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## Results of the Archbold Expeditions. No. 88 The Historical Misapplication of the Name *Mus fuscipes* and a Systematic Re-Evaluation of *Rattus lacus* (Rodentia, Muridae)

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*MUS FUSCIPES* WATERHOUSE, 1839

The first formal description of any native Australian murid now included in the genus *Rattus* was made by Waterhouse when he described *Mus fuscipes* in 1839. The animal was taken at King George's Sound, Western Australia, in March, 1836, during the famous voyage of H.M.S. "Beagle," and it is possible that Charles Darwin himself was the collector, since Waterhouse quoted a habitat note made by Darwin. This single specimen on which the description was based was presented to the Museum of the Zoological Society of London by Darwin and listed as the brown-footed mouse, *Mus fuscipes*, in Waterhouse's (1838) catalogue of mammals preserved in that museum.

In 1852 the Council of the Zoological Society decided to reduce its collections and to donate or sell all important specimens to the British Museum (Sclater, 1901). The Council expressed in its Report for 1855 the decision "that the first step to be taken was to transfer to the Trustees of the British Museum the whole of the types of species described in the

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Society's publications, in order that they may be there preserved during the longest possible period for the purpose of reference and identification . . . Having thus provided for the safety of these historic types, the Council entered into a negotiation with the Trustees of the British Museum for the transfer of such other portions of the collection by sale as were desirable for the purpose of filling up desiderata in the National Museum" (Mitchell, 1929, pp. 102-103).

Sometime after its description, the type specimen of *Rattus fuscipes* was lost, and there is no evidence that it ever reached the British Museum. It was not among the collections as early as 1843, for Gray (1843) did not list it in his compilation of that date. Thomas (1906a) made no mention of *R. fuscipes* in his listing of types in the collection, nor did he refer to it along with other type material in his resumé of the important contributions of Darwin and Waterhouse. Furthermore, in 1965, Mr. J. E. Hill (personal communication) wrote: ". . . the holotype specimen of *Mus fuscipes* Waterhouse does not appear to be preserved in the collections of this Museum [British Museum (Natural History)] and I can find no evidence to suggest that it was ever in the collections. A number of specimens described by this author [Waterhouse] came here with the collection of the Zoological Society of London during the middle years of the last century, but this particular specimen does not appear to have been among them." One of us (Horner) also examined the Australian specimens of *Rattus* in the British Museum and was unable to find the specimen. We have studied the collections of Australian *Rattus* in the Queensland Museum; Australian Museum; National Museum of Victoria; South Australian Museum; Western Australian Museum; Macleay Museum (University of Sydney); Queen Victoria Museum, Launceston; Tasmanian Museum, Hobart; the American Museum of Natural History; United States National Museum of the Smithsonian Institution; Museum of Comparative Zoology; Museum of Vertebrate Zoology; Field Museum of Natural History; Museum of Michigan State University; Museum of Natural History of the University of Kansas; Zoologisk Museum, Oslo; and Rijksmuseum van Natuurlijke Histoire, Leiden. We have been in correspondence with the authorities of the Muséum National d'Histoire Naturelle in Paris, Zoologisches Museum in Berlin, and Museo Civico di Storia Naturale in Genoa. The type of *fuscipes* could not be found in any of these institutions.

A unique feature of the holotype of *fuscipes* which would facilitate its recognition and which we bore in mind during our search was its possession of black lower incisors (Waterhouse, 1839). Although we have collected individuals of *fuscipes* ourselves and have examined virtually

all the specimens in public museum collections, we have not observed this dental coloration in any specimen. We have seen it, however, in one old specimen of *Rattus lutreolus* (A.M.N.H. No. 668); the incisors were lead-black, and the black could not be rubbed off. Presumably, the dark color of the incisors of the type of *fuscipes* was of a similar nature. We suspect that the color was an artifact caused possibly by some preservative or reagent used in preparation. The incisors of all species of Australian *Rattus* are normally orange to ivory in color.

