NESTING STRATEGIES OF THE WATER MOUSE *XEROMYS MYOIDES* IN SOUTHEAST QUEENSLAND

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Studies of *Xeromys myoides* nests on three islands of Moreton Bay and at ten coastal sites on mainland southeast Queensland have revealed a variety of nesting strategies ranging from the construction of large, free-standing, termitarium-like mounds up to 66cm high, to the excavation of inconspicuous tunnels in the supralittoral bank at the marine/terrestrial boundary. Techniques employed to locate nests and useful features for confirming the identification of *X. myoides* nesting structures are provided. Information from a total of 110 nests was compiled. Of these, 21 were free-standing structures within areas of sedgeland, chenopod shrubland, *Sporobolus virginicus* grassland or mangroves. Others were associated with small, slightly elevated 'islands' standing away from the supralittoral bank (20 nests) or with the supralittoral bank itself (20). Thirty-one examples of nests constructed in living or dead trees situated in the intertidal zone (or at its landward edge) were documented. Another eighteen nests were recorded in spoil heaps of human origin. Information about the height of nest structures and the number of holes providing access to nests is supplied. Where mound structures were present, their height was built up over time with repeated plastering of 'mortar' brought from within or below the nest and smeared from one or more entry holes to the mound top in clearly defined tracks. Well-established mounds were rarely inundated entirely. Nest location and, therefore, nest type were interpreted as resultant compromises between the ability to withstand spring tides versus proximity to the most highly productive resources of the mangrove zone. ❑ *Xeromys, False Water-rat, rodents, survey, southeast Queensland.*

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Magnusson et al. (1976) described an extraordinary, 60cm-high mud structure resembling a termite mound, built at ground level against the trunk of a living *Bruguiera parviflora* in a mangrove forest on Melville Island, Northern Territory. From this structure they extracted an adult female *Xeromys myoides* and two young, thereby documenting the first record of a nest for this poorly known species. In 1991, a number of sedge-covered peat mounds attributed to *X. myoides* were found on North Stradbroke Island, southeast Queensland (Van Dyck, 1992; Van Dyck & Durbidge, 1992). None of these occurred in mangroves but rather in immediately adjacent areas of sedgeland or on the more landward supralittoral bank (Van Dyck, 1997). The present investigation of *X. myoides* nesting elsewhere on North Stradbroke Island, as well as on South Stradbroke and Bribie Islands and at ten mainland sites in coastal southeast Queensland, has revealed a variety of nesting strategies for the species. These ranged from the construction of large free-standing termitarium-like mounds to the exploitation of hollow trunks within (or at the landward edge of) the tidal zone and the excavation of inconspicuous tunnels in the supralittoral bank at the marine/terrestrial boundary. The information presented here has been compiled from a total of 110 nests documented by us since 1991. It presents a broad range of nesting strategies hitherto unrecorded for this threatened species.

METHODS

Nesting structures were documented as part of an ongoing survey of *X. myoides* in southeastern Queensland and northeastern New South Wales. Nests were recorded at sites examined between the Great Sandy Strait, Queensland (25°47'S, 152°58'E) and the Richmond River area of New South Wales (28°54'S, 153°31'E), 345km to the south (Table 1, Fig. 1). Nests were generally located by searching in the intertidal zone between the supralittoral bank and the outer (frequently seaward) edge of the mangroves. However, some nests involving simple holes excavated in the supralittoral bank or in spoil heaps were revealed only during the radio-tracking of individuals that

TABLE 1. *Xeromys myoides* nest localities, abundance and nest reference numbers in Queensland, and localities searched (unsuccessfully) in New South Wales (ordered by increasing latitude).

	Locality	Lat. (S)	Long. (E)	Total Nests	Ref. Nos.
Queensland	Kauri Creek Conservation Park	25°47'	152°58'	6	1-6
	Noosa North Shore	26°23'	153°04'	6	7-12
	Maroochy River	26°38'	153°04'	1	13
	Pumicestone Passage	26°59'	153°04'	8	14-21
	Gallagher Point, Bribie I.	27°00'	153°06'	5	22-26
	Bullock Creek Conservation Park	27°00'	153°04'	3	27-29
	Donnybrook	27°01'	153°03'	17	30-46
	White Patch, Bribie I.	27°01'	153°07'	1	47
	Amity, N. Stradbroke I.	27°25'	153°26'	4	48-51
	Rainbow Channel, N. Stradbroke I.	27°27'	153°25'	10	52-61
	Canalpin Creek, N. Stradbroke I.	27°36'	153°24'	1	62
	Stockyard, N. Stradbroke I.	27°43'	153°24'	1	63
	Steiglitz	27°45'	153°20'	4	64-67
	Jacobs Well	27°46'	153°21'	1	68
	Pimpama River	27°48'	153°20'	1	69
	Coomera River	27°50'	153°22'	22	70-91
	South Stradbroke I.	27°51'	153°25'	19	92-110
New South Wales	Cobaki Broadwater (3 sites)	28°11'	153°30'		
	Terranora Creek A (2 sites)	28°11'	153°32'	-	-
	Ukerebagh Island	28°11'	153°33'	-	-
	Terranora Creek B (3 sites)	28°12'	153°31'	-	-
	Ukerebagh Mainland	28°12'	153°33'	-	-
	Fingal	28°12'	153°34'	-	-
	Terranora Broadwater (3 sites)	28°13'	153°30'	-	-
	Banora Point (4 sites)	28°13'	153°33'	-	-
	Chinderah Bay (3 sites)	28°14'	153°33'	-	-
	Cudgen Creek, Kingscliff	28°17'	153°34'	-	-
	Hastings Point (2 sites)	28°22'	153°34'	-	-
	Brunswick River	28°32'	153°32'	-	-
	Marshalls Creek, Brunswick Heads	28°32'	153°33'	-	-
	Simpsons Creek, Brunswick Heads	28°33'	153°33'	-	-
	Belongil Creek, Byron Bay	28°38'	153°35'	-	-
	North Creek, Ballina	28°51'	153°34'	-	-
	South Ballina	28°53'	153°33'	-	-
	Hermans Wharf, Richmond River	28°54'	153°31'	-	-

used these tunnels (Van Dyck, 1997). A more detailed description of search techniques is provided below.

