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The ground vertebrate fauna of coastal areas between Busselton and Albany, Western Australia.

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Abstract

Coastal areas between Busselton and Albany have been altered substantially since European settlement in the 1830s. Previous studies show that the mammalian fauna in parts of the region changed significantly prior to European settlement; subsequently several additional species have disappeared.

This study, using Museum records and local area sampling, indicates most mammalian populations are small and often isolated. The Ringtail Possum *Pseudocheirus occidentalis* and Quokka *Setonix brachyurus* persist but are rapidly diminishing. The herpetofauna has not previously been documented and it appears that assemblages in the Busselton-Margaret River areas differ from those further south and east. A positive correlation between the percentage of viviparous reptiles in subregional assemblages and the annual number of rainy days, suggests that viviparity probably confers a reproductive advantage in these cool moist climates.

Environmental factors such as predation, competition, disease and particularly habitat fragmentation and fire will continue to threaten many species of birds and mammals with local extinction.

Introduction

The near-coastal areas of the lower south-west of Western Australia between Busselton and Albany have come under increasing pressures since European settlement. In the last decade the region has become the focus of major developments for agriculture, mining and tourism; these have exacerbated the fragmentation of the unique landforms and biota of the region.

Reviews of the literature on vertebrate fauna (Daze 1984), invertebrate fauna (Majer and Chia 1980) and aquatic fauna (Chiffings and Brown 1977) in Western Australia, coupled with the records and collections of the WA Museum, have highlighted the paucity of collections and publications on the fauna of most near-coastal areas of the lower south-west.

Considerable historical information was collected by early navigators (see Beard 1981), and data collected by early naturalists has been summarised for plants (Beard 1981), mammals (Shortridge 1909, 1936, Kitchener *et al.* 1978) and birds (Whittell 1954a). Most of these collections were made around regional centres of population, e.g. Albany and Busselton, or on trips from Perth.

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Our study concentrated on the ground vertebrate fauna (mammals, terrestrial birds, reptiles and amphibians), principally in the areas from Busselton to Augusta, which face the greatest pressure from development and tourism, and from Augusta to Walpole, which has received limited attention in the past and contains the major south coastal reserve (D'Entrecasteaux National Park).

Study area and methods

The study region encompasses a 15-25 km wide coastal strip from south and east of Busselton to Two Peoples Bay east of Albany (Figure 1). The geomorphology, geology and vegetation of this area has been reviewed by Smith (1973) and Beard (1981).

The area around Busselton lies on the extreme southern end of the Quaternary sands of the Swan Coastal Plain. The coastal strip to the west lies on the Leeuwin-Naturaliste Ridge and consists of sands and calcarenite overlying Precambrian granites and granulites. The most extensive geomorphological unit in the study region is the Scott Coastal Plain, these active and lithified sand dunes extend from east of the Blackwood River to the extreme east of the study region where they

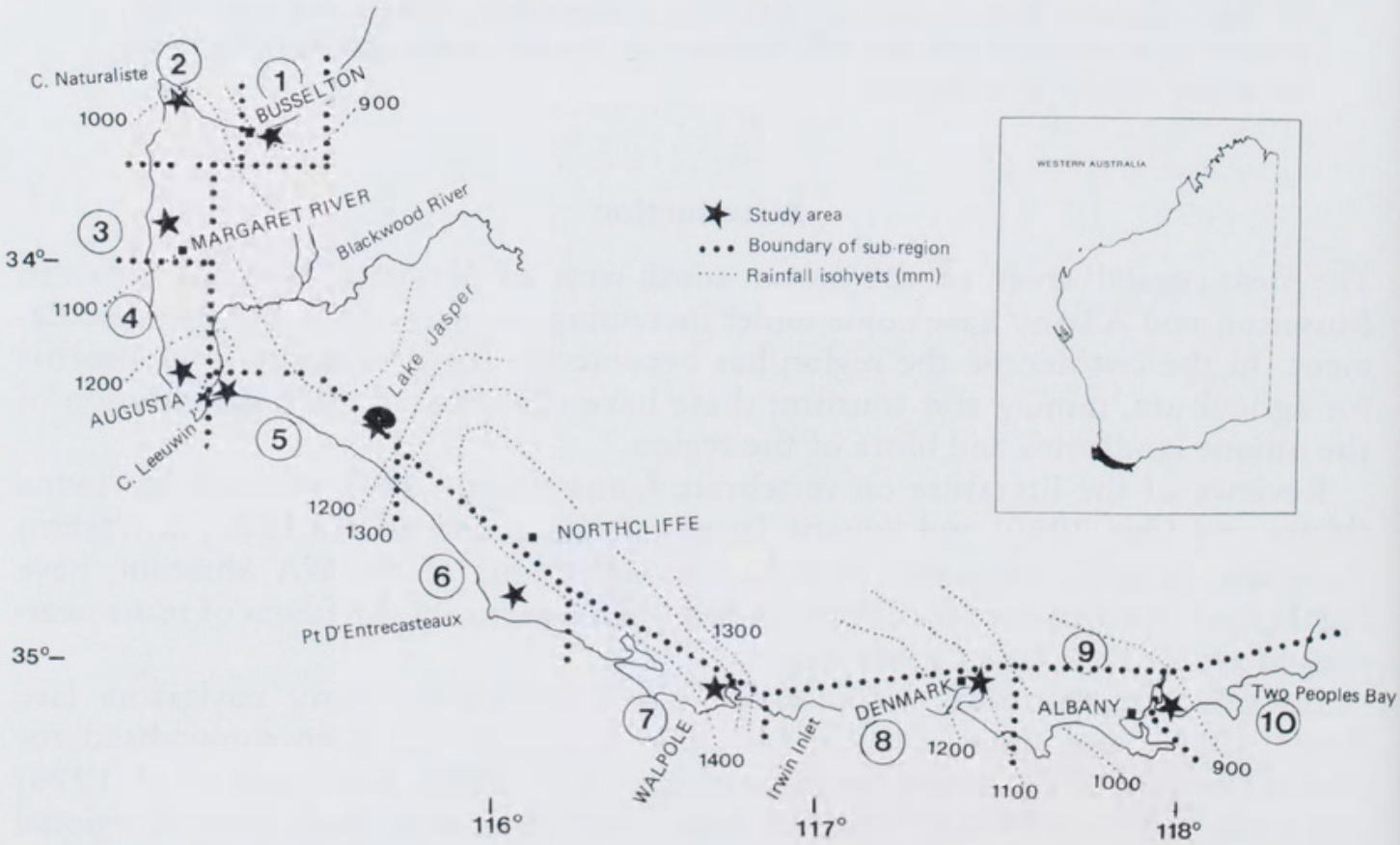

Figure 1 Map of the south-west coast of Western Australia. The ten subregions used in this study are outlined by dotted lines and identified by numbers in circles. The sites studied are indicated by star symbols and the isopleths for mean annual rainfall (mm) are indicated together with the major regional centres.

