FAUNA *of* AUSTRALIA

26. PHALANGERIDAE

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DEFINITION AND GENERAL DESCRIPTION

The Phalangeridae contains 15 species in three [now four (ed.)] genera (Honacki, Kinman & Koeppl 1982). Two of the genera are endemic in Australia and the third extends from northern Australia through New Guinea to the eastern half of the Indonesian archipelago.

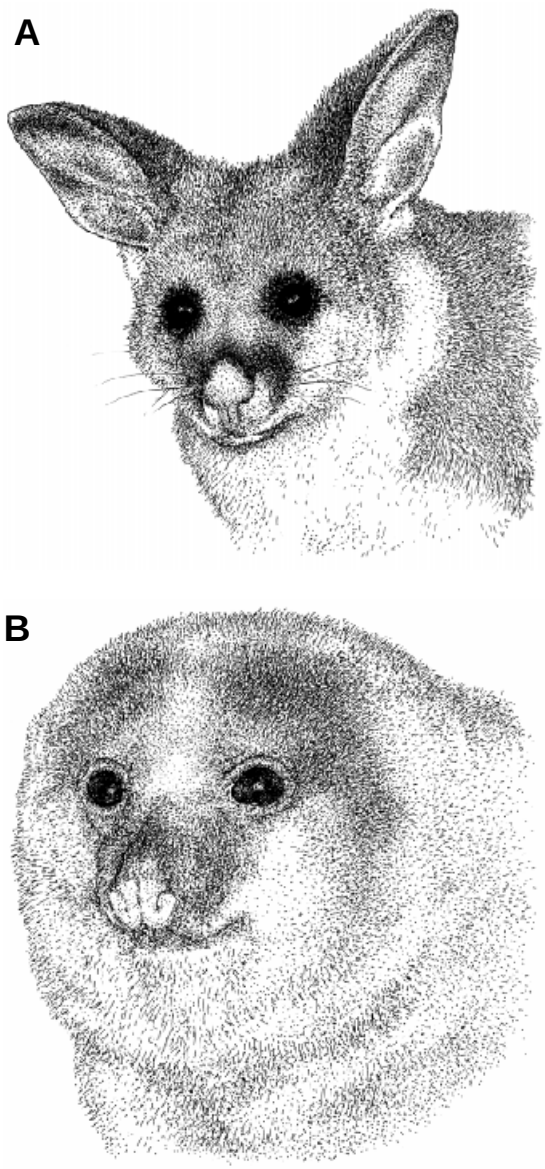

Figure 26.1 Head of **A**, Common Brushtail Possum and **B**, Spotted Cuscus showing the prominent membraneous ears of the former and the small ears of the latter. (© ABRS) [K. Hollis]

Phalangerids are medium-sized mammals varying in size from 350–450 mm in head and body length and 1100–4500 g in weight. Some species are slender in appearance but most are bulky. The pelage is soft and has a dense underfur. The rhinarium and inner surfaces of the ears are naked. The face has a relatively short snout and the eyes protrude. The ears may be prominent and membranous or small and furred (Fig. 26.1). The strongly prehensile tail has a ventral friction pad and varies between genera in the amount of fur present (Fig. 26.2). The soles of the feet are granulated. The hind foot has a clawless opposable hallux and the forefoot of some species has limited opposability of the first two digits. The second and third digits of the hind foot are reduced in size, syndactylous and enclosed for most of their length in a common sheath of skin. The pouch opens anteriorly and contains either two or four teats, but is never divided by a median septum as in some Petauridae. The digestive tract of Brushtail Possums has an enlarged caecum and proximal colon.

The skull is broad and massive with a relatively short rostrum and strong zygomatic arch (Fig. 26.3). The palate has large posterior vacuities. The dentition is diprotodont with herbivorous adaptations (Fig. 26.4). The three pairs of upper incisors, the first of which is normally longer than the other two, are opposed by a dominant procumbent first lower incisor. A minute tooth (which may be a second lower incisor) lies immediately behind the first. The upper canines are normally prominent. Both upper and lower premolars vary in number from two to three. The first upper premolar is normally caniniform but distinctly smaller than the

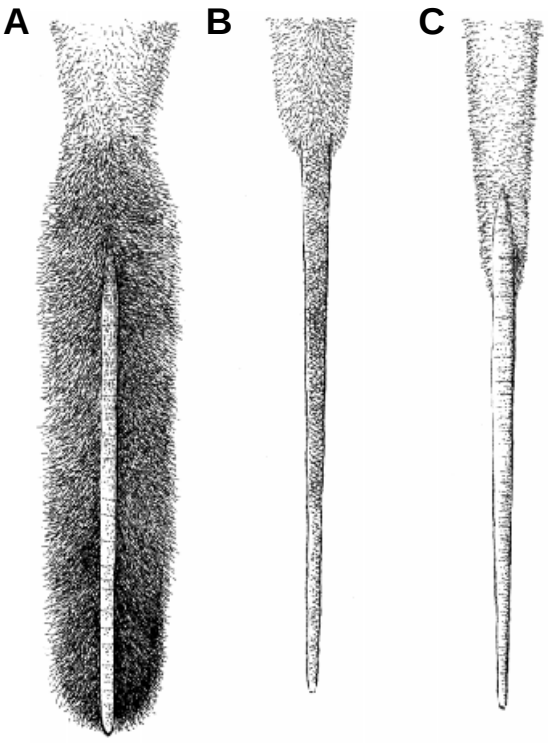

Figure 26.2 Tail of **A**, Brushtail Possum; **B**, Scaly-tailed Possum; and **C**, Cuscus showing in ventral view the variation in the amount of fur and the extent of the naked tip. (© ABRS) [F. Knight]

canine. The second upper premolar, if present, is a reduced, single cusped tooth. The third upper premolar is high crowned and may be either massive and conical or blade-like and set at an angle to the molar row. The first and second lower premolars may be present as tiny vestigial teeth, but the third lower premolar is similar to the corresponding tooth in the upper jaw. The molars are sublophodont (Archer 1984b) with ridges partially connecting the cusps.

Diagnostic characters are: size medium, tail with prominent ventral friction pad and naked at least at tip, skull robust with short rostrum and prominent posterior palatal vacuities, second upper premolar vestigial or absent, molars sublophodont.

HISTORY OF DISCOVERY

A phalangerid has the distinction of being the first Australasian marsupial to be discovered by Europeans. In the mid 16th Century the Portuguese governor of the Moluccas described an animal from that region called ‘kuskus’, a name still in use today for members of the genus *Phalanger*, which according to Calaby (1984) could only have been the Grey Cuscus, *P. orientalis* [now *intercastellanus* (ed.)]. This early discovery went unheralded for over two centuries until the species was again discovered by science and described by Pallas (1766) as *Didelphis orientalis*. The generic name *Phalanger* was first used by Storr (1780). This species also occurs on Cape York, but was not discovered there until 1932 (Tate 1952b).

Cook and Banks apparently did not discover any phalangerids during their brief stay in eastern Australia although the ‘opossum’ found at Endeavour River possibly may have been a Common Brushtail Possum, *Trichosurus vulpecula* (see Chapter 27). This species was first described by the earliest reporters from the First Fleet (Phillip 1789; White 1790) and named *Didelphis vulpecula* by Kerr (1792). Lesson (1828) proposed the generic name *Trichosurus*. The second species in this genus, the Mountain Brushtail Possum, *T. caninus*, was not discovered until about 40 years later and was first described by Ogilby (1836).