A complication involving the missing holotype arises from Jentink's statement in his catalogues of mammal specimens in the Leiden Museum (Jentink 1887, 1888) that a topotypical mounted specimen ("a.") of *Mus fuscipes* and its skull is "un des types de l'espèce." The specimen is still in the collections of the Rijksmuseum van Natuurlijke Histoire in Leiden. Only the rostrum of the skull remains, and the mandible is missing, as it was in Jentink's day. The collector, the date of collection, the mode of acquisition, and the date of receipt of the specimen are unknown. Dr. A. M. Husson (personal communication) has brought to our attention an undated note in the museum's archives stating, among other things, that one specimen of *Mus fuscipes* was sent to Temminck by Gould. There is some evidence suggesting that the note was written in 1840 or 1841. However, it cannot now be proved that the specimen mentioned in the note was in fact an example of *fuscipes*. Some, and probably all, material received from Gould at the British Museum around this date and listed by Gray (1843) as *fuscipes* is misidentified *lutreolus* (see below). One of us (Horner) has examined Jentink's specimen "a." and confirmed its identity as *fuscipes*. That only a single specimen was available to Waterhouse for his original description is evident from his own words and from Darwin's field note (Waterhouse, 1839), hence there can be no question of syntypes. Although there is no evidence for it, the possibility exists that Jentink's specimen may be the holotype. However, it is virtually useless as a type, because only a small fragment of the skull remains, and skull characters are of prime importance in the systematics of the genus *Rattus*.

Loss of the type specimen would have been of little consequence if the species had been well understood, but, as the following account shows, the name has been extensively misapplied over the past century. Gray made no mention of *fuscipes* in his list of Australian mammals compiled in 1841, but in that same work he introduced a new species, *Mus lutreola*, from various localities in eastern and southern Australia. Two years later, in 1843, he placed *lutreolus*, which is the second Australian murid to be described of the murids presently included in *Rattus*,

in subjective synonymy with *fuscipes*, and one can assume that he never saw the type of *fuscipes*, for the two species are quite distinct. The long subsequent history of confusion no doubt stemmed from this action of Gray's. It influenced Gould who followed this synonymy and whose great monograph on the Australian mammals (1845–1863) was the standard reference for many years.

The six specimens that Gray refers to *fuscipes* are all from Gould's collection. Because Gray did not list them by catalogue numbers, it is impossible to identify them with certainty with specimens housed in the British Museum today. Four of them, however, must surely be the same as four specimens of *lutreolus* that bear identical data and are also from the Gould collection. They are listed by Gray's symbols and by their British Museum numbers as follows: "b. = B.M. 41.1257, c. = B.M. 41.1255, d. = B.M. 41.1258, e. = B.M. 41.1254." Of the missing two, specimen "f." from Van Diemen's Land (Tasmania) is almost certainly *lutreolus*, for *fuscipes* (even in its broadest interpretation [Ellerman, 1949; Horner and Taylor, 1965]) has never been recorded in Tasmania,<sup>1</sup> and only Gray's specimen "a." with no other locality than "Australia," remains unaccounted for.

Gould [1851 (1845–1863, vol. 3), pl. 11 and text] gave a reasonably full description which is accompanied by a colored plate of the rat he called *Mus fuscipes*. Actually both the description and the plate are of *lutreolus*. In the collections of the Australian Museum is a specimen identified as *fuscipes* and marked "Gould's type" (Australian Museum No. 23), which may be the one from which he made his description and sketch. There are no data with the specimen, and until mid-1965 the skull was in the skin. At our request it was removed, and it was found to consist of the anterior portion only, plus the mandible. It is clearly *lutreolus*. Gould, in both his written and artistic portrayals, featured the aquatic habits of the rat, habits that are characteristic for *lutreolus* but, as is now known, are not diagnostic for *fuscipes* (Horner and Taylor, 1965). It should be stated here that Gould described his material from external features alone. There is some similarity between *fuscipes* from Western Australia and *lutreolus* in the generally dusky coloration, and from old dried or alcoholic material it is sometimes difficult to distinguish them. The confusion was further magnified in that Gould [1858

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<sup>1</sup> Thomas (1882) once referred to two specimens of *fuscipes* from Tasmania, but later (1921) corrected his error. Guiler's (1958) suggestion that a member of "the *assimilis* group" probably occurs in Tasmania has not been substantiated, and we consider its occurrence there very unlikely.

(1845–1863, vol. 3), pl. 15 and text; and 1858] incorporated the characters of true *fuscipes* into his description of *Mus assimilis* and hence, in effect, subordinated the importance of Waterhouse's original description of *fuscipes* by submerging it partially under the later-described species *assimilis*.