are replaced by dunes of the Albany Slopes. The interdunal areas of the Scott Coastal Plain are characterised by numerous swamps.

The entire region lies within the Darling Botanical District of the South-West Botanical Province and principally within the Warren Sub-district (Beard 1980). Small areas in the north and north-east are within the Drummond and Menzies Sub-districts, while the area east of Albany also lies within the Menzies Sub-district.

In the present study, 10 areas were selected (Figure 1) to document the terrestrial vertebrate fauna; the location of these study areas was determined by examining vegetation and soil maps. Five sites representing the major edaphic and vegetation heterogeneity within each area were selected, and fenced pitlines and metal traplines were established. Additional opportunistic collections were made from the study area. Each study area was examined over a 4-5 day period in either March 1985, October-November 1985 or January-February 1986. Three study areas were examined twice, in late summer and spring.

Data in the collections in the Western Australian Museum were separated into 10 subregions of roughly similar area (Figure 1). The subregions identified by a major geographical feature or locality are:-

1	Busselton	6	Point D'Entrecasteaux
2	Cape Naturaliste	7	Walpole
3	Margaret River	8	Denmark
4	Augusta	9	Albany
5	Scott River	10	Two Peoples Bay

The species listed in Appendix I and II are referable to these subregions.

Climatic data (Anon 1975) were taken from the recording station closest to the centre of the subregion.

Subregional assemblage dendrograms were produced by WPGMA cluster analysis on Jaccard's indices of association for presence/absence data (Southwood 1978). The indices were clustered using the WPGMA method (Sneath and Sokol 1973). The statistical significance of the clusters was determined following Strauss (1982) by taking the 95% occurrence of each node level following the accumulations of about 3500 nodes using the same clustering procedure derived from randomizing the data matrix. In the randomization process the number of species per site was kept constant but the species present were randomly allocated. Regression analysis was carried out using least-squares method.

Data and discussion

Mammals

Species represented in the collections of the Western Australian Museum are presented by subregions in Appendix I. Nine marsupial families representing 16 species, and seven orders of eutherian mammals comprising 14 families and 32

species have been collected within the region and lodged in the collection. The eutherians include Cetacea (12 spp.), Pinnipedia (2), Lagomorpha (1), Carnivora (3), Artiodactyla (2), Chiroptera (7) and Rodentia (5).

Records of the twelve whale species result from skeletal remains of beached specimens that have been lodged in the WA Museum. Seals are generally confined to islands (Abbott 1979) but skeletal material has been collected from some mainland beaches. Both ungulates (Roe Deer and Pig), two carnivores (Fox and Cat), the lagomorph (Rabbit) and two rodents (Mouse and Black Rat) were introduced since European settlement and have subsequently become feral. Domestic sheep, goats, cattle and horses are widespread in the study region but are not included in Appendix I.

Only 14 species of mammal were recorded during the present field study. These species (with the subregional study areas in which they were recorded or collected) were *Sminthopsis griseoventer* (5, 10), *Macropus fuliginosus* (2, 4, 5, 6, 8, 10), *M. irma* (10), *Setonix brachyurus* (6?), *Isoodon obesulus* (6, 8, 10), *Pseudocheirus occidentalis* (1, 5, 9, 10), *Trichosurus vulpecula* (1, 2), *Tarsipes rostratus* (2, 6, 10), *Mus musculus* (2, 5, 6, 8, 10), *Pseudomys albocinereus* (10), *Rattus fuscipes* (2, 5, 6, 8, 10), *R. rattus* (2, 8, 10), *Eptesicus regulus* (8), *Falsistrellus mackenziei* (6). The most significant is the southernmost record of *Pseudomys*, the first time it has been collected live in the region. The newly described *F. mackenziei* (Kitchener *et al.* 1986) was relatively common near water in Karri forest north of Point D'Entrecasteaux in March 1985. Few bats were observed and very few captured during the study.

Most mammal species were infrequently recorded and consequently extensive effort is required to ascertain the complete assemblages at the subregional level. This is supported by the fact that only five species of marsupial have been collected from the D'Entrecasteaux subregion, an area with considerable environmental heterogeneity and where *Macropus irma, Isoodon obesulus* and *Trichosurus vulpecula* have recently been observed (G. Gardner pers. comm.).

Comparisons of trapping success for mammals between this study and other surveys (How *et al.* 1984 and unpubl.) show that capture rates for south-coastal assemblages are low (Table 1). Capture in pitfall traps is the lowest recorded in any of our recent surveys and significantly ($p<0.001$) less than that recorded along the Great Australian Bight. Capture in aluminium Elliot traps is significantly ($p<0.001$) higher than along the Great Australian Bight but similar to that recorded in the sparse populations of the semi-arid Eastern Goldfields (Table 1). Capture rate on the south coast is significantly lower ($p<0.001$) than that recorded in Elliotts (7372 traps/423 captures) for a relatively sparse small mammal assemblage in north-eastern New South Wales (Barnett *et al.* 1978). Of the 60 individuals caught in Elliott traps on the south coast, *Rattus fuscipes* (31), *Mus musculus* (21) and *Rattus rattus* (4) predominated: the preferential capture of rodents in Elliott traps has been recorded previously (How *et al.* 1984).

Table 1 Comparison of trapping success in recent WA Museum surveys for mammals in both Elliott and fenced pitfall traps. Capture rate per 100 trapnights is bracketed.