Up to four different vegetation communities occurred in the intertidal search area and, wherever possible, the location of each *X. myoides* nest was recorded with respect to these communities. Based on the definitions of Clifford & Specht (1979), the communities encountered were:

1) sedgeland — an often well-defined zone of rushes and sedges growing to about 1m and typically including *Juncus kraussii* and *Baumea juncea*. The Mangrove Fern *Acrostichum speciosum* occasionally grows here.

2) chenopod shrubland — a less frequently encountered low, open shrubland of succulents with a dwarf shrub habit growing on soils that dry out and crack between inundations. Plant species typically include *Enchylaena tomentosa*,

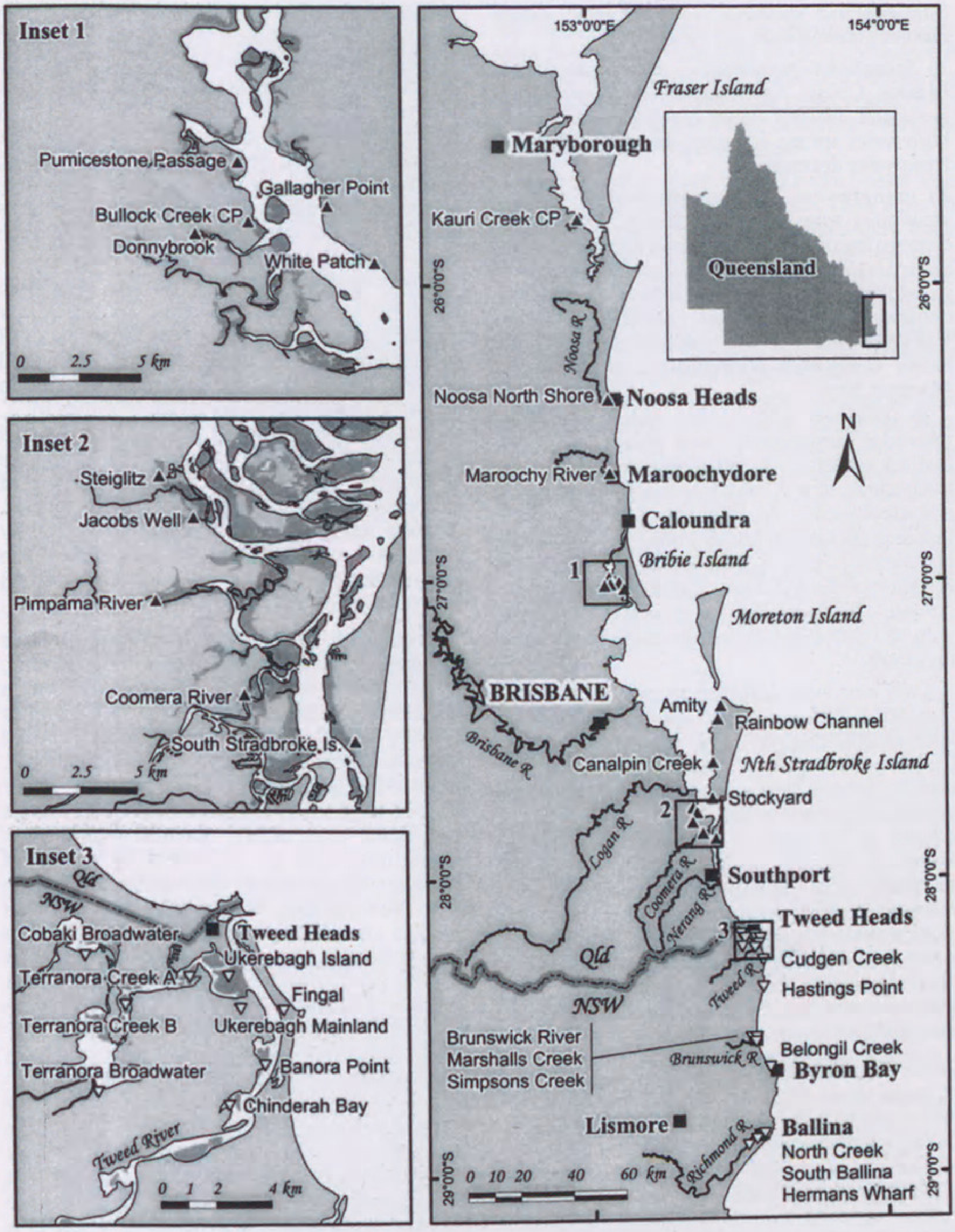

FIG. 1. Distribution of *Xeromys myoides* nesting localities in Queensland (▲), and localities searched (unsuccessfully) in New South Wales (▽).

Sarcocornia quinqueflora, *Suaeda arbusculoides* and *Suaeda australis*.

3) *Sporobolus* grassland — a salt meadow of Marine Couch *Sporobolus virginicus* closed grassland, usually found closest to the extreme high water spring tide mark and associated with freshwater drainage.

4) mangroves — a community of varying structural type and complexity, but usually comprising one or more of *Avicennia marina* var. *australasica*, *Rhizophora stylosa*, *Bruguiera gymnorhiza*, *Aegiceras corniculatum* and, less commonly, *Ceriops tagal*. Dowling (1986) and Van Dyck (1997) provide additional details of the many mangrove communities occurring in Moreton Bay.

In situations where more than one of these intertidal communities was present at a site, distinct zonation was often apparent. This made assignment of a *X. myoides* nest to a particular community easy. At other times the boundaries between the various communities were blurred or the communities interdigitated such that clear zonation of the different vegetation types was not obvious. In these cases, a nest was associated with the dominant vegetation community in its proximity.

Each nest was assigned to one of five nest categories (below) and its location determined with a GPS navigator. The vegetation cover on the nest, nature of the mound material, number and position of entrance/exit holes and height and circumference of the mound were recorded. The degree of moating by high tides was also assessed. Finally, the nest's position in the intertidal zone was put into perspective in relation to the vegetation communities occurring along a linear transect that started at the terrestrial boundary and passed through the nest to terminate at the closest deep channel or large body of water out into or beyond the associated mangroves.

SEARCH TECHNIQUES. Techniques employed to locate nests of *X. myoides* are described. As previously stated, manual searching was conducted across the entire intertidal zone. Particular attention was paid to areas of higher ground abutting or lying within the various intertidal vegetation communities, i.e. places that offer some elevation and, therefore, refuge against the high tide. Where a defined supralittoral bank existed, this was searched thoroughly for mud moundings or other signs of *X. myoides*. Other areas of high ground that were potentially suitable for nesting were detected by the different nature of the vegetation they supported. Small 'islands' at the same elevation as the supralittoral bank often existed in the landward sections of the intertidal zone. These supported terrestrial trees or shrubs such as *Melaleuca quinquenervia*, *Casuarina glauca* and *Baccharis halimifolia*, and were surrounded by *Sporobolus* grassland, sedgeland or chenopod shrubland. Locations seaward of the supralittoral bank where such trees occurred were investigated closely.