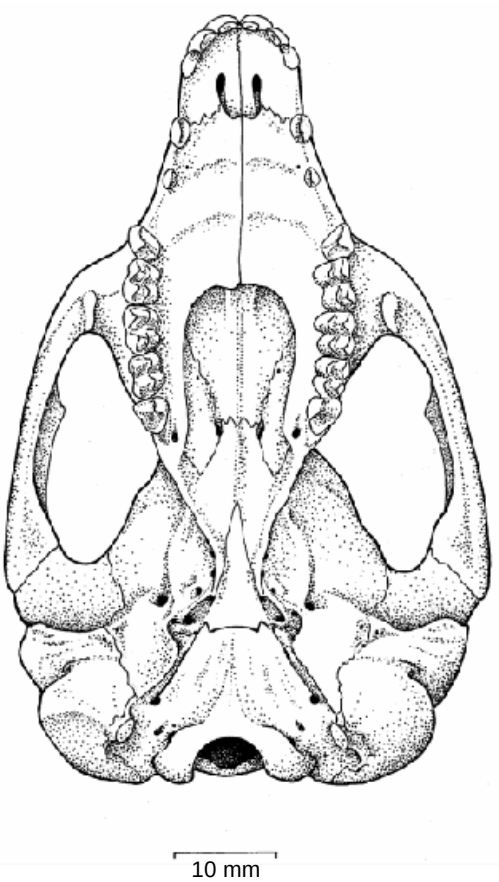

Figure 26.3 Ventral view of the skull of a Brushtail Possum showing robust zygomatic arch, short pointed rostrum and large posterior palatal vacuity. (© ABRS) [S. Weidland]

The first specimen of *Phalanger* from Australia was discovered in 1838 by MacGillivray and named *Phalangista (Pseudocheirus) nudicaudata* by Gould (1850). It was first included as a subspecies of *Phalanger maculatus* by Gray (1866) as *Cuscus maculatus ochropus*. The monotypic genus *Wyulda* (comprising the Scaly-tailed Possum, *W. squamicaudata*) remained undiscovered until a living female was sent to the Perth Zoo from Violet Valley Station in the south-eastern Kimberley region of Western Australia in 1917 (Alexander 1919). The second specimen, a male, was obtained from Kunmunya Mission on the north-western coast in 1942 and another female with a pouch young was collected at Wotjulum Mission in 1954. Further specimens have been collected or observed at several other localities in more recent years (Burbidge 1983; Humphreys *et al*. 1984).

MORPHOLOGY AND PHYSIOLOGY

External Characteristics

Diagnostic external characters have been described above. The Common Brushtail Possum exhibits a wide range of coat colours as illustrated by the seven colour classes recognised by the New Zealand fur industry (Wodzicki 1950). In Australia, it is related to wet (dark phase) and dry (grey phase) forests in Tasmania (Guiler & Banks 1958) or to subspecific variation with red races in northern Queensland rainforest (Tate 1952b). Colour sexual dimorphism is evident in the Spotted Cuscus, *Phalanger* [now *Spilocuscus*; (ed.)] *maculatus*, in which there are spotted males and plainer grey females. The Common Brushtail Possum exhibits a distinct cline in general body size and thickness of coat from large (3.75 kg: Fitzgerald 1984) well-furred animals in Tasmania to animals half that size (1.5 kg: How 1983; Kerle 1983) and sparsely furred, in northern Australia.

Figure 26.4 Upper dentition of a Brushtail Possum showing lack of second upper premolar and sublophodont molars. Note the blade-like third premolar. (© ABRS) [S. Weidland]

Body Wall and Skeletal System

The fur is dense and soft and, unlike the fur of petaurids, adheres to the skin after death, making the pelt suitable for tanning. This property led to the early exploitation of the Brushtail Possum for the fur trade.

The musculature of the Common Brushtail Possum was described in detail by Barbour (1963). The musculature and skeleton do not show any marked specialisations, but rather are typical of a generalised arboreal or scansorial mammal. The only distinct specialisation is the ability of some species to partially oppose the first two digits of the manus to the other three, a character convergent on the phascolarctids and some petaurids.

Locomotion

All phalangerids are careful, deliberate climbers and use the strongly prehensile tail as a ‘fifth hand’ while travelling along or feeding on small branches. They descend trees head first. As with many other larger, arboreal marsupials, the fore- and hind limbs grasp the substrate alternately when ascending a vertical trunk, but a crossed extension gait is used when moving on smaller branches. The walk, half-bound and bound are the three main gaits used by the Common Brushtail Possum on the ground (Goldfinch & Molnar 1978). Gait transition as described by Molnar & Goldfinch (1981) changes from a walk at low speed to a half bound at speeds greater than about 1.4 m/sec. Cuscus species are slow, deliberate climbers and on the ground bound at the speed of a fast human walk (Winter 1983a, 1983b).

Feeding and Digestive System

Food manipulation was described for Brushtail Possums (Winter 1975). The hands are used to draw a leaf or fruit bearing twig to the mouth, but are not used to pick items of food off a twig (Fig. 26.5) or the ground and then convey it to the mouth, as in primates. Rudimentary prey-catching behaviour was described for this genus (Winter 1975; Morgan 1981).

Figure 26.5 Food manipulation in the Mountain Brushtail Possum. (Drawn from photo by R. How in Strahan 1983, p. 150) (© ABRS) [K. Hollis]

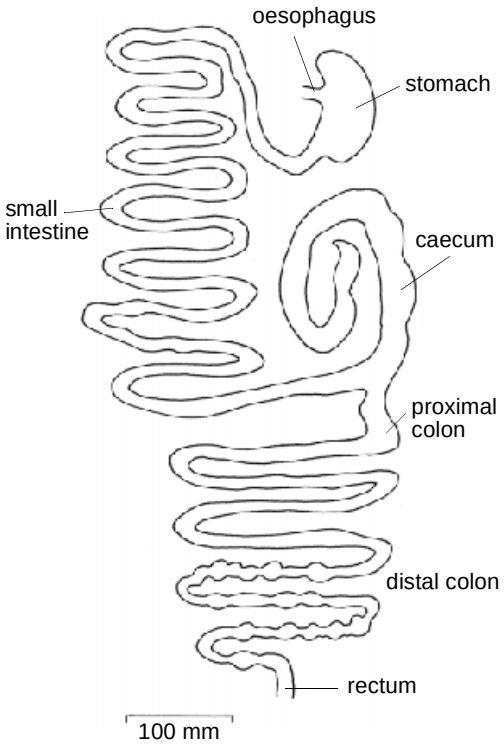

Figure 26.6 Digestive tract of the Common Brushtail Possum. (After Hume 1982; © ABRS) [K. Hollis]

The dentition of phalangerids is described above. The digestive tract of the Common Brushtail Possum (Fig. 26.6) consists of a simple stomach, but with a well-developed caecum and proximal colon acting as fermentation chambers (Hume 1982). The rate of passage of food through the gut is dependent on fibre content with mean retention times of 64 hours for fluid and 71 hours for fibrous material (Hume 1982). The broad spectrum diet of the Common Brushtail Possum and its ability to utilise high fibre diets, combined with a low metabolic rate, a low maintenance requirement for nitrogen and a low water turnover rate, help to explain the wide distribution of this possum in Australia and its successful introduction into New Zealand (Hume 1982). No information is available on the alimentary tract anatomy and digestive physiology of the other genera. They can be expected to differ from Brushtail Possums according to their dietary ecology.

Circulatory, Respiratory and Excretory Systems

As with many other aspects of the biology of this family, there is limited information, mostly derived from studies of the Common Brushtail Possum. Barbour (1977) summarised the available studies from an anatomical viewpoint and concluded that there are few unusual features apart from the relatively bird-like anatomy of the heart and the presence of alkaline phosphatase in the granules of the basophil leukocytes in Brushtail Possums.

The only part of the respiratory system to have received any attention is the larynx of the Common Brushtail Possum (Fig. 26.7). It has a unique dilated thryroid cartilage, forming a rigid walled spherical chamber about the size of a pea (Negus 1949; Winter 1975). It opens through the floor of the larynx via a 1.5 mm circular aperture and possibly acts as a resonating chamber which is consistent with this species being amongst the most vocal of marsupials.