Survey	Elliotts/Captures	Pitfalls/Captures
South Coastal WA	2054/60 (2.92)	967/16 (1.66)
Great Australian Bight WA[1]	1050/8 (0.76)	732/25 (3.42)
Eastern Goldfields WA[2]	4311/75 (1.74)	8780/169 (1.93)

Data from (1) our unpublished
(2) How, Humphreys and Dell 1984

The Chuditch *Dasyurus geoffroii* is the only dasyurid known to have changed status significantly within the study region. Shortridge (1909) found abundant tracks along the coast at Margaret River and assumed the species to be plentiful there but observed that it did not appear to extend far inland. He noted that it was being actively killed by farmers. There is no museum record from the study region in the last 20 years although several sightings have been reported from the Leeuwin-Naturaliste Ridge between 1984-1986 (P. Lambert pers. comm.). The status of the Mardo *Antechinus flavipes,* Brush-tailed Wambenger *Phascogale tapoatafa* and Coastal Dunnart *Sminthopsis griseoventer* appears to have changed little in recent years.

The record of the numbat *Myrmecobius fasciatus* from the Albany subregion is of doubtful provenance. It is based on a very early specimen sent from the Torbay District but possibly not collected there.

The Brown Bandicoot *Isoodon obesulus* occurs around swamps within the study region, although many of the populations in the Busselton-Margaret River areas may have been severely fragmented by land clearance.

The Ringtail *Pseudocheirus occidentalis* and Brushtail *Trichosurus vulpecula* Possums have changed status considerably since European occupation. The Ringtail, once abundant in most *Agonis* forests and along banks of rivers and swamps (Shortridge 1909), has declined alarmingly over much of its former range and is now abundant in only a few areas. We examined several natural areas where *P. occidentalis* previously occurred and noted all nests appeared to be unused or abandoned. Apparently viable populations occur within the towns of Busselton, Quindalup, Dunsborough and Albany, in several forest locations (Christensen *et al.* 1985) and in Two Peoples Bay Reserve (Hopper 1981). The Brushtail Possum was once common throughout the south-west and extended inland to the woodlands of the Eastern Goldfields; hunting and predator pressure, disease, land clearance and fire have all probably had a pronounced influence on reducing its range. Nowhere within the study area are dense populations of either possum species known to occur.

The Western Pygmy Possum *Cercartetus concinnus* has been intermittently recorded from the study region over the last 20 years but is probably widespread,

being trapped mainly in fenced pitfall traps, a technique that is still infrequently used. The Honey Possum *Tarsipes rostratus* is the most widespread marsupial and is abundant in the floristically rich heaths and understories of the region.

The Woylie *Bettongia penicillata* has not been recorded in the study region within the last 50 years and is now confined to the forests at Perup (Christensen *et al.* 1985). It was abundant in the Yallingup-Margaret River area around the turn of the century when it was destructive to crops (Shortridge 1909). *Potorous tridactylus* is known only from cave material, although Shortridge (1909) thought it occurred at Cape Leeuwin.

Of the five rodents known from the region, the introduced Mouse *Mus musculus* and the Black Rat *Rattus rattus* and endemic Bush Rat *R. fuscipes* are widespread and common. The Bush Rat is the most abundant of all ground mammals in the study region. The Water Rat *Hydromys chrysogaster* is infrequently captured but from the evidence of feeding sites appears to be widespread along watercourses. The Ash-grey Mouse *Pseudomys albocinereus* is regionally known from only one locality.

The bats have never been documented systematically in near-coastal areas, and only since 1950 have specimens been regularly lodged in the Museum (Appendix I). Christensen *et al.* (1985) documented the bat fauna of the more inland forested areas. They reported that the Great Pipistrelle *Falsistrellus mackenziei (Pipistrellus tasmaniensis* in Christensen *et al.)* and the King River Eptesicus *Eptesicus regulus* were both widely distributed.

Assessment of Western Australian Museum records from within the study region over the last 35-40 years show only slight faunal changes (Table 2). The number of marsupial species has declined slowly, although the rodents show an increase with our record of the Ash-grey Mouse. Three species of marsupial have not been lodged in the collection since 1950, viz. *Macropus eugenii* (1931), *Myrmecobius fasciatus* and *Bettongia penicillata* (1933), while *Dasyurus geoffroii* was represented only by skeletal material in 1964-65. The bat *Nyctophilus gouldii* has similarly not been collected since 1965, and then only as skeletal material from caves near August. There are no records of the Echidna *Tachyglossus aculeatus.*

Shortridge (1909, 1936) made several statements on the status of species. He thought that the Brush Wallaby *Macropus irma* did not occur in southern coastal

Table 2 Number of species of recent mammals represented in the Museum collections from the near-coastal areas of the lower south-west of Western Australia.

Order	Period		
	<1950	1950-1975	1975-1986
Marsupialia	15	12	11
Rodentia	4	4	5
Chiroptera	2	7	6

districts between Cape Naturaliste and Leeuwin, an area where it now occurs in low numbers. By 1930 the Tammar *M. eugenii* was rapidly disappearing from cultivated lands; it has not since been represented in Museum collections from near-coastal sites. Both species have been recorded in forests inland from the present study region (Christensen *et al.* 1985), although the Tammar was found in only one locality. The Quokka *Setonix brachyurus* was common in swampy patches along the coast in the early 1900s but is currently much more restricted having suffered a major epidemic in the 1920s (White 1952, G. Gardner pers. comm.); but footprints sighted near Point D'Entrecasteaux during the present survey were probably of this species.

Comparisons between the prehistoric mammalian fauna of caves in the Augusta area (Archer and Baynes 1972) with that recorded and collected between 1904 and 1907 by Shortridge (1909, 1936) around Margaret River and with the more recent records of the WA Museum show considerable changes in status and distributions. Species represented in the Augusta cave fauna but not collected live have been summarised by Archer and Baynes (1972); they include the marsupials *Sarcophilus harrisii, Potorous tridactylus* and *Bettongia lesueur,* the bat *Nyctophilus timoriensis,* and the rodents *Pseudomys albocinereus, P. shortridgei, P. praeconis* and *Rattus tunneyi.* More recent Museum information indicates that *N. timoriensis (=N. major)* survives on the Leeuwin-Naturaliste Ridge.