Local topography at each site was also carefully considered. At some localities, for example, narrow tongues or even large islands of coastal woodland lay partly or entirely encircled by mangroves or other intertidal vegetation types, offering many nesting opportunities for *X. myoides*. These terrestrial isolates were located by scanning across the canopy of the mangrove community to detect the obvious crowns of *Casuarina glauca* or other terrestrial tree species. Routine study of colour aerial photography (1:12,000 scale or better) of each survey site ensured that the discovery of such areas of high ground was not left to chance.

In addition to searching for these obvious topographical features offering nesting potential, subtler evidence was sought of raised areas within the intertidal zone created directly by *X. myoides* activity or by human disturbance. Amidst *Sporobolus* grassland or chenopod shrubland, mounded nest structures constructed by Water Mice or mounds of artificial origin (e.g. human spoil piles) were usually obvious. Within taller vegetation, such as sedgeland or stands of *Acrostichum speciosum*, this was not always the case. Nevertheless, because the tops of such mounds are seldom, if ever, inundated by high tides, they often bore a lush growth of *Sporobolus virginicus*. Consequently, stands of *Juncus kraussii*, *Baumea juncea* or *A. speciosum* were scanned for these tell-tale clumps of *S. virginicus*. Where these clues to possible nest structures were lacking, extensive areas of *J. kraussii*, *B. juncea* or *A. speciosum* were systematically traversed using parallel transects to locate otherwise concealed nest mounds. Minor contour changes in the overall height of the sedge or fern stands were closely investigated to determine whether these were due to raised substrate or a nest mound. Within the intertidal zone, bund walls, piles of spoil material from earthworks and bulldozed trees with associated root clods were examined carefully for evidence of colonisation by *X. myoides*.

Reward for search effort was greatly increased if surveying for nests in dense intertidal vegetation or lush ground cover on the supralittoral bank was undertaken after recent fires had swept through an area. At such times, signs of *X. myoides* activity including access holes, mud tracks and daubing (below) were more readily observable. In some cases, nest structures were revealed that had been overlooked during previous surveys.

Nest searching within the mangrove zone was conducted less methodically due to the often extensive area needing to be covered. Dead trees and stumps and hollow, living mangroves encountered while conducting such searches or while setting Elliott trap transects were inspected for evidence of *X. myoides* nesting activity. Signs of occupation sought included mounded mud structures located at ground level within hollow trunks, mud packing against the bases of trunks or any mud or peat material in tree trunks and limbs above ground level.

RESULTS

DISTRIBUTION OF NESTING RECORDS. A total of 110 nests belonging to *X. myoides* was discovered at 17 of 28 localities searched along the coastline of southeastern Queensland (Fig. 1, Table 1). These searched localities were scattered from Kauri Creek, Great Sandy Strait (25°47'S, 152°58'E), south to Currumbin Creek on the Gold Coast (28°08'S, 153°28'E). No evidence of *X. myoides* nesting activity was found at four mainland sites south of the Coomera River in Queensland or at any of the 31 sites (from 18 localities) surveyed in New South Wales (Fig. 1, Table 1).

NESTING STRATEGIES. Nesting structures of *X. myoides* encountered at sites surveyed in southeast Queensland were categorised into one of the following five broad types: 1) free-standing nests, 2) island nests, 3) supralittoral bank nests, 4) tree trunk nests, and 5) spoil heap nests. Photographs (Figs 2-15) and relevant details of nests from each class should aid recognition of these structures by field workers. Figure 16 illustrates the diversity of *X. myoides* nest types and locations within the different intertidal vegetation communities. Although these five categories offer a useful scheme for documenting the range of *X. myoides* nesting structures, the classification proved to be somewhat arbitrary with, in some situations, the divisions between certain nest types being unclear. For example, free-standing mounds built against tree bases or against clods of soil between the roots of upturned trees could be classified as tree trunk nests or spoil heap nests, respectively (below). Such difficulties, however, were the exception rather than the rule.

1. Free-standing Nests. Free-standing nests were solitary, termitarium-like mounds. They were not associated with either the supralittoral bank, areas of substrate elevated above their surroundings ('islands' and spoil piles) or (except in rare instances) hollow tree trunks or stumps. They occurred in: (i) the mangrove zone (Fig. 2); (ii) sedgeland (Fig. 3); (iii) chenopod shrubland; or (iv) *Sporobolus* grassland (Fig. 4).

The locations and physical features of free-standing mounds documented during the study appear in Table 2. Free-standing nests were always more conspicuous than other nest types, often being large constructions up to 66cm high (mean = 42cm, SD = 12cm, n = 20; minimum height of occupied nests 25cm). All experienced 360° moating at high tide. This nest type was recorded mainly from areas of sedgeland and *Sporobolus* grassland (18 out of 21 cases), with only one example from chenopod shrubland and two noted inside the mangrove zone. One of these mangrove mounds (Stockyard #63) had been abandoned at some point up to 3.5 years after it was first discovered (below). The other (Pumicestone Passage #17) was situated in an area of minimal tidal influence. Occupied nests were thickly covered with Marine Couch (14 out of 20 cases), the sedges *Juncus kraussii* or *Baumea juncea* (5 out of 20 nests) or a combination of sedge and couch (one case). A smaller additional component of cover was contributed in some instances by *Suaeda arbusculoides*, *S. australis*, *Vitex bicolor* or *Acrostichum speciosum*. When first recorded, nest #63 at Stockyard, North Stradbroke Island, was partially covered with *S. australis*. However, when revisited 3.5 years later, this vegetation had all died and the nest was abandoned.