Thermoregulation is maintained by panting and water loss through the skin (Dawson 1969; Bell, Baudinette & Nicol 1983). At high air temperatures the Spotted Cuscus, relies mainly on panting for evaporative cooling (Dawson & Degabriele 1973).

Sense Organs and Nervous System

In his review of the anatomy of marsupials, Barbour (1977) concluded that there are few observed differences between the Brushtail Possum and other marsupials and, apart from the presence of the fasciculus aberrans in all diprotodonts and the lack of the corpus callosum in all marsupials, there is little difference between marsupials and eutherians. More recent work by Gates &

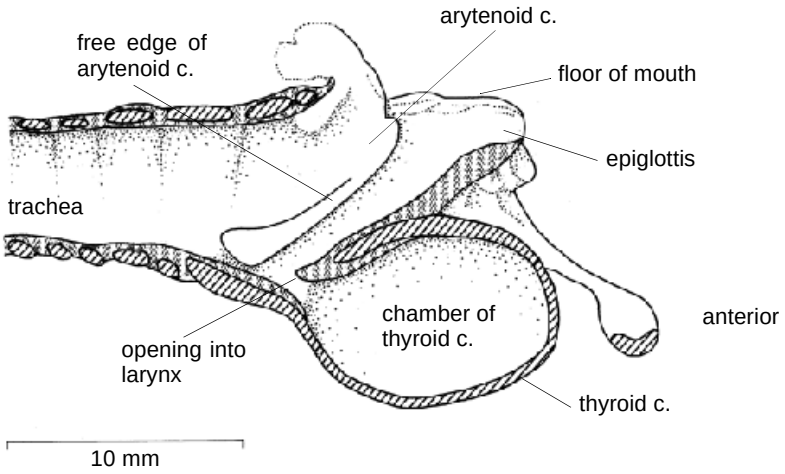

Figure 26.7 Larynx of the Common Brushtail Possum showing 'vocal box'. (After Winter 1975; © ABRS) [B. Scott]

Aitken (1984) has demonstrated a marked difference between Brushtail Possums and other mammals in the spatial organisation of the auditory cortex and this species also may have unique specialisations of the visual cortex.

As with other arboreal marsupials, the tactile organs are important to phalangerids. Lyne (1959) described the vibrissae or tactile hairs of the Common Brushtail Possum. He found that this species, together with other highly active arboreal forms such as *Tarsipes* and *Marmosa*, has the greatest development of vibrissae in all of the major tracts on the head and limbs.

Endocrine and Exocrine Systems

The adrenocortical functions in the Common Brushtail Possum were reviewed by McDonald (1977). In the marsupials examined, the Brushtail Possum provides the most striking variation from the 'classic' eutherian pattern in adrenocortical structure. The cortex of the female has a special inner zone of unknown function which becomes particularly conspicuous during pregnancy and lactation. The Brushtail Possum, along with the Macropodidae, shows a distinct sexual dimorphism in the size of the adrenals. The adrenal/body weight ratio of females is approximately double that of males, but again no functional explanation is proposed. The major corticosteroid detected in Brushtail Possums and most other marsupials is cortisol.

Peripheral blood and plasma concentrations of cortisol are in the lower part of the range for Eutheria and are affected by stress and corticotrophin stimulation in much the same way as in the Eutheria. The secretion of adrenocorticotrophic hormone is apparently subject to regulation by the peripheral blood plasma corticosteroid concentration. The data on the metabolic actions of corticosteroids in marsupials are meagre, but in Brushtail Possums the actions of glucocorticoids closely resemble the generally accepted actions in the eutherians. The functions of the adrenal cortex are considered to be intimately related to the metabolic adjustments and other mechanisms of adaptation to environmental stress.

The structure of the thymus and thyroid of the Common Brushtail Possum was described (Kathiresan 1969; Yadav 1973), as were that of the parathyroids and thymo-thyroid bodies (Adams 1955). There has been no suggestion that these glands have any characteristics peculiar to the Phalangeridae.

The role of the pituitary in the synchrony of reproductive cycles has been studied in some detail in the macropodid *Macropus eugenii*, the Tammar Wallaby (Hearn 1975a). Little work has been done on the Phalangeridae, though seasonal changes in the gonadotrophins in the pituitary of the male Common Brushtail Possum were described by Gilmore, Sirett & Purves (1968). Observations on the secretions of the pineal gland of that species have been made by Tulsi (1979) and the islets of Langerhans were described by White & Harrop (1975).

The exocrine glands of the Common Brushtail Possum have received considerable attention. Eccrine sweat glands occur on the naked prehensile region of the tail and on the pads of the feet and apocrine and sebaceous glands occur in the hairy skin (Green 1963a). There are two mammary glands, one on each side of the mid-line, level with the groin, each with a single teat with six to 10 minute orifices arranged around the apex through which the milk exudes. The milk is high in solids, protein, calcium, phosphorus and cholesterol, but low in lactose in comparison to cow and human milk and shows an increase in protein content as the young matures (Gross & Bolliger 1959). A brown patch on the chest is a sternal gland, larger in males (Bolliger & Hardy 1944; Green 1963a), which enlarges and becomes more oily in the breeding season (Bolliger 1944; Gilmore 1969). The morphology of the gland is similar to that of the surrounding skin except that the sebaceous and apocrine glands are larger and more active, producing an oily secretion (Bolliger & Hardy 1944; Gilmore 1969). That it is a secondary sexual character was demonstrated by castration and treatment with testosterone (Bolliger 1944). No prominent sternal gland has been described for Scaly-tailed Possums or Cuscus, but the former is described as having a slight yellowish tinge under the throat and inside the forelimbs (Calaby 1957; Fry 1971) which may be indicative of glandular activity.

Common Brushtail Possum

The Common Brushtail Possum has two sets of paracloacal glands. The scent glands secrete a viscous pungent creamy coloured liquid, often in copious quantities when the animal is alarmed, whilst the cells glands continuously secrete cells into the urine (Bolliger & Whitten 1948; Green 1963b; Kean 1967). The Cuscus has three pairs of paracloacal glands, though nothing is known about their secretions (Biggins 1984). Although there is no information on the Scaly-tailed Possum, the presence of paracloacal glands is probable.

Reproduction

Available data on cytogenetics in the Phalangeridae are reviewed by McKay (1984); apart from Brushtail Possums little is known. Both species of this genus have a diploid karyotype of 20 acrocentric or telocentric chromosomes. The DNA value of 102 (relative to the Western Grey Kangaroo, *Macropus fuliginosus* = 100) given by Hayman & Martin (1974) is indicative of the relatively small amounts of constitutive heterochromatin present in the chromosomes (Rofe 1979). Vandeberg *et al*. (1979) suggested that data on the expression of the sex-linked enzyme PGK-A are consistent with inactivation of the paternally derived X chromosome in females, a condition so far only proven in macropodines. The Scaly-tailed Possum has not yet been studied and only two extralimital species of Cuscus have as yet been examined, both of which have a secondarily derived diploid karyotype of 14 chromosomes (Hayman & Martin 1974).

Reproductive structures and patterns of male Common Brushtail Possums were reviewed by Temple-Smith (1984a). The reproductive tract is of a very generalised mammalian pattern. The testes and epididymides are located in a prepenial scrotum. The vasa deferentia lead to the prostatic portion of the urethra at the base of the bladder. A single carrot-shaped prostate gland and a pair of Cowper's glands are associated with the urethra. The testicular arteries and veins are associated in a rete mirabile where multiple branches of each vessel lie adjacent to each other. Although the function of this rete is not completely understood, it may serve to lower the temperature of the testes or to reduce the pulse in the testicular circulation without lowering overall blood pressure. Spermatogenesis follows the typical mammalian pattern. Reproductive activity in the male may be distinctly seasonal and such seasonality may be reflected in changes in the size of the prostate gland although not necessarily the size of the testes (Gilmore 1969; McFarlane, Carrick & Brown 1986).