The major change to the mammal fauna between 25 000 and 12 000 B.P., as examined in deposits of Devils Lair, was a consequence of either glacio-eustatic changes in sea level altering the extent of habitats, or such changes acting in concert with climate and increased regional rainfall to alter the environment (Baynes *et al.* 1975). The marked change since European settlement probably results from direct and indirect anthropogenic factors (Shortridge 1909, 1936, Carter, 1923, Kitchener *et al.* 1978) such as changed fire regime, land alteration for agriculture, exotic diseases and introduced predators and competitors.

Birds

Zoogeographically south-western Australia is an area where Eyrean and Bassian faunas mingle (Serventy and Whittel 1954). The coastal areas dealt with in this study contain a number of Bassian endemics or species with disjunct populations in south-western and south-eastern Australia. In general these species have extremely curtailed distributions and have attracted considerable comment (Smith 1977). All have been affected markedly by the activities of European man in the last 100 years.

The first bird collections were made in the south-west coastal regions within a few years of the establishment of colonies around the Avon River and King George Sound. John Gilbert made three collecting trips to the region: in February 1840 he collected at King George Sound and inland to Cranbrook; in November 1842 with the botanist James Drummond he collected between Perth and Augusta; and in June 1843 he made an overland collecting trip from Perth to King George

Sound via Kojonup. Specimens collected by Gilbert were often new to science and provided the main source of material for Gould. Gilbert's collecting trips are documented by Whittell (1941, 1954a).

The next major ornithological work was by Milligan (1902) who in 1901 collected and made numerous field notes in the area immediately north of Margaret River. A notable feature of this work was the first collection of the Rufous Bristlebird *Dasyornis broadbenti.* Milligan commented on the abundance of birds in the coastal hills where he encountered "tens of thousands" of Grey Currawongs *Strepera versicolor* and Ring-necked Parrots *Platycercus zonarius* and provided notes on a total of 57 species in the area. Most of the species recorded by Milligan are still relatively abundant. However the Whipbird *Psophodes nigrogularis,* Rufous Bristlebird, and Mallee Fowl *Leipoa ocellata* and probably the Stone Plover *Burhinus grallarius* are now locally extinct.

Carter (1923) presented an annotated list of 197 species of birds that he had encountered within a radius of 250 km of Broomehill. He provided data on 131 species that he recorded in coastal areas such as Busselton, Cape Naturaliste, Cape Mentelle, Cape Leeuwin, Augusta, Warren River, Denmark and Albany. Carter's paper was the first attempt to appraise the distribution, status, and habitat of all the known birds of the south-west. He was also aware of changes in abundance resulting from activities of European man:- he stated that in 1902 Mallee Fowl were not uncommon in the coastal scrubs between Cape Naturaliste and the mouth of the Warren River but by *c.* 1920 had diminished because of burning off the coastal vegetation to improve grazing for cattle. This population was extinct by 1950 (Storr 1954).

Similarly Carter identified the decline in Western Bristlebird and Rufous Bristlebird; "I revisited the same locality in March, 1916, 1919 and 1922 and found that where there had been dense impenetrable scrub, was mostly bare sand drifts caused by fires made to improve the country for cattle". He considered also that feral cats were hastening this extinction.

Further data on coastal avifauna were provided by Ashby and LeSouef (1928), Whitlock (1939), Whittell (1933, 1938) Lane (1975) and Abbott (1976). Information on coastal islands was provided by Storr (1965), Abbott (1978a, b, c, d, e, f, 1980), Fullagar (1978), Kolichis and Abbott (1978) and Lane (1978). These studies and the summary distributions in Blakers *et al.* (1984) provide the background for the avifauna of the region.

Herpetofauna

There has been a marked change in our understanding of the herpetofauna of Western Australia in the last 20 years with a significant increase in the information published (Daze 1984), a vast increase in collections and surveys and a doubling of the number of species described or recognised. The principal systematic revisions have occurred in the lizards (Lacertilia), although several new species of frogs (Batrachia) and snakes (Serpentes) have also been described (Figure 2). Many of

these new species have resulted from a re-evaulation of previously known taxa, but most have been collected in remote areas. It has consequently been difficult to evaluate historical changes in this group; this difficulty is further compounded by a general disinterest in reptiles by early collectors, and a poorly documented and researched sub-fossil fauna.