Free-standing nests occurred either in areas receiving infrequent flooding by tides or areas that experienced more regular inundation but offered a high degree of protection from erosional action (wind-induced waves and/or tidal currents). This protection was due to the buffering effect of an adjacent broad mangrove zone or because the areas were situated along calm waterways. The sheltered Marine Couch and *Sarcocornia quinqueflora* flats of the western shores of Pumicestone Passage,

FIG. 2. A free-standing nest in the mangrove zone (nest #17, Pumicestone Passage, November 1996). Photo Ian Gynther.

intersected by extensive natural ponds and shallow drainage ditches, and located far from the deep water of the Passage itself, provided the most numerous examples of this nest type. In such areas, given the limited exchange of surface waters, mangrove community composition was limited to one species (*Avicennia marina*) that grew no taller than 5m.

Nests on the Noosa River (#s 9,10) and Coomera River (#s 76,77,87) were subject to more extensive tidal inundation than those at Pumicestone Passage but occurred in similarly sheltered areas amid broad expanses of *Sporobolus* grassland or sedgeland and, in these cases, adjacent to calm river channels. The free-standing nests at Kauri Creek Conservation Park (#s 2,6), Rainbow Channel (#57) and South Stradbroke Island (#s 95,102,103) were all recorded closer to potentially destructive tidal influences, but occurred on the landward side of 153-400m-wide mangrove stands that included *Rhizophora stylosa* as a significant component. The dense tangles of prop roots typical of this mangrove species would offer an effective barrier against strong tidal currents, storm surge and wind-induced waves. As would be expected in such regularly inundated sites, these nests were densely consolidated by species with a greater salt water tolerance, namely sedges and Mangrove Fern, and were closer to more diverse mangrove communities. The remaining nest, at Bullock Creek Conservation Park (#29), represented an intermediate situation. Although the surrounding sedgeland here was not extensive, a 290m-broad mangrove zone stood between it and the relatively sheltered waters of Pumicestone Passage.

Free-standing nests were often constructed at great distances from both the terrestrial woodland community and deep water, further emphasizing the typically sheltered nature of the locations at which these nests occurred. For example, nests #17 (Pumicestone Passage) and #63 (Stockyard) were 131m and 200m, respectively, from the marine/terrestrial boundary, and many nests (#s 2,6,10,29,63, 95,102,103) were at least 250m from the nearest body of deep salt water. Those at Kauri Creek Conservation Park (#s 2,6) were 427m and 520m from the closest channel. With one exception (Rainbow Channel #57), all Type 1 nests were located adjacent to sections of the shoreline that lacked a distinct supralittoral bank.

FIG. 3. A free-standing nest in sedgeland (nest #10, Noosa North Shore, April 1997). Photo Ian Gynther.

FIG. 4. A free-standing nest in *Sporobolus* grassland (nest #18, Pumicestone Passage, November 1996). Photo Steve Van Dyck.

The greatest number of access holes (25) of any nest type was recorded from a free-standing nest mound (Pumicestone Passage #14).

2. Island Nests. 'Island' nests were constructed away from the supralittoral bank in areas of substrate that were slightly higher than their surroundings and generally above the level of spring tides. They were often consolidated by the roots of trees such as *Melaleuca quinquenervia* and *Casuarina glauca*, or thickly covered with sedges and/or *Sporobolus virginicus*. These 'islands' may represent vestiges of the supralittoral bank, eroded by the combined effects of spring tides, wind-induced waves and storm surge. Most 'islands' were, therefore, closer to the supralittoral bank than to the mangroves. Island nests occurred in: (i) the mangrove zone (Fig. 5); (ii) sedgeland (uncommonly including *Acrostichum speciosum*) (Fig. 6); (iii) chenopod shrubland; or (iv) *Sporobolus* grassland. They sometimes comprised simple holes with no other signs of working by *X. myoides*, but more often were complex constructions with additional mounding.

Locations and physical features of island nests are shown in Table 3. Nests constructed on islands were second to free-standing nests in their ease of detection. The maximum recorded size of such an island was approximately 15m^2 (Donnybrook #44). The mean height of island nests above the surrounding littoral substrate was 51cm (range = 30-75cm, SD = 13cm, n = 20). All islands were fully moated at high tide and most (19 out of 20 examples) were consolidated by the roots of a few salt-tolerant shrubs and trees such as *Casuarina glauca*, *Baccharis halimifolia* and *Melaleuca quinquenervia* or the mangroves *Avicennia marina* and *Aegiceras corniculatum*. The only island nest not associated with shrubs or trees (Donnybrook #38) was situated in the middle of an extensive area of low, *Sporobolus virginicus*-covered plateaux, intersected by a labyrinth of natural, shallow channels and poorly draining pools.

All islands were thickly covered with ground layer vegetation: Marine Couch (11 out of 20 cases, including nest #38), sedges (five out of 20), couch and sedges (two out of 20) or sedges and Mangrove Fern (two out of 20). Marine Couch cover generally characterised more sheltered locations (e.g. Donnybrook; sections of Gallagher

FIG. 5. An island nest with obvious mounding in the mangrove zone (nest #37, Donnybrook, November 1996). Photo Ian Gynther.

FIG. 6. An island nest in sedgeland (nest #72, Coomera River, November 2001). Photo Ian Gynther.

spring tides was apparent at around 20cm above the substrate level.

The tops of all but one island nest (Amity #50) were plastered by *X. myoides* with successive layers of mud or peat daubing which, over time, had produced mounds, effectively increasing their height against spring tides.

The greatest number of access holes recorded from island nests was seven (nest #s 37,48,110).

3. Supralittoral Bank Nests. Supralittoral bank nests were built into or on the earth bank formed by erosional action at the marine (mangrove, sedgeland, chenopod, *Sporobolus*)/terrestrial (swamp, wallum, coastal woodland) ecotone by the highest of tides (Fig. 7). Such nests were either: (i) simple holes excavated into the vertical bank; or (ii) more elaborate constructions with additional mounding (Fig. 8).

Twenty supralittoral bank nests were recorded. The physical features of these are provided in Table 4. Type 3 nests were more difficult to locate than other types because banks were naturally uneven in profile and thickly covered with Marine Couch, sedges or shrubs, and because mounding associated with such nests was either nonexistent or occurred in various stages of development. In the former case, inconspicuous holes were built among peat and roots in the bank. In the absence of peat or mud plastering above these nests, the three recorded examples (Rainbow Channel #s 54,55; Canalpin Creek #62) were discovered only during the course of radio-tracking studies.

In one case, at Donnybrook, a recent fire that had burned to the supralittoral bank and into the fringes of the *Sporobolus* grassland exposed three nests that had not been detected during an earlier survey (Fig. 17).