Until Thomas (1906b) corrected the confusion, all authors followed Gray and Gould and misapplied the name *fuscipes* to specimens of *lutreolus*. No Western Australian material was included under *fuscipes* by Gerrard (1862), Thomas (1882), and Waite (1900), and both eastern and Western Australia were included in the range of *fuscipes* by Kreffit (1864, 1871), Ogilby (1892), and Trouessart (1897). Also following Gould, true *fuscipes* of Western Australia was included in *assimilis* by Gerrard (1862), Kreffit (1871), and Ogilby (1892). Most of these contributions were merely lists of specimens or obvious compilations from literature, but Waite (1900) gave an extended description of what he believed to be *fuscipes*. In fact, the description is of *lutreolus*, and his illustrations of the skull and a dental row portray very well the diagnostic characters of that species.

The loss of the type specimen had taken its toll, for these workers had no reference specimen, and in this period there was almost no material of *fuscipes* from Western Australia in any of the Australian museums, except for a few alcoholic specimens and life mounts from which skulls had not been removed. Almost all the *fuscipes* material in existence at this time was in the British Museum.

Thomas (1906b), in the light of his examination of fresh material of *fuscipes* from Western Australia, supported the integrity of that species and pointed out Gould's error. He (1906b, 1910, 1921) also supported Gray's original proposal of *lutreolus* as a full species. The traditional reliance on Gould's authority and the lack of reference collections in Australia, however, largely vitiated Thomas' clarification of the situation, and only Lord and Scott (1924) followed his recommendation regarding *lutreolus*. Lucas and LeSouëf's (1909) treatment of *fuscipes* and *assimilis* was copied from Ogilby (1892), and Longman (1916) maintained the customary view of *assimilis* and *fuscipes*, although he synonymized *lutreolus* with *fuscipes* with some reservations.

Troughton (1920), in his extended description of *assimilis* modeled after Waite's paper, made direct comparisons between that species and Waite's *fuscipes* without realizing that Waite's description was of *lutreolus*. That Troughton's concept of *assimilis* included the true *fuscipes* is manifest by his reference to topotypical material of *fuscipes* from the Gould collection. Because of the current trend of describing *fuscipes* by the morpho-

logical characters of *lutreolus*, which, however, does not occur in either the type locality of *fuscipes* or elsewhere in Western Australia, Troughton and others failed to recognize *assimilis* and true *fuscipes* as allies, but considered, rather, that the range of *assimilis* extended from eastern to southwestern Australia.

LeSouef and Burrell (1926) presented yet another interpretation of these three species. Their view of *assimilis* was the same as Troughton's and included true *fuscipes*, and their description of *fuscipes* is actually of *lutreolus*, for it is a slight rewording of Gould's erroneous one. The distinction in this work is that *lutreolus* is acknowledged as a full species, and Waite's error has been recognized, for they identify *Mus fuscipes* Waite with *lutreolus*. In fact their description of *lutreolus* is a rewording of Waite's extended description of "*fuscipes*." After more than 80 years of confusion, this attempt was among the earliest by Australian mammalogists to recognize *lutreolus* as a full species and to associate with it the features originally proposed by Gray in 1841. Although still failing to dissociate the diagnostic features of *lutreolus* from Gould's description of *fuscipes*, LeSouef and Burrell, unlike Gould, believed that *fuscipes* was confined to southwestern Australia, as did Thomas (1921), and hence thought that they were excluding *lutreolus* from it. The incongruities in their treatment of these forms were not apparent to them.

Jones (1925) gave *lutreolus*, *fuscipes*, and *assimilis* full specific rank, but he believed that *fuscipes* and *lutreolus* were closely related. He avoided LeSouef and Burrell's error by taking his description of *fuscipes* from Waterhouse, but by copying the description and geographical range of *assimilis* from Gould he unwittingly incorporated *fuscipes* in that species.