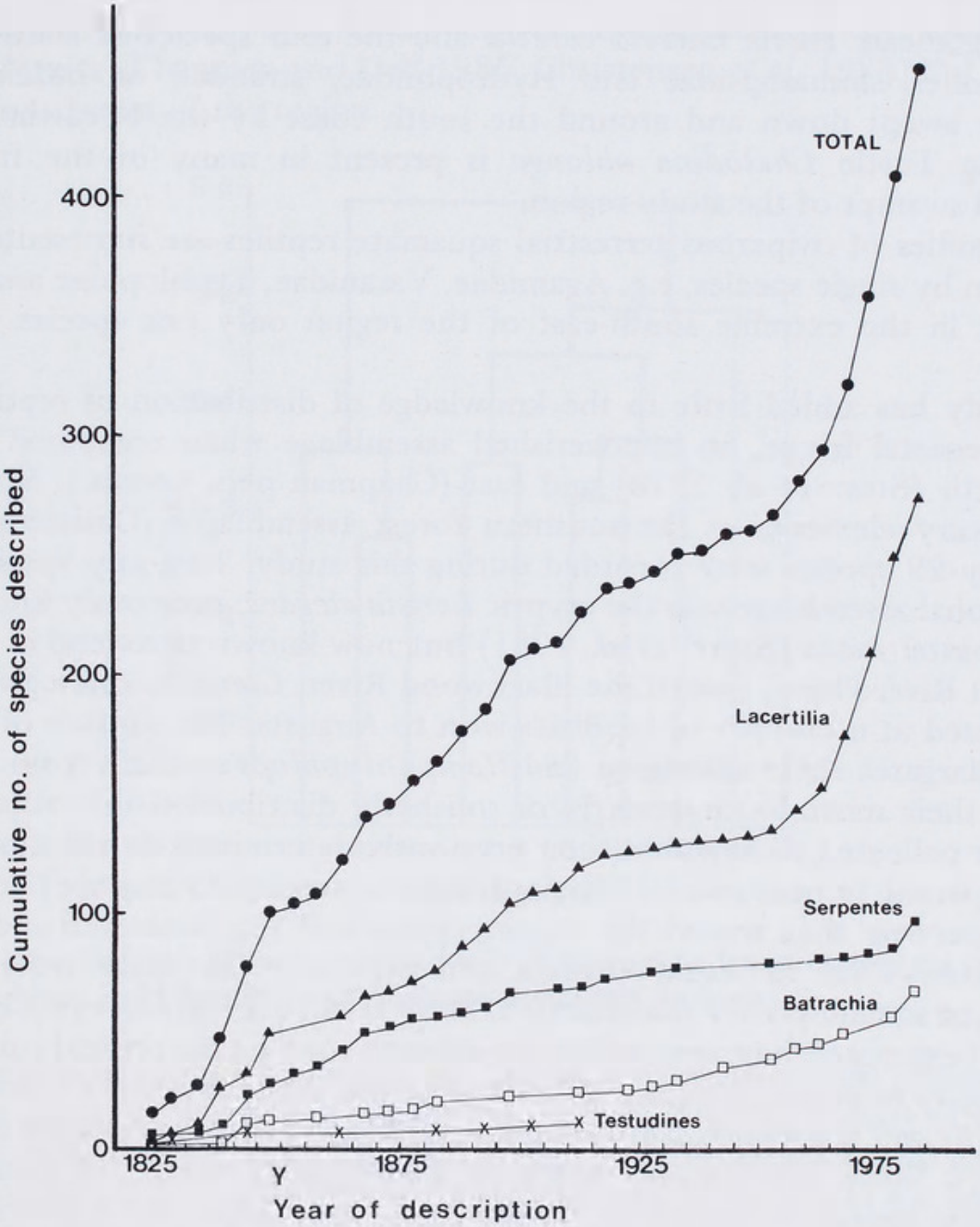

Figure 2 Species of Reptilia and Amphibia described in Western Australia accumulated for five-year intervals. (Both species of Crocodylidae were described before 1873).

Few new frog locality records resulted from our study, principally because sampling was undertaken in the late spring-late summer period when most frogs are inactive. The record of *Ranidella subinsignifera* in the Point D'Entrecasteaux area is a southwestward extension of its known range (Tyler *et al.* 1984) while

Heleioporus psammophilus has now been shown to occur along the Scott River Plains, and *H. inornatus* has been recorded from the Cape Naturaliste area. The two species of *Litoria* were infrequently collected in the Busselton-Dunsborough area but recent revision of the *Geocrinea rosea-lutea* complex has shown that two undescribed species also occur in the study region (Roberts and Wardell-Johnstone pers. comm.).

The Loggerhead Turtle *Caretta caretta* and the four species of marine snakes in the families Homalopsidae and Hydrophiidae, stranded on beaches, were presumably swept down and around the south coast by the Leeuwin Current. The Oblong Turtle *Chelodina oblonga* is present in many of the freshwater streams and swamps of the study region.

Many families of oviparous terrestrial squamate reptiles are represented in the study region by single species, e.g. Agamidae, Varanidae, Typhlopidae and Boidae, and except in the extreme south-east of the region only one species of gecko occurs.

This study has added little to the knowledge of distribution of reptiles occupying the coastal fringe, an impoverished assemblage when compared to those further north (Storr *et al.* 1978) and east (Chapman pers. comm.). However, it contains many elements of the southern forest assemblages (Christensen *et al.* 1985). Only 29 species were recorded during this study. The only species added to the regional assemblage was the cryptic *Lerista elegans*, previously known from the west-coastal sands (Storr *et al.* 1981) but now known to extend as far south as the Scott River Plains, east of the Blackwood River. *Ctenotus catenifer* has now been collected at a number of localities west to Augusta. The capture of *C. impar* from the Margaret River subregion and *Ramphotyphlops australis* from Denmark represents their most south-westerly or southerly distribution. All other reptiles observed or collected were within their previously determined distributions.

Gaps apparent in near-coastal distributions (Appendix II) may well be changed by future surveys that record the more cryptic and less abundant species, particularly from areas between Augusta and Denmark that have received little attention and remain poorly documented. The southern forest surveys (Christensen *et al.* 1985) examined four areas which are encompassed by the present study region viz. Boranup in Augusta subregion (4), Yeagerup and Dombakup in D'Entrecasteaux subregion (6) and Woolbales in Walpole subregion (7). All representative specimens collected by those surveys are lodged in the Western Australian Museum and consequently appear in Appendix II. However, they made the following observations that are new for the subregions, or in two cases, the region: the skinks *Cryptoblepharus plagiocephalus, Ctenotus impar, Lerista distinguenda* and *Menetia greyi* in the Boranup survey; *Egernia luctuosa, Morethia lineoocellata, M. obscura, Hemiergis initialis, Tiliqua rugosa,* the legless lizard *Delma fraseri,* the snake *Rhinoplocephalus bicolor* and monitor *Varanus gouldii* at Woolbales. It is unlikely that the distributions of *V. gouldii, M. obscura, H. initialis* and *D. fraseri* extend to the southern coast (Storr *et al.* 1981, 1983), hence these may have been

misidentified by Christensen *et al.* (1985); all other observations represent plausible new distribution records for the coastal region.

Species such as *Pygopus lepidopodus, Egernia kingii, E. luctuosa, E. pulchra, Sphenomorphus australis, Varanus rosenbergi, Notechis curtus, N. minor* and *Rhinoplocephalus bicolor* probably occur throughout near-coastal areas, although the abundant litter skinks *Menetia greyii* and *Lerista distinguenda* and the dragon *Pogona minor* do not occur in the higher rainfall areas of the south coast or adjacent forests (Chapman and Dell 1985, Christensen *et al.* 1985) but re-occur in the drier south-east of the region.