Supralittoral bank nests, being located at the marine/terrestrial boundary, were not as prone to inundation and so experienced less moating than other nest types. The usual extent of moating of nests in the supralittoral bank was 180°, although the maximum recorded (270°) occurred in situations where the bank formed small promontories jutting out into the adjacent

Point on Bribie Island) whereas sedges or the combination of sedges and fern, i.e. species tolerant of a higher frequency of inundation by salt water, occurred in areas potentially more prone to erosion by spring tides, wind-induced waves and storm surge (e.g. certain sections of Kauri Creek Conservation Park, Amity, Rainbow Channel and South Stradbroke Island). Nest #27 at Bullock Creek Conservation Park, situated in an area exposed to only moderate erosional forces, consisted of a *Sporobolus*-covered island (with a single *Casuarina glauca*) within dense sedgeland. Nest #74 at Coomera, another area of intermediate shelter, was covered by a combination of Marine Couch and sedges (with an individual *C. glauca*). Couch and sedges also covered one Donnybrook nest (#44), although Marine Couch dominated, as was consistent with the nest's sheltered location.

Island nests were usually located closer to the supralittoral bank or, where this was poorly defined, the marine/terrestrial boundary (median distance = 12m) than were free-standing nests (median distance = 41m) or tree trunk nests (median distance = 75m), most probably because the island landforms bearing *X. myoides* nests originated through erosional processes operating on the supralittoral bank. One exception, nest #37 at Donnybrook (Fig. 5), was located on an island in an isolated, raised area of sparse *Sporobolus* a distance of 195m into the mangroves from the landward edge of the intertidal zone. Although couch-covered, undermining of the structure by

TABLE 2. Free-standing nest mounds (Type 1) of *Xeromys myoides* from southeast Queensland. * The term 'sedge' refers to the combination of *Juncus kraussii* and *Baumea juncea*. Abbreviations: CP, Conservation Park; H, height of nest mound; Circ., circumference of nest mound at base.

Ref. No.	Locality	Lat (S)	Long (E)	Veg. Zone	H (cm)	Circ. (m)	Material	Holes	Veg. Cover
2	Kauri Ck CP	25°46'57"	152°58'28"	sedgeland	60	4.5	peat/mud/ sand	12; 10 @ 0cm, 10cm, 20cm	*S. virginicus*
6	Kauri Ck CP	25°47'14"	152°57'44"	sedgeland	35	1.5	black soil	2; 2 @ 0cm	*J. kraussii*
9	Noosa North Shore	26°23'31"	153°03'58"	sedgeland	31	2.5	grey sand	6; 2 @ 0cm, 2 @ 2cm, 2 @ 3cm	*J. kraussii, S. virginicus*
10	Noosa North Shore	26°23'35"	153°03'47"	sedgeland	36	3.0	sand	3; 2 @ 0cm, 5cm	*S. virginicus*
14	Pumicestone Passage	26°59'10"	153°03'46"	*Sporobolus*	60	6.0	dark loam	25; 6cm, 2 @ 8cm, 9cm, 10cm, 2 @ 13cm, 14cm, 15cm, 2 @ 16cm, 3 @ 17cm, 2 @ 18cm, 19cm, 2 @ 20cm, 2 @ 21cm, 2 @ 22cm, 31cm, 32cm	*S. virginicus*
15	Pumicestone Passage	26°59'18"	153°03'51"	chenopod	35	4.7	peat/mud	9; 0cm, 3cm, 5cm, 6cm, 8cm, 3 @ 10cm, 11cm	*S. virginicus*
16	Pumicestone Passage	26°59'21"	153°03'59"	*Sporobolus*	40	3.8	peat/mud	13; 6 @ 0cm, 8cm, 10cm, 14cm, 15cm, 16cm, 18cm, 25cm	*S. virginicus, S. arbusculoides*
17	Pumicestone Passage	26°59'21"	153°04'03"	mangrove	60	5.1	peat/mud	23; 12 @ 0cm, 3 @ 12cm, 3 @ 15cm, 3 @ 18cm, 22cm, 24cm	*S. virginicus, S. australis*
18	Pumicestone Passage	26°59'21"	153°04'09"	*Sporobolus*	48	4.7	mud/sand/ loam	10; 0cm, 3cm, 5cm, 8cm, 10cm, 12cm, 14cm, 20cm, 34cm, 48cm	*S. virginicus*
19	Pumicestone Passage	26°59'26"	153°04'01"	*Sporobolus*	48	4.1	mud	8; 3cm, 8cm, 11cm, 12cm, 2 @ 13cm, 24cm, 46cm	*S. virginicus*
20	Pumicestone Passage	26°59'26"	153°04'08"	*Sporobolus*	27	2.4	peat/loam	8; 2 @ 0cm, 6cm, 2 @ 8cm, 10cm, 2 @ 15cm	*S. virginicus*
21	Pumicestone Passage	26°59'31"	153°03'42"	*Sporobolus*	40	4.5	mud/loam	19; 13 @ 0cm, 5cm, 3 @ 8cm, 10cm, 11cm	*S. virginicus*
29	Bullock Ck CP	27°00'47"	153°04'11"	sedgeland	48	3.2	clay/mud/ sand	17; 13 @ 0cm, 10cm, 13cm, 14cm, 15cm	*S. virginicus*
57	Rainbow Channel	27°27'35"	153°25'38"	sedgeland	66	4.7	peat/mud/ sand	6; 3 @ 0cm, 20cm, 40cm, 45cm	sedge* (1.6m), *Vitex bicolor*
63	Stockyard	27°43'29"	153°24'26"	mangrove	23	3.7	mud	none (abandoned)	dead *S. australis*
76	Coomera R	27°50'27"	153°22'41"	*Sporobolus*	25	3.4	mud	1; 20cm	*S. virginicus*
77	Coomera R	27°50'30"	153°22'45"	*Sporobolus*	25	6.0	mud	7; 5 @ 5cm, 2 @ 20cm	*S. virginicus*
87	Coomera R	27°50'52"	153°22'22"	*Sporobolus*	36	3.6	mud	4; 10cm, 2 @ 25cm, 31cm	*S. virginicus*
95	S Stradbroke	27°51'34"	153°25'06"	sedgeland	37	4.2	black peat	5; 4 @ 0cm, 33cm	*J. kraussii* (1.3m), *A. speciosum*
102	S Stradbroke	27°51'39"	153°25'08"	sedgeland	40	4.4	peat/grey sand	6; 3 @ 0cm, 24cm, 35cm, 40cm	*J. kraussii, A. speciosum*
103	S Stradbroke	27°51'39"	153°25'10"	sedgeland	50	4.8	peat/grey sand	13; 5 @ 0cm, 7 @ 20-25cm, 40cm	*J. kraussii, A. speciosum*

intertidal area (Donnybrook #s 31,32). An intermediate degree of moating at high tide was noted for two nests, #s 56 and 57, at Rainbow Channel (210° and 200° moating, respectively). The mean height of supralittoral bank nests was 55cm (range = 35-80cm, SD = 15cm, n = 17). Nests were documented up to 32m from the mangrove community and up to 11 access holes were recorded. Ten of the nests were incorporated among the roots of living or dead trees or shrubs.

