	41
1915	9.5	2 345	46
1916	8.5	2 754	51
1917	9.0	3 094	82
1918	8.5	3 461	54
1919	4.0	3 161	73
1920	6.0	2 874	50
1921	8.0	2 819	31
1922	4.0	3 179	44
1923	7.0	3 276	45
1924	1.5	2 786	34
1925	6.5	2 681	35
1926	3.5	2 764	31
1927	8.5	2 966	32
1928	3.5	3 158	31
1929	7.5	4 003	29
1930	8.0	4 097	22
1931	7.0	4 337	23
1932	4.5	4 383	18
1933	4.5	4 580	24
1934	8.5	4 619	32
1935	3.0	4 548	45
1936	1.5	3 191	33
1937	3.5	2 434	37
1938	3.5	2 431	30
1939	4.0	2 529	35
1940	2.0	2 397	42
1941	6.0	2 207	44
1942	8.5	2 130	41
1943	4.0	2 487	41
1944	1.0	2 416	42
1945	6.5	2 328	70
1946	4.0	2 294	99
1947	9.0	2 533	54
1948	8.0	2 768	48
1949	5.0	2 893	34
1950	2.5	2 734	45
1951	8.0	2 643	42
1952	5.0	2 636	18
1953	4.0	2 484	18
1954	3.0	2 480	20
1955	8.0	2 447	20
1956	3.5	2 320	20
1957	3.5	2 295	15

1958	9.0	2 370	13
1959	2.0	2 276	19
1960	8.0	2 328	15
1961	6.0	2 465	15
1962	3.0	2 594	20
1963	9.5	2 682	23
1964	3.5	2 764	19
1965	8.5	2 938	16
1966	5.0	2 946	21
1967	5.0	2 924	27
1968	8.0	3 110	30
1969	1.5	3 188	35
1970	4.0	3 202	38

B. Data Relevant to Derivation of the Western Grey Kangaroo and Brush Wallaby Harvest Equations, Table A II. 1

Year	SWRN	FMLD	PI	PIBR
1900	6.0	-	-	-
1901	2.5	-	-	-
1902	2.5	-	-	-
1903	7.5	-	-	-
1904	8.5	-	-	-
1905	8.0	-	-	-
1906	5.0	-	-	-
1907	8.5	-	-	-
1908	3.0	-	-	-
1909	8.0	-	-	-
1910	8.5	836 000	-	-
1911	1.0	1 031 000	-	-
1912	3.0	1 226 000	-	-
1913	6.0	1 421 000	-	-
1914	1.0	1 618 750	41	10.9
1915	9.5	1 710 600	46	14.7
1916	7.0	1 823 900	51	18.2
1917	10.0	1 705 000	82	49.2
1918	8.0	1 748 250	54	23.1
1919	3.0	1 791 550	73	33.2
1920	8.0	1 910 100	50	37.5
1921	9.0	1 996 450	31	28.5
1922	5.0	2 320 200	44	40.2
1923	9.5	2 439 950	45	36.5
1924	3.5	2 849 000	34	37.6
1925	4.0	3 054 050	35	35.0
1926	9.0	3 323 800	31	23.8
1927	8.0	3 787 850	32	23.7
1928	8.5	4 295 050	31	29.8
1929	6.0	4 877 800	29	13.9
1930	7.0	5 072 050	22	4.6
1931	8.0	5 028 900	23	5.4
1932	8.0	5 007 300	18	5.5
1933	7.0	5 201 550	24	8.5
1934	9.5	5 169 200	32	7.0
1935	4.5	5 277 100	45	11.3
1936	2.5	5 439 000	33	21.1
1937	3.5	5 687 200	37	22.5
1938	4.0	5 816 650	30	12.0
1939	9.5	5 859 850	35	16.9
1940	1.0	5 838 300	42	14.0
1941	3.5	5 892 250	44	11.0
1942	5.0	5 837 250	41	0
1943	5.0	5 762 250	41	0
1944	1.5	5 692 250	42	0
1945	9.0	5 620 000	70	0
1946	5.5	5 989 350	99	24.8
1947	8.0	6 164 350	54	18.0
1948	5.0	6 444 350	48	20.7

1949	4.0	6 644 350	34	6.7
1950	3.5	6 822 750	45	3.6
1951	8.0	7 172 750	42	
1952	6.0	7 572 750	18	
1953	6.0	7 822 750	18	
1954	2.0	8 250 000	20	
1955	10.0	8 700 000	20	
1956	5.0	9 010 000	20	
1957	5.0	9 420 000	15	
1958	7.0	9 730 000	13	
1959	2.0	10 040 000	19	
1960	6.0	10 258 632	15	
1961	6.0	10 618 365	15	
1962	3.0	11 019 331	20	
1963	9.0	11 407 229	23	
1964	5.0	11 922 342	19	
1965	9.0	12 471 011	16	
1966	3.0	12 861 957	21	
1967	4.0	13 230 577	27	
1968	6.0	13 593 296	30	
1969	1.0	14 113 426	35	
1970	6.0	14 233 618	38	

39325/3/85—1M - L/3880

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