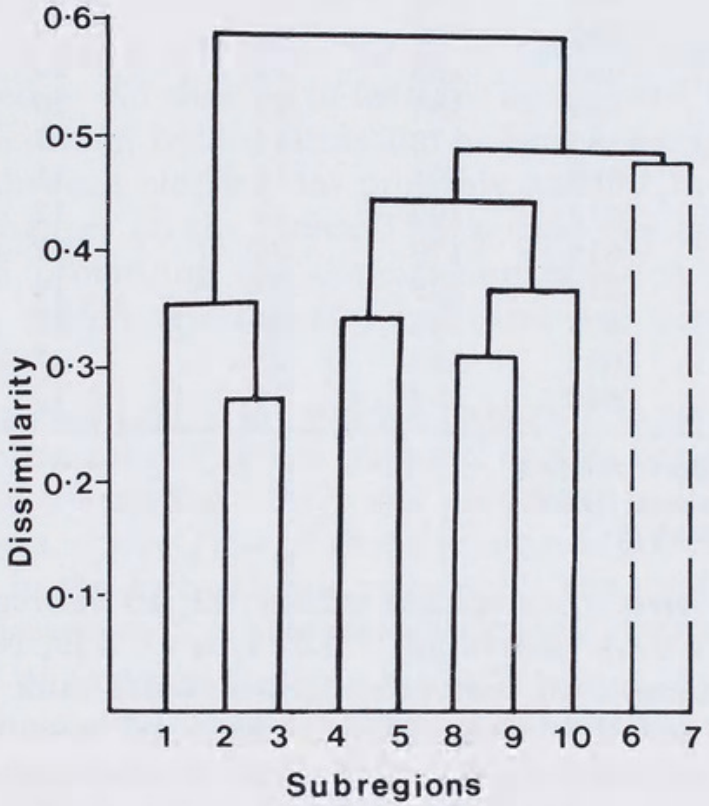

Figure 3 Dendrograms of faunal dissimilarity of subregions for the terrestrial reptile assemblage. Bold lines link significant groupings (see Methods).

Comparison of assemblage similarity indices for the subregions (from Appendix II) shows that for terrestrial snakes and lizards there is a marked dichotomy between the Busselton, Cape Naturaliste, Margaret River subregions and all other subregions (Figure 3). This suggests a zoogeographic boundary in the area between Margaret River and Augusta with the northward range termination here of *Ctenotus catenifer* and *Sphenomorphus australis* and a southward range termination of *Aprasia repens, Lialis burtonis, C. impar, Lerista distinguenda* and *Menetia greyi.*

Examination of the assemblages of terrestrial squamate reptiles in the 10 subregions and adjacent regions (Table 3) indicates a major change in the percentage occurrence of viviparous species. The highest percentage of viviparous species occurs in the Walpole subregion (61%) and the lowest in Cape Naturaliste

(33%). The inference from Table 3 is that the more southerly, higher rainfall subregions have a higher percentage of live-bearing species.

Table 3 Percentage of viviparous species in the terrestrial squamate reptile assemblage of near-coastal subregions and adjacent areas. The mean annual rainfall and mean rain days are presented for the nearest recording station.

AREA	Rainfall	Rain Days	Squamate Reptiles	Viviparous Species	Vivi-parity (%)
Busselton	838	137	26	10	39
Cape Naturaliste	838	156	27	9	33
Margaret River	1192	147	23	9	39
Augusta	994	183	22	10	46
Scott River	994	183	21	10	48
Point D'Entrecasteaux	1387	178	14	7	50
Walpole	1369	185	18	11	61
Denmark	1012	192	24	12	50
Albany	815	179	26	12	46
Two Peoples Bay	815	179	27	14	52
Fitzgerald N. Pk[1]	628	118	40	12	30
Southern Forests[2]	1055	153	25	12	48
Northern Swan Plain[3]	849	102	55	11	20

Data from 1. Chapman (pers. comm.)
2. Christensen *et al.* (1985)
3. Storr *et al.* (1978)

The proportion of viviparous species within the 10 subregions is not related to rainfall (Spearman's rank correlation = 0.324, $t_8 = 0.969$, N.S.) but is strongly correlated with the number of rainy days (Spearman's rank correlaton = 0.694, $t_8 = 2.726$, $p = 0.026$) and this relationship is enhanced when data from adjacent areas (Table 3) are included (Spearman's rank correlation = 0.762, $t_{11} = 4.156$, $p = 0.0016$) which yields the relationship $y = 3.869x + 2.352$ ($N = 13$, $r = 0.884$, $p < 0.001$), where $y = \sin^{-1}\sqrt{}$ proportion viviparous and x = number of rainy days.

These findings are in close agreement with those of Shine and Berry (1978), who concluded, from a detailed examination of climatic correlates of viviparous species, that live-bearing is as closely correlated with measures of precipitation, evaporation and humidity as it is with environmental temperatures and irradiance measures and that viviparity essentially conferred a selective advantage for reproduction in cold-moist climates.

Conclusion

". . . and I declare that neither in Victoria nor Queensland have I seen so many species and individuals within a similar area to that traversed." (Milligan 1902).

The above quotation refers to the avifauna of the Cowaramup-Margaret River area which at that time included Stone Plovers, Western Whipbirds, Rufous

Bristle-birds and Mallee Fowl. These species were greatly reduced only 20 years later, a fact attributed to the alteration of habitat by fire (Carter 1923); they are now extinct in the area.

The destructive impact of fires on fauna is a recurring theme in Western Australia. Fire is blamed for the decline of marsupials in the Leeuwin-Naturaliste area (Shortridge 1909), and of the mammals of the south-west of the State (Shortridge 1936), Swan Coastal Plain (Kitchener *et al.* 1978) and deserts (Burbidge and MacKenzie pers. comm.). In coastal habitats of southern New South Wales, it has been shown that wildfires markedly change faunal assemblages and that post-fire recovery is variable (Newsome *et al.* 1975).