4. Tree Trunk Nests. Tree trunk nests relied on a hollow tree or stump to provide the supportive

TABLE 3. Island nests (Type 2) of *Xeromys myoides* from southeast Queensland. Abbreviations: CP, Conservation Park; H, height of the island plus any additional mounding (often it was impossible to dissociate the two); Circ., circumference of the island. * The term 'sedge' refers to the combination of *Juncus kraussii* and *Baumea juncea*.

Ref. No.	Locality	Lat (S)	Long (E)	Veg. Zone	H (cm)	Circ. (m)	Material	Holes	Veg. Cover
5	Kauri Ck CP	25°47'10"	152°58'24"	chenopod	45	5.1	mud/sand	4; 3 @ 0cm, 10cm	*J. kraussii*, *C. glauca*
22	Gallagher Pt	27°00'18"	153°06'03"	sedgeland/ *Sporobolus*	45	3.9	peat/loam	4; 0cm, 2 @ 8cm, 11cm	dead *C. glauca* (1.2m), *S. virginicus*
23	Gallagher Pt	27°00'18"	153°06'03"	sedgeland/ *Sporobolus*	32	3.1	peat/loam	4; 3 @ 0cm, 12cm	*S. virginicus*, dead *C. glauca* (0.7m), *M. quinquenervia*
27	Bullock Ck CP	27°00'43"	153°04'11"	sedgeland	55	10.2	mud/grey sand	3; 3cm, 2 @ 10cm	*S. virginicus*, *C. glauca* (7.0m & 1.2m)
34	Donnybrook	27°00'59"	153°02'57"	*Sporobolus*	45	6.2	clay-mud/ loam	6; 2 @ 10cm, 2 @ 13cm, 22cm, 45cm	*S. virginicus*, *A. corniculatum* (1m)
37	Donnybrook	27°01'08"	153°03'09"	mangrove	75	5.6	peat/mud	7; 3 @ 20cm, 23cm, 2 @ 30cm, 45cm	*S. virginicus*, *C. glauca* (4m)
38	Donnybrook	27°01'09"	153°03'03"	*Sporobolus*	74	9	clay/ humus/sand	3; 29cm, 39cm, 72cm	*S. virginicus*
42	Donnybrook	27°01'16"	153°03'00"	*Sporobolus*	58	12	clay/loam	4; 2 @ 0cm, 3cm, 37cm	*S. virginicus*, *B. halimifolia*
43	Donnybrook	27°01'17"	153°03'08"	sedgeland/ *Sporobolus*	58	12	clay/loam	6; 8cm, 9cm, 10cm, 20cm, 29cm, 31cm	*S. virginicus*, *C. glauca* (8m)
44	Donnybrook	27°01'21"	153°03'13"	chenopod	59	13.7	clay/loam	5; 0cm, 8cm, 2 @ 10cm, 21cm	*S. virginicus*, sedge*, *A. marina* (1.6m)
45	Donnybrook	27°01'22"	153°03'12"	chenopod	60	7	clay/loam	2; 27cm, 42cm	*S. virginicus*, *M. quinquenervia* (4m)
48	Amity	27°24'41"	153°26'23"	sedgeland	45	2.7	grey-black peat/sand	7; 7 @ 0cm	*S. virginicus*, *M. quinquenervia* (4m)
49	Amity	27°25'25"	153°26'14"	sedgeland	60	4.1	grey peat/sand	3; 2 @ 0cm, 20cm	*B. juncea*, *M. quinquenervia* (4m)
50	Amity	27°25'26"	153°26'15"	sedgeland	40	?	nil	2; 2 @ 25cm	sedge* (1m), *C. glauca*, *M. quinquenervia*
51	Amity	27°25'31"	153°26'13"	sedgeland	60	3.1	grey peat/sand	5; 2 @ 0cm, 2cm, 4cm, 48cm	sedge*, *M. quinquenervia* (5m)
60	Rainbow Channel	27°27'52"	153°25'39"	sedgeland	60	2.4	peat/mud	5; 3 @ 0cm, 2 @ 60cm	sedge* (1.6m), *Phragmites australis*, *M. quinquenervia* (4m), *C. glauca* (6m)
72	Coomera R	27°50'23"	153°22'25"	sedgeland	40	9.8	black sandy peat	5; 3 @ 0cm, 12cm, 35cm	*S. virginicus*, *C. glauca* (9m)
74	Coomera R	27°50'24"	153°22'24"	sedgeland	30	6.4	black sandy peat	2; 0cm, 30cm	*S. virginicus*, *J. kraussii*, *C. glauca* (4m)
106	S Stradbroke	27°51'41"	153°25'09"	sedgeland	38	5.1	grey sand	6; 5 @ 0cm, 15 cm	*J. kraussii* (1.3m), *A. speciosum* (1.2m), *M. quinquenervia* (4m)
110	S Stradbroke	27°51'44"	153°25'07"	sedgeland	45	8.8	peat/mud/ grey sand	7; 6 @ 0cm, 17cm	*J. kraussii* (1.3m), *A. speciosum* (1.3m), *M. quinquenervia* (5m)

frame for the mud structure built within. These mostly involved dead stags of *Eucalyptus tereticornis* (Fig. 9) or living or dead *Avicennia marina* situated within the mangrove zone (Figs 10-13). Additional examples of tree trunk nests involved living or dead *Casuarina glauca*, *Melaleuca quinquenervia* or *Excoecaria agallocha* growing at or near the marine/terrestrial boundary.