The structure of the testicular interstitial tissue and testosterone-secreting Leydig cells between the seminiferous tubules of marsupials shows the same basic structure and the same variability between species as in eutherian mammals except that in some marsupials, including the Common Brushtail Possum, the Leydig cells are less abundant (Green 1963b; Setchell 1977). The number of Leydig cells in Brushtail Possums is greater in individuals with enlarged prostate glands (Gilmore 1969). A diurnal variation in plasma concentrations of testosterone and corticosteroids has also been detected (Allen & Bradshaw 1980). Testosterone is secreted by the testis into the blood at a rate comparable with that for eutherian species (Carrick & Cox 1973; Setchell 1977).

The structure of the female reproductive tract is typical of marsupials with paired lateral vaginae and a temporary birth canal which is formed anew at each parturition. One of the most complete descriptions of a marsupial oestrous cycle is available for the Common Brushtail Possum and the reproductive pattern is reviewed by Tyndale-Biscoe (1984b). Ovulation normally occurs between days 1 and 2 of the oestrous cycle and a corpus luteum forms from the wall of the Graafian follicle after it has ruptured to release the egg. The corpus luteum then goes through a cycle of endocrine secretion, first with a progesterone precursor to day 8 then with the hormone relaxin. After day 12, the corpus luteum declines to insignificance by day 18 of the oestrous cycle. If the animal is unmated, a new crop of follicles begins to enlarge. Experimental removal of the corpus luteum has led to the conclusion that this structure inhibits follicular development during the first half of the oestrous cycle and initiates, but does not maintain, the luteal phase of the uteri. The corpus luteum, possibly through the action of relaxin, controls the loosening of connective tissue surrounding the uterus and the birth canal and possibly the enlargement of the pouch.

In the Common Brushtail Possum, the non-pregnant oestrous cycle is 26 days and if fertilisation occurs, parturition is on day 16 to day 18. Removal of pouch young causes a return to oestrus after 8–9 days. Normally only a single egg is ovulated, but Hughes & Hall (1984) found two examples of twin ovulation in a sample of 64. Lactation commences once the neonate attaches to a teat. The onset of lactation is independent of the preceding pregnancy as non-pregnant females can successfully rear fostered pouch young (Sharman 1962). For the first 80 days of lactation the active mammary gland remains small but then increases 12-fold in size over the next 70 days. Milk composition changes during lactation (Gross & Bolliger 1959) but details of the changes have as yet not been studied.

Reproduction in the Mountain Brushtail Possum, *Trichosurus caninus* is similar to that in the Common Brushtail Possum (Smith & How 1973), but little is known of the reproductive patterns in any of the other species.

Embryology and Development

Hughes & Hall (1984) presented the first detailed account of the early embryonic development in the Common Brushtail Possum. As the fertilised egg passes down the fallopian tube it becomes covered progressively with a mucoid coat. By this stage, cleavage has already commenced. On or before entry into the uterus the mucoid coat is surrounded by shell platelets and a disulphide-rich protein which fuse to form a shell membrane. By day 3, the continuing cell divisions have produced a blastocyst consisting of a single layer of protoderm. For the next 3 days the blastocyst expands, followed by the separation of endoderm from the protoderm at the future animal pole. By about day 10, mesoderm begins to form and the primitive streak has developed. By day 12, organogenesis has begun and a 13–day embryo shows a well-developed head with mouth and tongue, clawed forelimbs, heart, lungs and digestive tract (Fig. 26.8). Development of the anterior half of the body is most rapid and by birth the lungs, olfactory system and gut are particularly well developed, but the hind limbs and tail and some posterior internal organs are still undergoing organogenesis. The functional kidney in the neonate is the mesonephros; the metanephros not developing until later.

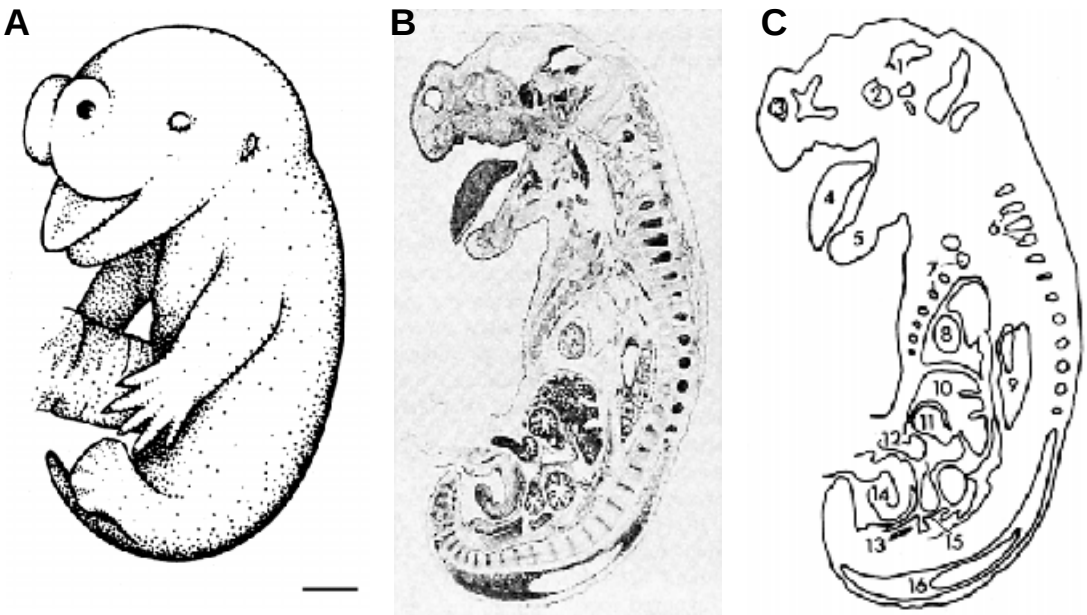

Figure 26.8 External view **A**, and longitudinal section **B**, of a thirteen day embryo of the Common Brushtail Possum. Organs shown in the longitudinal section are numbered in **B**: 1 = myelencephalon; 2 = trigeminal ganglion; 3 = nasal chamber; 4 = tongue; 5 = Meckel's cartilage; 6 = spinal ganglion; 7 = rib; 8 = heart; 9 = lung; 10 = liver; 11 = duodenum; 12 = herniated midgut; 13 = rectum; 14 = phallus; 15 = gonadal ridge; 16 = spinal chord. Bar line = 1 mm. (From Hughes & Hall 1984)

Postnatal growth and development were described by Lyne & Verhagen (1957). For the first 80 days of pouch life the young is naked, permanently attached to the teat and growing slowly. From this point, the growth rate increases and by day 150 to 170 the young begins to leave the pouch. The pattern of growth and pouch life in the Mountain Brushtail Possum and in the Scaly-tailed Possum appears similar, but in these two species the duration of pouch life is slightly longer.

NATURAL HISTORY

Life History

The life history is best known for the Common Brushtail Possum and almost all the demographic data are based on studies in New Zealand where large removal samples are possible because the animal is regarded as a pest. Factors determining the population characteristics of the possum are the number of young weaned per female, age of maturity and mean life expectancy.

There are two teats in the pouch and usually one young is reared at a time. Twins are rare (Kean 1971). In Australia, most births occur during autumn with a median date from April to early May. Sometimes a birth season with reduced productivity occurs in spring (September-November), with a mean contribution of 18% of the yearly births (Green 1984). The variation, however, is considerable with breeding throughout the year in northern Australia and Adelaide, to a restricted autumnal season in Tasmania (Kerle 1984c). Two factors suggested as influencing the incidence of spring births are latitude, with smaller northern females producing more young than larger southern females, and heavier females in better condition producing more young and more likely to be both autumn and spring breeders (Green 1984). Kerle (1984c) was unable to find a significant correlation between the breeding seasonality index and the plant growth index.