The Leeuwin-Naturaliste area was one of the first settled in the State, and as population increased so did clearing of land for agriculture, forest plantations and, more recently, viticulture, hobby farms and holiday homes. The fragmentation of native vegetation through clearing has probably had the most pronounced effect of all man-made changes on the fauna. This is exacerbating the impacts of most other changes and promoting the competition between introduced herbivores (such as ungulates, rabbits and rodents) and carnivores (cats and foxes) and their native counterparts.

Disease has been blamed for the sudden reduction in range and abundance and possibly even disappearance of several mammal species between the 1880s and the turn of the century (Shortridge 1909) and even later in the 1920s (White 1952). George Gardner (pers. comm.) stated that the swamps around Northcliffe were full of Quokka bodies in the early 1920s, presumably the result of a major epizootic. The influence of disease on changing assemblages will remain anecdotal.

The first record of foxes in Western Australia was in 1911-12 (King and Smith 1985), and after their arrival they are believed to have had a significant impact on the medium-sized mammals through predation (King *et al.* 1981). The decline in the mammal fauna of the Perup forest in 1973-74 has also been attributed to the high incidence of predation by foxes (Christensen 1980). Feral cats have similarly been destructive of native mammals and reptiles. Predation by 'cats gone wild' was believed to be an important factor in species reduction in the early 1900s (Shortridge 1909), and numerous species of native vertebrate are represented in museum collections that were 'brought in by cats'.

Nearly all known mammal species, including widespread ones, occur in low densities in the study region, thus requiring considerable effort to adequately document the assemblages of subregions. The marked decline in abundance and distribution of the Brushtail *Trichosurus vulpecula* and Ringtail Possums *Pseudocheirus occidentalis* in near-coastal localities is of particular concern. The Brushtail Possum was once widespread through the mesic and semi-arid south-west of the State and abundant in the lower south-west where it was hunted for its skin (Serventy 1954); the Ringtail Possum is confined to the lower south-west. Recent work has shown that the numbers of both species, although fluctuating,

are considerably reduced and that some range contraction is still occuring (Christensen *et al.* 1985).

The impact of environmental changes on lizards has been evaluated in a survey of nature reserves in the semi-arid wheatbelt of Western Australia (Kitchener *et al.* 1980). Despite the major fragmentation of native vegetation with increasing demand for agricultural land, it appears that there has been no large-scale loss of lizard species from that region (unlike the situation for mammals), and their assemblages probably remain little altered. Kitchener *et al.* (1980) concluded also that the richness of lizard species correlated with vegetation associations which in turn correlated with edaphic factors.

The predominantly sandy soils of south-western near-coastal areas, together with the cool, moist environment, results in a considerably reduced assemblage of ectothermic vertebrates. The prolonged winter, lower temperatures and higher rainfall have been advanced as factors explaining the lower number (32) of reptile species present in southern forests compared with the rich (55) assemblage of the northern Swan Coastal Plain (Christensen *et al.* 1985). The significant positive correlation between the percentage of viviparous squamate species and the mean annual number of rainy days suggests a reproductive advantage for live-bearing species in these cool-moist climates.

Reptile species richness is greatest at each end of the study region and decreases centrally. This may be partly accounted for by reduced sampling in the less accessible high rainfall areas of the central subregions, although some coastal species near Margaret River and Augusta are apparently absent from the wetter south coast subregions but appear further east. Several west coast species only extend south to Busselton and on to the Leeuwin-Naturaliste ridge. These two factors combine to differentiate the reptile assemblage of the Busselton-Margaret River area from the other near coastal subregions.

The mammal and bird faunas of coastal and near-coastal areas between Busselton and Albany have considerably changed since European settlement, resulting in the disappearance of several species and a contraction of range in others. It is unlikely that any single factor has been responsible, more probably the accumulated effects of changed fire regimes, land clearance for agriculture, predation, competition and disease have acted in concert.

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Appendix I List of the mammal species represented in the collection of the Western Australian Museum from ten subregions in the near-coastal region of the lower south-west. Horizontal lines represent specimens collected before 1950, vertical lines between 1950-1975 and circles after 1975. Materal from cave deposits has been excluded.

Family/Species	Subregions									
	1	2	3	4	5	6	7	8	9	10
MARSUPIALIA										
BURRAMYIDAE										
Cercartetus concinnus	–	+	–	⊕	1	1		–	–	1
DASYURIDAE										
Antechinus flavipes			1				1		⊕	◐
Dasyurus geoffroii	–	–		–				1	1	
Phascogale tapoatafa	⊕	+	+	⊕	1	○	–	–	○	
Sminthopsis griseoventer	1	1	–	⊕	◐		◐	⊕	⊕	○
MACROPODIDAE										
Macropus eugenii		–		–						
Macropus fuliginosus		◐		⊕	◐	1	1	1	◐	1
Macropus irma		◐	1	+	–				–	
Setonix brachyurus		⊖	⊕	–	◐	1	◐	◐	–	◐
MYRMECOBIIDAE										
Myrmecobius fasciatus									–	
PERAMELIDAE										
Isoodon obesulus	+	1	+	○	◐		○	◐	⊕	◐
PETAURIDAE										
Pseudocheirus occidentalis	◐	◐		1	◐				⊕	◐
PHALANGERIDAE										
Trichosurus vulpecula	1	○	–						○	
POTOROIDAE										
Bettongia penicillata				–					–	
TARSIPEDIDAE										
Tarsipes rostratus	+	○		–		○	○	+	⊕	○
RODENTIA										
MURIDAE										
Hydromys chrysogaster	⊕	1	–	⊖	○			+	+	⊖
Mus musculus	⊕	○		+	1	1		◐	+	⊖
Pseudomys albocinereus										○
Rattus fuscipes	–	○	○	◐	○	◐	◐	◐	+	◐
Rattus rattus	⊕	⊕	1	+	○	1	◐	◐	⊖	⊕
CHIROPTERA										
VESPERTILIONIDAE										
Chalinolobus gouldii	1	○		○	○					
Chalinolobus morio			○	◐	○		○	○		1
Eptesicus regulus	⊕	○	–	1	1	○	○	◐	◐	
Falsistrellus mackenziei				1		◐	1			