In spite of the number of tree trunk nests recorded in or adjacent to the mangrove

FIG. 7. A supralittoral bank where tunnels made by *Xeromys myoides* are either hidden among roots or are indistinguishable from crab holes (nest #62, Canalpin Creek, North Stradbroke Island, September 1997). Photo Steve Van Dyck.

community (31), this nesting strategy was not documented widely throughout the survey area (Table 5). Numerous examples (14) were recorded from a limited area (approximately 60m × 530m) on South Stradbroke Island inside the hollowed bases of large, decayed *Eucalyptus tereticornis* stumps, now completely surrounded by a mangrove open woodland. Although an almost unlimited number of hollow-trunked mangroves is available, only ten records (Noosa North Shore #12; Donnybrook #36; Coomera River #s70,71,73, 75,78-81) were made of nests inside the trunks of living mangroves (*Avicennia marina*). Two other records were of nests inside the trunks of dead mangroves. In one case (Noosa North Shore #11), the tree involved was the rotting stump of a Milky Mangrove *Excoecaria agallocha*. In the other (Donnybrook #30), a nest was discovered in the small, leaf-lined (leaves of *Aegiceras corniculatum*) trunk of a dead mangrove, possibly *Avicennia marina*. The remaining five tree trunk nests were located inside dead or hollow-trunked but living *Melaleuca quinquenervia* (#s 1,3) or *Casuarina glauca* (#s 4,28,52) growing at the marine/terrestrial boundary or within the uppermost zone of tidal influence.

Tree trunk nests assumed a variety of forms. In most cases cavities within living or dead trees were either packed with mud or contained a mounded mud structure visible from the outside (Figs 9,10). An exception was discovered within a living *Avicennia marina* at Coomera River (nest #75). Here, the basal hollow was not entirely mud-filled but instead contained a 60cm-high, ramped mud structure built against the tree's sloping, interior wall.

Other tree nests were located within relatively small trunks that lacked large holes and so precluded the structure of the nest being observed from the outside. Consequently, it was impossible to determine whether or not the internal cavity was mud-filled. In some cases, it was not even obvious that such trunks were hollow. Even so, *X. myoides* was clearly occupying these trees because of additional mud working including mounds with at least one access hole built against the tree's base (Fig. 11), plastering of the tree's exterior surface, footprints creating tracks along

FIG. 8. A supralittoral bank nest with additional mounding (nest #24, Gallagher Point, Bribie Island, March 1999). Photo Ian Gynther.

FIG. 9. A tree nest at the base of a *Eucalyptus tereticornis* stag (nest #105, South Stradbroke Island, June 1995). Photo Ian Gynther.

the uppermost surface of sloping trunks, especially near ground level, and plugging of knot holes or the ends of broken trunks or branches (Fig. 12). In one example (Coomera River #80), the plugging of a gap in the upper surface of a dead, horizontal trunk of a living *A. marina* apparently led to the construction of a small mound of mud (10cm high) atop the broken-off trunk at a height of 86cm above ground (Fig. 13). When examined on a subsequent visit, this mound had been destroyed and a nesting chamber of leaves inside the trunk's cavity was visible. Change over time in the extent of mud working associated with tree trunk nests was not uncommon and, in certain cases involving smaller diameter mangrove trees in particular (e.g. Coomera River nest #s 70,73,78), nests were not active on later visits or could not be relocated at all as no signs of former occupation by *X. myoides* were detectable.

A final variation in tree trunk nests was seen in situations involving the broken and decaying stumps of *Casuarina glauca* or *Melaleuca quinquenervia* near the edge of the sedge zone (Kauri Creek Conservation Park #s 1,4; Bullock Creek Conservation Park #28). Here, mud mounds were constructed in and around the remains of the stump such that the timber appeared to act as internal reinforcing for the completed structure.

Occasionally the local landform at sites with tree trunk nests prevented individual nests fitting neatly into the standard habitat zonation scheme. In these cases, Table 5 provides simple descriptive terms for the physical location/vegetation at the nest site. For example, 'woodland/sedgeland' was applied to situations where a distinct supralittoral bank was lacking at the boundary between the intertidal area and adjacent *Melaleuca quinquenervia* or *Casuarina glauca* woodland. The term 'woodland tongue' was applied to a promontory of dry land that lay between areas of mangrove and saltmarsh. The overall landform and the size of the tongue made it too big to be considered an island and its situation within the intertidal zone ruled out the possibility of it being termed a true supralittoral bank.

Visible mud heights in Type 4 nest structures reached 86cm above the surrounding littoral substrate (Coomera River #80), but in some cases may have been higher in the concealed cavities inside the trunks. Nest #98 at South Stradbroke Island, a small mound inside a wide, hollow

FIG. 10. A tree nest in the trunk of a living *Avicennia marina* (nest #12, Noosa North Shore, April 1997). Photo Ian Gynther.

TABLE 4. Supralittoral bank nests (Type 3) of *Xeromys myoides* from southeast Queensland. Abbreviations: M, height of mound structure, if present; B, height of supralittoral bank; H, total nest height, i.e. M+B; Circ., basal circumference of any mounding; indet., indeterminate. Hole heights are measured from the bank base. * The term 'sedge' refers to the combination of *Juncus kraussii* and *Baumea juncea*.