Survival of pouch young is put at 87% and 85% for Australian and New Zealand populations, respectively (Green 1984). Young remain in the pouch for 170–190 days, are weaned between 200–250 days (Lee & Cockburn 1985) and vacate the maternal den at 7–16 months (Winter 1975). Females are capable of breeding in their first year, but it is not until the third year class that close to 100% are breeding (Green 1984). Most males are not mature until the second breeding season after birth (Smith, Brown & Frith 1969).

The oldest known age for Common Brushtail Possums under natural conditions (Crawley 1970) is 12 years, but using cementum layers in molar teeth as an ageing technique (Clout 1982), maximum ages of 14 years have been recorded (Brockie, Bell & White 1981; Coleman & Green 1984). Brockie *et al.* (1981) estimated that in New Zealand, of 1000 animals that leave the pouch, 47 could be expected to survive until their 13th year, that newly-dependent young had a mean life expectancy of 6.2 years and that 3–4 year-olds may live for another 5 years. The only comparable information from Australia is for three animals known to be alive 5 years after first capture as adults (MacLean 1967) and animals estimated to be 8 years old based on tooth wear (Winter 1980).

Sex ratio of pouch young in Australia significantly favours males, but for adults it is usually 1:1 (Hope 1972). New Zealand populations have deviated significantly from this ratio, differentially favouring males and females in separate populations or in different age classes (Brockie *et al*. 1981; Coleman & Green 1984). Such imbalances, however, particularly those favouring males, may represent methodological biases owing to the greater activity of males or to colonising effects of new areas (Coleman & Green 1984; Green 1984).

The Mountain Brushtail Possum produces only one young per year, weaning is slightly later (8–9 months), dispersal of the young is at 18–36 months and female maturity takes place at 24–36 months. How (1978) related this variation to a different life history strategy with a tendency towards the *K* end of the *r-K* continuum in the more predictable rainforest and wet sclerophyll forest it inhabits, though Lee & Cockburn (1985) considered that the ‘bet-hedging’ model is more appropriate to explain the differences between the two species.

The Scaly-tailed Possum has two teats and raises one young at a time which vacates the pouch from 151–210 days of age. Females and males probably do not mature until their second year. Pouch mortality appears to be low (Humphreys *et al*. 1984). Nothing is known about the life expectancy of adults. The pouch in the Cuscus has four teats with up to three pouch young recorded, but it was assumed that usually only one is raised (Winter 1983a, 1983b).

Ecology

The diet of Brushtail Possums consists primarily of the leaves of trees and shrubs, but grasses may provide a substantial proportion (Owen & Thomson 1965; Freeland & Winter 1975; Fitzgerald 1984; Green 1984; Seebeck, Warneke & Baxter 1984). The proportion of *Eucalyptus* leaves in the diet varies enormously, from 0–95%, and reflects the availability of other plant species as well as the presence of eucalypt species (Kerle 1984c). In northern Australia, fruit and flowers form a much higher proportion of the diet than in southern Australia, sometimes as high as 80% in any one month (Kerle 1985). A range of eucalypts may need to be eaten each night to counteract leaf toxicity (Freeland & Winter 1975), but in at least one locality one species of *Eucalyptus* comprised 95% of the diet (Kerle 1984c). High levels of toxins are not necessarily deterrents because the leaves of two favoured food plants, *Solanum mauritianum* and *Erythrophleum chlorostachys*, contain highly toxic alkaloids (Kerle 1985; Van Dyck 1979b). There are reports of Brushtail Possums capturing insects (Winter 1975; Murray 1977), a bird (Morgan 1981) and of eating carrion (Gilmore 1967).

Feeding on the blossom of a eucalypt is the only feeding record for the Scaly-tailed Possum in the wild (Calaby 1957). A captive female prised seeds from cones of *Causuarina humilis* and cached nuts, the only possum species recorded to do so (Fry 1971). This behaviour, together with the large sectorial third premolar, suggests that nuts may be an important element in the diet. The Cuscus has been recorded eating fruit, flowers and leaves and the stomach of one specimen was filled with a paste apparently derived from the seeds of the Black Bean tree, *Castanospermum australe* (Winter 1983b). The relatively large canines suggest a carnivorous diet and in captivity they readily eat meat (Dawson & Degabriele 1973; Winter 1983a, 1983b).

The Brushtail Possum occurs in most areas with trees large enough to contain day time dens, ranging from rainforest to eucalypt woodland (Dunnet 1964; Tyndale-Biscoe & Calaby 1975; McIlroy 1978; Kerle 1985). The age at which eucalypt trees, the main hollow-forming trees, develop suitable hollows is variously put at 50–200 years (Disney & Stokes 1976; Saunders, Smith & Rowley 1982; Mackowski 1984) and at least 200 years in some eucalypts (Mackowski 1984). A positive association between foliage nutrients and the density of arboreal mammals, including Brushtail Possums, has been demonstrated in south-eastern Australia (Braithwaite 1984; Braithwaite, Turner & Kelly 1984). On Kangaroo Island, the Common Brushtail Possum lives in shrubland and dens in ground burrows of other animals (Jones 1924).

The Scaly-tailed Possum occurs in vine thickets and eucalypt woodland associated with massive boulders and rock piles. It shelters in rock crevices during the day, emerging to feed in the trees at night (Humphreys *et al*. 1984). The Grey Cuscus, *Phalanger orientalis*, is restricted to rainforests and the *Acacia* fringes of the rainforest; while the Spotted Cuscus, *Spilocuscus maculatus*, occurs mainly in rainforest, it has also been recorded in adjacent habitats (Winter 1983a, 1983b, 1984a). The latter species does not use a den but sleeps on open branches (Winter 1983a).

Known predators of Brushtail Possum are varanids (Troughton 1962), owls (Seebeck 1976; Estbergs & Braithwaite 1985), the Tasmanian Devil, *Sarcophilus* (Guiler 1970a), dogs, *Canis* (Newsome *et al*. 1983a), the fox, *Vulpes* (McIntosh 1963a; Brunner, Lloyd & Coman 1975), the cat, *Felis* (Coman & Brunner 1972) and pythons. There are no records for the other genera but a similar range of predators is to be expected.

In a review of the parasites and diseases of *Trichosurus*, Presidente (1984) listed as ectoparasites 19 species of mite and 10 each of ticks and fleas, but no lice. The common condition of rumpwear is thought to be an allergic reaction to mites or fleas. A strong resistance to the establishment of the paralysis tick, *Ixodes holocyclus*, has been demonstrated for the Common Brushtail Possum.

Endoparasites include six protozoan, three cestode, one trematode and 26 nematode species (Presidente 1984). However, the number of endoparasites commonly encountered in free-ranging Common Brushtail Possums is small and includes only one protozoan, one cestode and five or six nematode species. Viral, Rickettsial, mycotic and bacterial infections have been recorded in free-ranging Common Brushtail Possums, but only leptospirosis and tuberculosis are of major concern as infective agents to humans and livestock. In New Zealand, possums are an important reservoir of bovine tuberculosis. Speare *et al*. (1984) listed three arthropods, four nematodes and two cestodes for Cuscus species in Australia. Also described are a cestode and two trematodes from the Scaly-tailed Possum (Humphreys *et al*. 1984).