Family/Species	Subregions									
	1	2	3	4	5	6	7	8	9	10
Nyctophilus geoffroyi				◐	○				1	
Nyctophilus gouldii				1						
Nyctophilus major	+	1	–	○	1		○		1	
ARTIODACTYLA										
CERVIDAE										
Capreolus capreolus				1						
SUIDAE										
Sus scrofa				1						
CARNIVORA										
CANIDAE										
Canis familiaris			1	1			1	–		
Vulpes vulpes					1			1		
FELIDAE										
Felis catus	1									
LAGOMORPHA										
LEPORIDAE										
Oryctolagus cuniculus									1	○
CETACEA										
BALAENIDAE										
Eubalaena glacialis								○		
BALAENOPTERIDAE										
Balaenoptera acutorostrata							1			
Balaenoptera borealis	–									
DELPHINIDAE										
Delphinus delphis	–								◐	
Grampus griseus	1									
Orcinus orca									○	
Pseudorca crassidens			○	○						1
Stenella coeruleoalba					○	–				
Tursiops truncatus		+		+				1		
PHYSETERIDAE										
Physeter catodon		–		–	–				+	
ZIPHIIDAE										
Mesoplodon bowdoini				1						
Mesoplodon grayi	○				1				1	
PINNIPEDIA										
OTARIIDAE										
Neophoca cinerea								○	–	
PHOCIDAE										
Hydrurga leptonyx									1	

Appendix II List of herpetofauna species represented in the collection of the Western Australian Museum from ten subregions in the near-coastal region of the lower Southwest. Crosses represent collections prior to the present study and circles those made during the present study.

Family/Species	Subregions									
	1	2	3	4	5	6	7	8	9	10
ANURA										
LEPTODACTYLIDAE										
Crinia georgiana		×	×	×	⊗	⊗	⊗	×	×	×
Geocrinia leai			×	×	⊗	⊗	⊗	×		×
Geocrinia rosea						×	×			
Heleioporus eyrei	⊗	⊗	⊗	⊗	⊗	⊗	×	⊗	×	⊗
Heleioporus inornatus		⊗						×		
Heleioporus psammophilus	×	×			○	⊗	×			
Limnodynastes dorsalis	×	×	⊗	○	○			⊗	×	⊗
Pseudophryne guentheri	⊗	⊗			○	×		×	×	⊗
Pseudophryne nicholsi		⊗		×	×		⊗		×	
Ranidella glauerti						×	⊗		×	×
Ranidella insignifera	⊗									
Ranidella subinsignifera						⊗		×		×
HYLIDAE										
Litoria adelaidensis		○	×	×	⊗	⊗	×	⊗	×	⊗
Litoria moorei		○	×	⊗	⊗	⊗	×	⊗	×	⊗
TESTUDINES										
CHELONIIDAE										
Caretta caretta gigas	×		×	×	×	×	×			
CHELUIDAE										
Chelodina oblonga	×				×		×		×	×
LACERTILIA										
GEKKONIDAE										
Phyllodactylus marmoratus marmoratus	⊗	×	⊗	×	⊗	⊗	○	⊗	×	×
Phyllurus milii									×	
Diplodactylus granariensis										×
PYGOPODIDAE										
Aprasia pulchella	×	×	○		×					
Aprasia repens	×	×							×	
Aprasia striolata									×	×
Delma australis										×
Lialis burtonis		×	×					×		
Pygopus lepidopodus	×	×	×	⊗			×	×	×	×
AGAMIDAE										
Pogona minor minor	○	○	⊗	×				×	×	
SCINCIDAE										
Cryptoblepharus plagiocephalus	⊗	×					×			
Ctenotus catenifer				×	○	⊗		⊗	×	⊗
Ctenotus impar	⊗	⊗	○							

Family/Species	Subregions									
	1	2	3	4	5	6	7	8	9	10
Ctenotus labillardieri		⊗	⊗	⊗	⊗	⊗	⊗	⊗	×	×
Egernia kingii	×		×	×	×	×	×	⊗	×	⊗
Egernia luctuosa					○			×	×	×
Egernia multiscutata bos										×
Egernia napoleonis	×	⊗	○	×	⊗	⊗	⊗	×	×	⊗
Egernia pulchra pulchra			×			×	×	×	×	×
Hemiergis peronii	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	×	×
Hemiergis quadrilineata	⊗									
Leiolopisma trilineatum	○	○	⊗	⊗	○	⊗		⊗	×	⊗
Lerista distinguenda	×	⊗	×						×	
Lerista elegans	○	○	○	○	○					
Lerista lineata	×									
Lerista microtis microtis					⊗	×	×	⊗	×	⊗
Menetia greyii	⊗	⊗						×	×	
Morethia lineoocellata	○	⊗	⊗	⊗	⊗					
Morethia obscura										×
Sphenomorphus australis				×	○		×	×	×	×
Tiliqua occipitalis								×		×
Tiliqua rugosa rugosa	○	⊗	⊗	○	⊗		×	○	×	⊗
VARANIDAE										
Varanus rosenbergi	○	⊗	×	⊗	○			⊗	×	×
SERPENTES										
TYPHLOPIDAE										
Ramphotyphlops australis	⊗	×		×	⊗	⊗		○		
BOIDAE										
Morelia spilota imbricata		×	×	×						×
HOMALOPSIDAE										
Fordonia leucobalia	×									
ELAPIDAE										
Notechis coronatus	×	×		⊗	⊗	⊗	⊗	×	×	×
Notechis curtus	×	×	⊗	×	×		⊗	×	×	×
Notechis minor	×			×		×	⊗	×	×	×
Notechis scutatus occidentalis	×	⊗	×	×	⊗	⊗	×	⊗	×	×
Pseudonaja affinis affinis	⊗	⊗	⊗	⊗	⊗	⊗	×	×	×	×
Rhinoplocephalus bicolor		×	×	×			×		×	×
Rhinoplocephalus gouldii		⊗								
Rhinoplocephalus nigriceps	⊗	×	×		×					
Vermicella semifasciata							×			
HYDROPHIIDAE										
Hydrophis elegans	×	×								
Hydrophis ocellatus	×									
Pelamis platura	×	×	×					×	×	×

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