The geographical ranges accorded to the three forms, *assimilis*, *fuscipes*, and *lutreolus*, by Iredale and Troughton (1934) in their check list of Australian mammals are substantially correct. However, subsequent remarks of Troughton (1937, 1965) show that, although he was unwilling to make *fuscipes* and *lutreolus* conspecific as he and others had done previously, probably owing largely to the historical confusion of these two species, he was reluctant to let them stand as independent species. In 1937 he referred to *fuscipes* and *lutreolus* as members of the same group, and in stating that "the haunts of the south-western *fuscipes* given by Gould are similar to those recorded by Waite for the Blue Mountains specimens of eastern *lutreolus*?" he demonstrated that his concept of *fuscipes* was still the confused one of LeSouef and Burrell. The following statement made by Troughton (1965, p. 282) makes it clear that he still considered the two species to be closely related within the genus *Rattus*: "The range of the species [*fuscipes*] was once vastly extended to include the eastern

swamp-rat [*lutreolus*], but owing to the break of range in the drier region along the Bight, and well-marked differences, the species are now regarded as distinct, though of similar habits." Brazenor (1936) expressed doubt as to the full species status of *lutreolus* as distinct from *fuscipes*. Shortridge (1936) recorded both *fuscipes* and *assimilis* in Western Australia and even gave "Southwestern Australia" as the type locality of *assimilis*; however, his paper recorded old field notes, and it is obvious that the nomenclature is applied uncritically.

Tate (1951), in his monograph on the rodents of Australia and New Guinea, made the judgment that *fuscipes* and *lutreolus* were conspecific, and he ignored the rule of priority by designating *fuscipes* as *Rattus lutreolus fuscipes*. Unlike most of his predecessors, Tate placed considerable importance on skull morphology in addition to external characters and he recorded having seen 11 specimens of *fuscipes* of which three were topotypes. The 11 specimens came from Western Australia, and we have since examined all of them and agree that all are true *fuscipes*. Tate was obviously disturbed by some of the characters of *fuscipes* and wrote, "the topotypes strongly resemble *R. assimilis* externally . . ." (p. 345). He was unwilling to recognize *assimilis* and *fuscipes* as conspecific, even though he also recognized certain similarities in their skulls. To a large extent he must have been strongly influenced by the statements of his predecessors, and especially by Troughton's (1948) remark that *fuscipes* was "water-loving," which Tate interpreted as "behavior that confirms the relationship to *lutreolus* suggested by the anatomy" (p. 345). Notwithstanding the obvious influence of earlier workers' assessments on Tate, it is still difficult to understand why he allied *fuscipes* with *lutreolus* when he relied so substantially on skull morphology. One can only assume that, in his final analysis, he referred heavily to the specimens surrounding him in his working quarters at the American Museum of Natural History, and it is among these specimens that a possibly important clue to his error has been found.

Early in 1965 we examined all the Australian *Rattus* material present in both the Archbold Collections and the collection of the Department of Mammalogy of the American Museum of Natural History. All the material was still essentially as it had been when Tate completed his work. We discovered that three of the four skins of *R. lutreolus lutreolus* in the Museum had mismatched skulls, a mistake due to an error of the eye and not of the numbering system. The four *R. l. lutreolus* skins available were A.M.N.H. Nos. 65965, 65966, 65967, and 65968. Only one (A.M.N.H. No. 65966) was matched with a *lutreolus* skull of the same number. The other three skins were matched with *assimilis* skulls

bearing the A.M.N.H. Nos. 65865, 65867, and 65868. These skulls were, however, all labeled *lutreolus*, and had been thus identified since the time Tate last examined the material (Van Deusen, personal communication). The mismatching of these skulls no doubt contributed to Tate's assessment of *fuscipes* as a member of the *lutreolus* group. Skulls of *fuscipes* and *lutreolus* are in fact quite distinct; it is rather that the skulls of *fuscipes* and *assimilis* are very similar, as the two forms are conspecific.

Ellerman (1949) was the first mammalogist to recognize the natural relationships of *assimilis*, *fuscipes*, and *lutreolus*. He established *assimilis* as a subspecies of *fuscipes*, and he considered *lutreolus* a full species. This systematic assessment has since been confirmed with a presentation of new evidence (Horner and Taylor, 1965).

The academic chaos that has accompanied the systematic position and recognition of *fuscipes* since it was originally defined more than 125 years ago has in part resulted from the loss to science of the type specimen. Although there have been two attempts to stabilize the natural position of *fuscipes* in recent years (Ellerman, 1949; Horner and Taylor, 1965), the monographic work by Tate is deservedly esteemed by present-day mammalogists, and his error in the *fuscipes-lutreolus* evaluation is still likely to be perpetuated. In order to facilitate for future investigators the recognition of *fuscipes* in the sense in which it was originally described, we consider it necessary to designate a neotype and thereby identify the name *fuscipes* with a reference specimen.