Home range size in the Common Brushtail Possum in Australia averages 5.4 ha for males and 2.4 ha for females, with equivalent range lengths of 394 m and 261 m (Green 1984). The smallest estimates of 1.1 ha and 0.9 ha for males and females, respectively, in eucalypt woodland in the Northern Territory (Kerle 1984c) may reflect the smaller size of the northern possums, but the smaller average home range size in New Zealand (males 1.9 ha, females 1.3 ha) may reflect a higher edible biomass per hectare in the forests (Green 1984). Most home range estimates are based on trapping, which may significantly underestimate their size as revealed by radio tracking (Ward 1984). There is considerable overlap of home ranges of individuals of the same sex, with territorial defence apparently restricted to den trees (Green 1984). Older, well-established adults may have exclusive home ranges with respect to other individuals of the same sex and status, a situation which is maintained by mutual avoidance between co-dominants of each sex and with tolerance of subordinates (Winter 1975; Green 1984). The larger home ranges of males tend to overlap more than one female home range (Dunnet 1964; Winter 1975). Young male Common Brushtail Possums disperse from their maternal area, whereas young females usually stay close to their maternal area. Young males also occur in higher proportions than females in recently colonised areas (Clout & Efford 1984).

The only data on dispersion for the Scaly-tailed Possum are mean maximum range lengths of 272 m for males and 221 m for females (Humphreys *et al*. 1984). Nothing is known for Cuscus.

Population densities of 0.23–4.0/ha have been recorded in Australia for Brushtail Possums (How 1981; Kerle 1984c) and as high as 10.7/ha in New Zealand (Coleman, Gillman & Green 1980). Changes in population density and home range size vary according to body size, the concentration of resources, notably den sites and food availability and the distance required to travel between den and feeding sites. The Scaly-tailed Possum has been recorded at 1 ha (Humphreys *et al*. 1984), and population densities of the Spotted Cuscus, *Phalanger maculatus*, were described as low with only one or two seen per hour of spotlighting (Winter 1983a).

The Common Brushtail Possum is solitary, with home ranges centred on the individual use of den hollows which rarely are shared with other adults, although a tree with more than one den may house a male and female (Russell 1984). Home ranges of dominant adults of both sexes tend to be exclusive with respect to co-dominants but may completely overlap those of younger subordinate individuals of the same sex. Dispersion is apparently maintained by mutual avoidance, established and occasionally reinforced by contact encounters and maintained by olfactory and auditory communication. During the autumnal mating season males establish a consort relationship with females, constantly following the females for 30–40 days before oestrus but ceasing once mating has occurred. Occasionally the female is accompanied by a secondary consort male, a younger individual subordinate to the primary consort male. A female lacking a consort male is mated by several males who converge on her on the one to two nights of oestrus and without any one male attempting to restrict access by the other males (Winter 1975). The mating system has been classified as a successive territorial polygyny (Lee & Cockburn 1985).

In contrast, the Mountain Brushtail Possum is monomorphic in size and apparently monogamous (territorial monogamy, Lee & Cockburn 1985) with core areas of male and female home ranges coinciding, males and females foraging together (caught together in the same trap) and with little overlap between adults of the same sex. Females mature later and fewer young are raised, but they remain dependent for longer (How 1981). In the Grey Cuscus, as in the Common Brushtail Possum, the male is larger than the female, but in the Spotted Cuscus the female is the larger. In the Scaly-tailed Possum there is no significant sexual dimorphism.

Behaviour

Individual behaviour has been described for the Common Brushtail Possum. Grooming includes face washing with the wrists, licking, biting and scratching with the syndactylous claws (Fig. 26.9). Quadrapedal and bipedal alert postures are adopted, sometimes followed by an alarm dash onto the base of a tree (Winter 1975). The Scaly-tailed Possum uses the syndactylous claws for scratching and both front paws simultaneously when grooming (Fry 1971).

Most interactions between individuals of Common Brushtail Possums are those in which one individual gives way to another without any individual body contact although nose to nose sniffing or threat behaviour involving vocalisations or an upright bipedal stance with forelimbs outstretched horizontally and mouth open may occur. Fights involving body contact and chases are far less frequent. Interactions between males and females are comparatively mild. Avoidance, brief chases and low intensity scuffle fights mostly occur during courtship when the male continually approaches the female and she repulses him. Interactions between males, though fewer in number, include a higher proportion of high intensity fights and longer chases, indicative of males establishing dominance over each other and of territorial type encounters. Interactions between females tend to be similar to the male encounters and most occur in den trees (Winter 1975). In captivity, males are the more aggressive, establishing a definite dominance hierarchy amongst themselves (Biggins & Overstreet 1978).

Cuscus react aggressively by giving harsh screeches and lashing out with the forelimbs, which may be held low in front of the body, in marked contrast to the arms apart posture of the Brushtail Possum. Males of the Spotted Cuscus are aggressive and cannot be housed together in captivity (Winter 1983a). Nothing is published on the Scaly-tailed Possum.

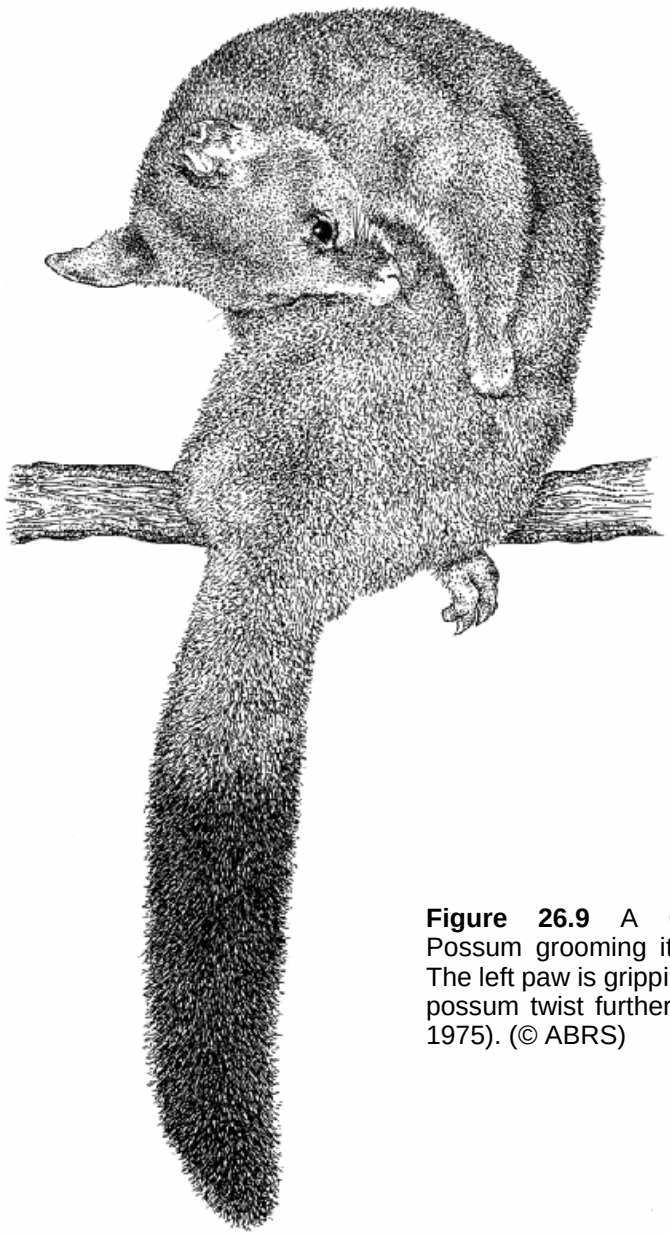

Figure 26.9 A Common Brushtail Possum grooming its fur with its teeth. The left paw is gripping the fur to help the possum twist further to the side (Winter 1975). (© ABRS) [K. Hollis]

Courtship in the Common Brushtail Possum includes a consort period of about 30 days during which the male continually approaches to within 1m of the female, then withdraws, giving soft shook calls similar to the lost call of a juvenile (Fig. 26.10). This eventually reduces the aggression of the female who allows mating to occur without fighting. Once mated, the male terminates the consort period. Without the benefit of a courtship period, several males may mate with the female in succession, despite the aggressive behaviour she directs at them (Winter 1975). The only information for the other genera is that oestrus in the Spotted Cuscus is accompanied by loud braying by the female (George 1982).

Parental behaviour in the Common Brushtail Possum is exclusively female and mostly passive. Adopting a reclining birth position (Lyne, Pilton & Sharman 1959), washing the pouch young, pausing to allow the juvenile to catch up when following and responding to the juvenile's distress call are the most obvious signs of parental behaviour. There are several transition stages as the female weans the young and prevents it from accompanying her (Winter 1975). Parental

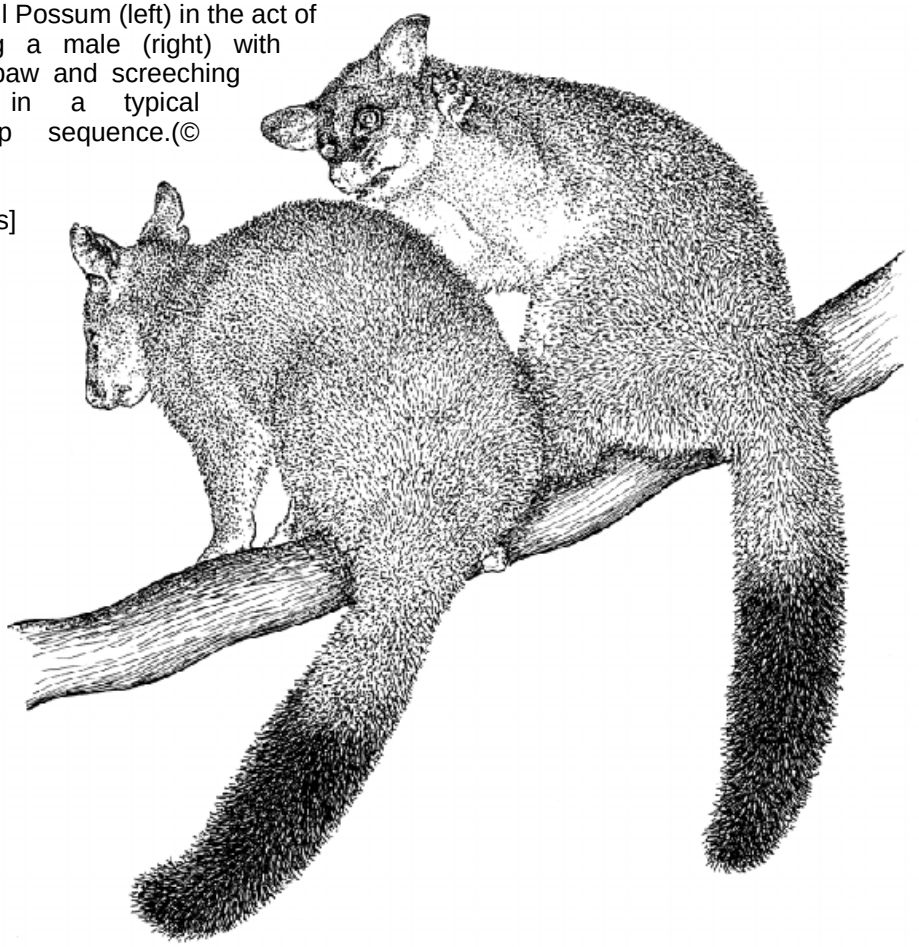

Figure 26.10 A female Common Brushtail Possum (left) in the act of rejecting a male (right) with raised paw and screeching threat in a typical courtship sequence.(© ABRS)

[K. Hollis]

behaviour possibly is more developed in the Mountain Brushtail Possum because the young remain dependent for considerably longer and males travel with females (How 1981).

Socialisation of the young Common Brushtail Possums begins in the pouch with distress calls. Once out of the pouch, the juvenile has the primary responsibility to maintain contact with its mother, but gradually it becomes more independent. Play is restricted to developing climbing skills and its main contact with other individuals is with the resident male (Winter 1975).

Several studies on the complex auditory and olfactory communication systems of the Common Brushtail Possum were reviewed by Biggins (1984). Eighteen vocalisations and a buccal click have been distinguished, spanning the four types of syllable described for marsupials except for the chatter which seems to be a uniquely phrased call amongst the marsupials. Another unique feature is the laryngeal cartilaginous chamber, possibly acting as a resonator (see above under respiratory system). Olfactory communication includes scent deposition by chin, sternum and cloacal rubbing and urine dribbling, distributing ‘identifier odours’ throughout an individual's home range. Two ‘emotive odours’ are the white sticky secretion from the scent glands released in response to fear and vaginal mucus passively smeared on branches by oestrous females. Visual communication is assumed usually to be minimal in a nocturnal species, but this discounts their visual acuity. Communication techniques may include acrobatics, tail wiggling, the display of pale body colours on the belly and face and the general position of the body (Biggins 1984; Kean 1967; Russell 1984; Wemmer & Collins 1978).

The sounds recorded from other genera are a chittering by juvenile Scaly-tailed Possums when distressed (Fry 1971) and harsh screeches and a click by the Grey Cuscus (Winter 1983b). In the related New Guinean Grey Cuscus, *Phalanger gymnotis*, hissing, coughing, snorting, squeaking and hooting have been described, with the squawks having an unusual hint of harmonics (Wemmer & Collins 1978). Spotted Cuscus oestrous females give a call described as a bray (Wemmer & Collins 1978; George 1982). The Grey Cuscus also deposits scent by dribbling urine and depositing scent gland secretion by means of a cloacal drag (Wemmer & Collins 1978).

All possums are nocturnal, though species of Cuscus also may be active during the day (Winter 1983a). The nightly activity of the Common Brushtail Possum includes periods of feeding, both on the ground and in trees, and of resting, slightly affected by the moon, with females returning to dens earlier than males (Kawata 1971; Winter 1975; MacLennan 1984).

Economic Significance

Traditional use of Brushtail Possum by Aborigines included hunting the animal for food and the use of its pelt to make rugs and smaller items of clothing such as girdles, loin cloths, necklaces and head bands (Smyth 1876; Berndt & Berndt 1977; Dixon & Huxley 1985). The Scaly-tailed Possum was eaten and its fur used to make string (Butler 1966). Cuscus species were hunted for food (Winter 1983a, 1983b). Although the fur or pelts do not appear to have been used in Australia, they are used for dress and ornament in New Guinea (Bulmer & Menzies 1972).

Commercial exploitation in Australia currently is limited to Tasmania, where the Common Brushtail Possum can be shot under permit for its pelts during an open season. Since 1979, between 118 300 and 405 578 have been taken annually without any apparent population decline; the estimated annual value of skins ranged from $ 291 747 and $ 1 623 000 (Tasmanian National Parks and Wildlife Service 1985). In New Zealand, the fur industry is larger, with a value in 1980 and 1981 of NZ$ 20 million per year (Dellow, Harris & Passman 1985). There is increasing interest in farming Brushtail Possum species in New Zealand (Presidente 1984).

Diseases carried in free-ranging populations of Brushtail Possum, and considered to be either actual or potential health problems to livestock and humans in Australia and New Zealand, are leptospirosis and tuberculosis. Tuberculosis is apparently rare in Australian possum populations, but bovine tuberculosis in New Zealand possum populations is a considerable livestock health problem (Presidente 1984).

Economic damage is caused by Brushtail Possum species to *Pinus* in commercial plantations (Barnett, How & Humphreys 1977), to regeneration of *Eucalyptus regnans* in Tasmania following clearfelling and burning (Cremer 1969; Statham 1984) and to suburban house ceilings and gardens (Troughton 1962). Control measures include poisoning with ‘1080’, trapping and relocation. In New Zealand, Brushtail Possums are causing localised damage to crops (Spurr & Jolly 1981) and more extensive and serious damage to the broad-leaf/podocarp native forests (Meads 1976; Green 1984), though the magnitude of tree deaths attributed to possum browsing may have been overrated (Veblen & Stewart 1982). Intensive control measures, particularly in bovine tuberculosis areas, are by aerial and ground baiting with ‘1080’ poison; kills of 67% have been recorded (Coleman 1981). Commercial hunting may significantly depress population numbers in New Zealand (Brockie 1982; Clout & Barlow 1982).