We hereby nominate as neotype of *Mus fuscipes* Waterhouse, 1839, specimen No. M6634 in the collections of the Western Australian Museum, adult female, collected January 4, 1966, by M. H. and W. G. Henderson, at the locality now designated as Crown Grant No. 24, "Little Grove" on Princess Royal Harbour, approximately 4 miles due south of Mt. Melville, Albany, Western Australia. This locality is approximately 4 miles from where H.M.S. "Beagle" is thought to have anchored in 1836, and is well within the area embraced by the settlement then known as King George's Sound (M. H. Henderson, personal communication). The skin and skull of the specimen are in excellent condition, and the skin shows the distinguishing characters of *fuscipes* plus the mammary formula. The specimen is consistent with Waterhouse's description, except that the color of the lower incisors is pale yellow rather than black. We have stated previously our belief that the black color of the lower incisors of the lost holotype was probably an artifact.

Characters of *fuscipes* that, taken together, distinguish this species from its allies are as follows: the skull is elongate, with uninflated bullae; the



length of each bulla is typically similar to, or shorter than, the crown length of the upper molar row; the palatal foramina are moderately expanded and gently tapering (rather than slitlike posteriorly as in *lutreolus*) and usually extend posterior to the anterior faces of the molar rows; the dorsal surface of the skull is relatively flattened as compared to the convex skull profile of several other Australian *Rattus* (including *lutreolus*); the nasals extend anterior to the anterior face of the upper incisors; supraorbital ridging is either absent or developed minimally (in *lutreolus* it is typically prominent); and the mammary formula is  $2 + 3 = 10$ . The pelage is generally fine, soft, and dense, with coarser hairs interspersed among the predominantly fine ones. The hairs of the back and sides show a gradual increase in length from the shoulders toward the rump, where they vary from approximately 20 to 32 mm. The dorsal and lateral coloration is a warm brownish gray, the hairs being gray at their bases and variously tipped or terminally banded with brown or black. The shorter, less dense ventral hairs, averaging 8 to 10 mm. long, are usually gray, tipped lightly with buff. The ears and feet are clothed with short, grayish, buff, or brownish hairs, and the tail, somewhat shorter than the head and body combined, is sparsely furred with short, coarse, dark brown and blackish hairs.

The specimen designated as neotype has been collected especially for this purpose at the type locality. Details regarding its precise habitat, including photographs and vegetation samples identified to species, are preserved in the Western Australian Museum, as also are 15 additional specimens of *Rattus fuscipes* from the same locality.

#### *RATTUS LACUS* TATE, 1951

Among the *Rattus* material taken by a professional collector, Gabriele Neuhäuser, and subsequently incorporated in the Archbold Collections of the American Museum of Natural History, are five specimens from which Tate (1951) described *R. lacus* as a new species. They were trapped in Queensland at Lake Barrine on the Atherton Tableland in October, 1937. The habitat was described as "bladey grass." To our knowledge, no specimens of this form have been trapped since.

The characters of *lacus*, as determined by its five museum representatives, have been well defined by Tate. He designated a type (A.M.N.H. No. 107312, male) and four paratypes, one with a mismatched skull. In November, 1964, we examined Tate's material, consisting of the type, a young adult paratype with a good skull (A.M.N.H. No. 107311, female), a paratype represented by skin only (A.M.N.H. No. 107313, male), a young adult paratype represented by a skin and broken skull (A.M.N.H.

No. 107314, male), and a paratype represented by a skin and a fragmented skull which does not seem to share the features of the other three specimens and is presumably the mismatched skull to which Tate was referring (A.M.N.H. No. 107315, female).

The concept that Tate had of *fuscipes* and *lutreolus* is not clear, and the presence of mismatched *lutreolus*-skin with *assimilis*-skull material before him at his headquarters may have been in part influential in his evaluation of the material from Lake Barrine, Queensland, and his consequent erection of a new species, *Rattus lacus*. In his judgment *lacus* and *sordidus* were related, although he stated so very tentatively. He suggested that *sordidus* may be the southern representative of *lacus*, but, as he was the first to appreciate, he had very little morphological evidence in support. (Tate acknowledged the existence of just two specimens of *sordidus*, both of which have broken skulls.) It is significant to our own evaluation of *lacus* that Tate linked it in combination with his *lutreolus-youngi-sordidus-gestri* division of *Rattus*, and in describing its external features he said, "The very dark coloring, which reminds one of the species *lutreolus* of southeastern Australia, is unusual for the group" (1951, p. 348).