The Scaly-tailed Possum and Cuscus currently have little or no economic significance.

All phalangerids are protected species throughout Australia. In Tasmania, the Common Brushtail Possum can be taken under licence during a 6–10 week open season, the effect of which is monitored (Johnson 1977b; Tasmanian National Parks and Wildlife Service 1985) and in other States, destructive animals can be taken under permit. Generally, conservation is based on preserving or maintaining a tree cover with trees suitable for dens, (Tyndale-Biscoe & Calaby 1975; McIlroy 1978; Winter 1985) with research directed at establishing carrying capacity of arboreal mammals in forests and the importance of tree hollows (for example, Braithwaite 1984; Mackowski 1984; Menkhorst 1984). The conservation status of all genera is considered to be good. The reason for this regarding the Scaly-tailed Possum and Cuscus species is because they occur in remote, relatively undisturbed areas and for Brushtail Possum because the species occur over a geographically wide area (Winter 1979), although discrete populations (such as that in south-western Western Australia) may be less secure.

The Common Brushtail Possum is one of the most thoroughly researched species of marsupial. It has been used widely as an experimental animal because it is easy to catch and keep in captivity (Bolliger 1940). It is a common and widely distributed species and it has become a pest in New Zealand where it was introduced. This is reflected in the number of papers published on the anatomy, physiology, ecology and behaviour of the species: 808 listed by Morgan & Sinclair (1983) to the end of 1982. In marked contrast is the dearth of information on other species, particularly the other two genera in the family, an imbalance deplored by Lyne (1969) and Tyndale-Biscoe (1984b).

BIOGEOGRAPHY AND PHYLOGENY

Distribution

Brushtail Possums and the Scaly-tailed Possum are endemic in Australia. The former is widely distributed over most of Australia including Tasmania and many off-shore islands. The latter is restricted to the rocky regions of north-western Australia. In Australia, Cuscus are restricted to Cape York Peninsula, but it also occurs in the New Guinean and Indonesian regions extending throughout New Guinea, to the Admiralty Islands, the St Matthias group and Waigeo Island in the north, to the southern Moluccas in the south-west and to the Solomon Islands in the east (Laurie & Hill 1954).

The Common Brushtail Possum was introduced to New Zealand as early as 1837. The main period of importation was between 1890 and 1898 (Pracy 1962).

Affinities with other Groups

The Phalangeridae appears to be a monophyletic group characterised by reduction of the second upper premolar and the possession of sublophodont molars (Archer 1984b). Bensley (1903) suggested that the phalangerids might have been descended from the Burramyidae, but Archer (1984b) maintained that while the evidence does not support this hypothesis, the two groups might be derived from a common ancestor. Baverstock (1984) presented data from analysis of albumin evolution which indicate that the phalangerids and the *Burramys* / *Cercartetus* lineage are closely related.

Affinities within the Phalangeridae

The two species of Brushtail Possums are very closely related as evidenced by morphology and albumin studies (Archer 1984b; Baverstock 1984), but their relationships to the Scaly-tailed Possum and Cuscus have long been an enigma (Alexander 1919; Finlayson 1942). Both these authors considered that the Scaly-tailed Possum shows characters intermediate between Brushtail Possums and Cuscus, but could not derive a satisfactory phylogeny because of the range of diversity within the latter genus. The molecular data appear to have clarified the issue in suggesting that the Brushtail Possum and Scaly-tailed Possums are sister groups which have a close relationship to one grouping of Cuscus, but that this cluster is more divergent from the rest of Cuscus (Baverstock 1984). Several authors are currently examining the relationships and composition of the genus *Phalanger* and there appears to be common consent that it is not a monophyletic genus. As there is not yet any agreement on the way it should be divided, we retain the older terminology for the purposes of this review.

Fossil Record

The brief fossil history of this group was reviewed by Archer (1984b). Several Cuscus-like fossils have been found in deposits ranging from Late Oligocene to Pliocene in Australia, the later deposits including forms referrable to *Phalanger* species. There also are several Pleistocene specimens, all of which are referrable to living species. The relatively widespread occurrence of fossil phalangerids in Australia lends support to a continental origin of these groups, with the Cape York populations of apparently Papuan animals representing isolated remnants of previously widespread species.

COLLECTION AND PRESERVATION

Collection

Spotlighting at night is the standard method for searching for all three genera, though Grey Cuscus also can be found during the day, when the Aborigines of Cape York Peninsula collect the animals (Winter 1983a). The Brushtail Possum is captured readily in cage traps set on the ground, the usual bait being apple (Dunnet 1964; Crawley 1973; How 1981; Presidente 1982). In Tasmania, fur trappers used a snare set on an inclined pole at the base of a tree, but this method is no longer legal (National Parks and Wildlife Service Tasmania 1973, 1985). Fur trappers in New Zealand use gin traps set in possum runways and other likely places on the ground, sometimes baited with dry flour scented with oil of aniseed (Pracy & Kean 1969). Captured animals have been restrained by merely placing them in a hessian bag, strapping them to various devices or by anaesthesia with ether, ethyl chloride, succinylcholine chloride, ketamine with acepromazine and halothane with oxygen (Taylor & Magnussen 1965; Hope 1971; Presidente 1982; Fitzgerald 1984). The Scaly-tailed Possum has been trapped successfully in cage traps set on the ground and baited with apple and a mixture of rolled oats, peanut paste and bacon (Humphreys *et al*. 1984). There is no information on whether Grey Cuscus will enter traps, but they can be shaken out trees although some species have a tenacious grip (Winter 1983a, 1983b).

Maintenance in Captivity

Phalangerids have been kept in cages from 0.33 m^3 (Presidente 1982) to 131 m^3 (Kean 1967) in size. In larger cages it is recommended that ample branches be provided for climbing (Bolliger 1940; Kean 1967; Hope 1971; George 1982), but even in the largest of cages behaviour of solitary species

can be distorted when two or more animals are housed together (Kean 1967). Maintenance diets have consisted of leaves, fruit, vegetables, grains and nuts and dog cubes (Bolliger 1940; Kean 1967; Smith & How 1973; Fairfax 1982; Presidente 1982). Leaves appear necessary for long term well-being of captive animals (Hope 1971). Scaly-tailed Possums have been kept in captivity for up to 6 years (Fairfax 1982), the Common Brushtail Possum for 10 years (Kean 1975) and Grey Cuscus to 11 years (George 1982), but the Grey Cuscus appears to have been the only phalangerid to have bred in captivity beyond the first captive bred generation. Haemorrhagic enteritis (George 1982) and lung mites (Fairfax 1982) have caused health problems.

CLASSIFICATION

Two genera are endemic in Australia: *Trichosurus* with two species, *T. vulpecula* and *T. caninus* and *Wyulda* with a single species, *W. squamicaudata*. *Trichosurus arnhemensis*, first considered as a distinct species by Ride (1970), is here considered a subspecies of *T. vulpecula* following Kerle (1984c).

The remaining genus, *Phalanger*, is currently under revision and eventually may be split into two or more genera (see above). As presently considered, it has two Australian species whose ranges include Cape York Peninsula: *P. maculatus* and *P. orientalis*.

DESCRIPTIONS

Trichosurus: Ears large to medium, membranous and prominent; tail well furred except at extreme tip and on ventral friction pad; colour variable, but always with terminal half of tail black.

Wyulda: Ears membranous and prominent; tail with proximal fifth furred, rest naked with coarse scales; pale grey above with dark mid-dorsal stripe, creamy white below, tail fur tinged with rufous.

Phalanger: Ears small and furred; tail with distal half naked; colour variable.

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