The pelage of *lacus* is dark dorsally and slightly less dark below; the legs and feet are also dark. The over-all color distribution is the same as in *lutreolus* from more southern parts of the continent, although it is not so dark. No other *Rattus* native to Australia has dark under parts. In all other species the ventral pelage contains a considerable quantity of light gray, cream, or white fur. Pelage color can be a labile character, and this in itself is not sufficient to align any two forms. The two intact skulls of *lacus* very closely resemble the skull of *lutreolus* from the mainland. In both taxa the palatal foramina extend just posterior to the anterior aspect of the first upper molar teeth, and they are long and taper to a slit posteriorly (a character that is very constant in *lutreolus*). The posterior end of the palate is approximately in line with the posterior aspects of the third molars. In both forms the skull is short, arched, and wide. Tate (1951) made the statement that the bullae of the "*Rattus sordidus* and *lacus* group" are much enlarged (p. 342), but he also stated that those of *lacus* are "a little smaller than normal" (p. 347), and "full but small" (p. 348). The examination we made revealed that the bullae are small and in this respect also closely resemble those of *lutreolus*.

The combination of pelage characters, external measurements, and skull characters closely allies *lacus* with *lutreolus*. We have personally examined the Lake Barrine area. The habitat near the shore of the lake provides long grass in a relatively moist environment and is in ecological harmony with the habitat requirement of *lutreolus* from the southern mainland. The

lakes of the Atherton Tableland are, however, one of the few areas north of Gympie, Queensland, that are suitable for a member of the *lutreolus* group today. The present geographical hiatus between the known range of *lacus* and that of the most northerly *lutreolus* representative hitherto recognized, from near Gympie, is almost 800 air miles and is comparable to the gap of 950 air miles between two representatives of the species *fuscipes*, *R. f. fuscipes* and *R. f. greyii* on the south coast of continental Australia (Horner and Taylor, 1965).

In every respect the morphology and habitat affinities of *lacus* and *lutreolus* are so close that in our judgment they are conspecific, though subspecifically distinct. We therefore propose that *lacus* be referred to the species *lutreolus* as *Rattus lutreolus lacus*.<sup>1</sup>

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<sup>1</sup> Troughton, who was with us at the American Museum of Natural History in November, 1964, when we examined the *lacus* material and discussed its affinities, orally agreed with our assessment of this form and has suggested this relationship in the latest edition of his book on the Australian mammals (Troughton, 1965, p. 283). He gave no morphological evidence in support and went on to suggest, obviously extrapolating from Tate's views on the relationship of *lacus* and *sordidus*, that *sordidus* may represent a race of *lutreolus*, and that *R. l. imbil* (Troughton, 1937) may be synonymous with *sordidus*, and, further (p. 284), that *R. conatus* may be a race of *sordidus*, and that *lacus* is "possibly included with this group." In our opinion members of the *sordidus-conatus* group cannot be linked with *lutreolus* subspecifically or even as closely related species.

mals, Zoological Society of London, rendered assistance in our attempt to obtain information about the type of *fuscipes* from the archives of that Society. Dr. A. M. Husson, Curator of Mammals, Rijksmuseum van Natuurlijke Historie, Leiden, offered historical information concerning the *fuscipes* specimens in the Leiden museum and made them available for examination. Dr. Jean Dorst, Director, Muséum National d'Histoire Naturelle, Paris; Dr. Georg H. W. Stein, Director, Zoologisches Museum, Berlin; Professor Enrico Tortonese, Director, Museo Civico di Storia Naturale, Genoa; and Dr. Rolf Vik, Director, Zoologisk Museum, Oslo, kindly supplied information regarding historically old specimens of Australian *Rattus* housed in their respective museums. The neotype of *fuscipes* here designated was collected by M. H. and W. G. Henderson, at the request of Dr. W. D. L. Ride, Director, Western Australian Museum, Perth. This project is being supported by Grant GB-1228 from the National Science Foundation.

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