Ref. No.	Locality	Lat (S)	Long (E)	M/B (cm)	H (cm)	Circ. (m)	Material	Holes	Veg. Cover
7	Noosa North Shore	26°23'10"	153°04'10"	16/64	80	1.9	sand	2; 63cm, 68cm	*C. glauca* (8m)
8	Noosa North Shore	26°23'12"	153°04'11"	20/43	63	1.6	peat/sand	2; 2 @ 43cm	*S. virginicus*, sedge*
24	Gallagher Pt	27°00'20"	153°05'59"	43/27	70	4.1	loam/sand	2; 27cm, 45cm	*S. virginicus*, *J. kraussii*, *C. glauca* (8m)
25	Gallagher Pt	27°00'29"	153°05'52"	?/?	38	3.8	loam/white sand	5; 2 @ 2cm, 6cm, 17cm, 38cm	*S. virginicus*, *J. kraussii*, *B. halimifolia*
26	Gallagher Pt	27°00'31"	153°05'52"	21/39	60	4.1	loam/white sand	2; 2 @ 0cm	*S. virginicus*, *J. kraussii*, *C. glauca* (4m)
31	Donnybrook	27°00'56"	153°02'56"	44/?	?	4.3	peat	11; 5 @ 8+?cm, 4 @ 15+?cm, 2 @ 18+?cm	burnt (?*S. virginicus*), *C. glauca* (4m)
32	Donnybrook	27°00'57"	153°02'56"	25/32	57	5.0	clay/humus	9; 0cm, 2cm, 4cm, 15cm, 33cm, 34cm, 2 @ 38cm, 47cm	*S. virginicus*
33	Donnybrook	27°00'58"	153°02'55"	38/?	?	6.8	?peat (burnt out)	5; 2 @ 8+?cm, 15+?cm, 16+?cm, 30+?cm	burnt (?*S. virginicus*), *C. glauca* (4.5m)
35	Donnybrook	27°01'01"	153°02'59"	25/50	75	3.4	sand/clay	3; 2 @ 25cm, 30cm	nil
39	Donnybrook	27°01'09"	153°03'08"	20/30	50	2.2	sand/clay	5; 2 @ 0cm, 15cm, 35cm, 40cm	*S. virginicus*
40	Donnybrook	27°01'11"	153°03'13"	?/?	35	3.1	sand/loam	5; 2 @ 0cm, 2cm, 10cm, 15cm	nil
41	Donnybrook	27°01'11"	153°03'14"	24/40	64	2.8	sand/clay	4; 0cm, 40cm, 45cm, 55cm (plugged)	*S. virginicus*
53	Rainbow Channel	27°27'28"	153°25'43"	10/30	40	2.2	peat/mud/ sand	2; 0cm, 30cm	*J. kraussii* (1m), *Imperata cylindrica* (1m)
54	Rainbow Channel	27°27'29"	153°25'43"	0/35	35	N/A (no mound)	nil	1; 8cm	sedge*
55	Rainbow Channel	27°27'30"	153°25'43"	0/35	35	N/A (no mound)	nil	undetected	tree roots
56	Rainbow Channel	27°27'34"	153°25'43"	30/40	70	3.9	peat/mud/ sand	6; 4 @ 0cm, 2 @ 70cm	*J. kraussii* (1.6m), *M. quinquenervia* (5m)
58	Rainbow Channel	27°27'40"	153°25'40"	30/30	60	3.9	peat/mud	6; 0cm, 4 @ 30cm, 60cm	*J. kraussii*
59	Rainbow Channel	27°27'44"	153°25'49"	10/?	?	1.1	peat/sand	3; ?cm, 2 @ 10+?cm	*J. kraussii*, *Caustis blakei*, *Gahnia sieberiana*
61	Rainbow Channel	27°28'01"	153°25'36"	15/20	35	indet.	peat/mud	2; 0cm, 35cm	*J. kraussii*, *B. halimifolia*
62	Canalpin Ck	27°36'19"	153°24'38"	0/60	60	N/A (no mound)	nil	1; 32cm	*Gahnia* sp., *M. quinquenervia* (11m), *B. halimifolia* (2m)

trunk, was the lowest recorded tree nest at only 25cm. Mean nest height inside tree trunks was 59cm (SD = 18cm, n = 26). Additional plastering of mud against the interior or exterior surfaces of the tree often extended much higher than the nest heights indicated in Table 5. Furthermore, in

TABLE 5. Tree trunk nests (Type 4) of *Xeromys myoides* from southeast Queensland. Abbreviations: CP, Conservation Park; H, height of visible mud structure only (actual nests may be higher inside trunks); Circ., maximum circumference of the tree nest at ground level (where relevant, including extent of any mud mounding or buttress roots used as nest access points); indet., indeterminate.

Ref. No.	Locality	Lat (S)	Long (E)	Veg. Zone	H (cm)	Circ. (m)	Material	Holes	Tree Species
1	Kauri Ck CP	25°46'57"	152°58'24"	sedgeland	35	3.2	peat/black soil/sand	5; 2 @ 0cm, 8cm, 2 @ 20cm	*M. quinquenervia*, dead, Ht. ?, CBH N/A
3	Kauri Ck CP	25°47'01"	152°58'22"	woodland/ sedgeland	28	3.3	peat/sand	5; 5 @ 0cm	*M. quinquenervia*, live, Ht. ?, CBH ?
4	Kauri Ck CP	25°47'06"	152°58'10"	sedgeland	25	1.8	black loam/sand	1; 0cm	*C. glauca*, dead, Ht. ?, CBH ?
11	Noosa North Shore	26°23'41"	153°03'43"	woodland tongue	51	2.7	grey sand	3; 0cm, 8cm, 15cm	*E. agallocha*, dead, Ht 0.6m, CBH N/A
12	Noosa North Shore	26°23'41"	153°03'45"	mangrove	63	1.9	sand	2; 0cm, 9cm	*A. marina*, live, Ht 6.5m, CBH 1.9m
28	Bullock Ck CP	27°00'47"	153°04'11"	sedgeland	45	3.4	mud	6; 2 @ 0cm, 5cm, 15cm, 16cm, 23 cm	*C. glauca*, dead, Ht 0.45m, CBH N/A
30	Donnybrook	27°00'55"	153°03'01"	mangrove	80	0.9	peat/mud	2; 2 @ 0cm	? *A. marina*, dead, Ht 1.8m, CBH 0.95m
36	Donnybrook	27°01'06"	153°03'09"	mangrove	48	3.6	mud	3; 2 @ 0cm, 32cm	*A. marina*, part-live, Ht 8m, CBH 2.8m
52	Rainbow Channel	27°27'22"	153°25'45"	woodland/ sedgeland	indet.	1.3	peat	1; 0cm	*C. glauca*, live, Ht 12m, CBH 1.2m
70	Coomera R	27°50'17"	153°22'49"	mangrove	85	1.1	mud	2; 0cm, 85cm	*A. marina*, live, Ht 6m, CBH 0.8m
71	Coomera R	27°50'22"	153°22'51"	mangrove	indet.	0.7	mud	2; 0cm, 30cm (in wood)	*A. marina*, live, Ht 5m, CBH 0.8m
73	Coomera R	27°50'23"	153°22'53"	mangrove	indet.	0.9	mud	1; 0cm	*A. marina*, live, Ht 5m, CBH 0.8m
75	Coomera R	27°50'24"	153°22'31"	mangrove	60	2.4	mud	1; 30cm	*A. marina*, live, Ht 6m, CBH 0.85m
78	Coomera R	27°50'31"	153°22'22"	mangrove	indet.	1.8	mud	2; 1cm, 2cm	*A. marina*, live, Ht 6m, CBH 0.7m
79	Coomera R	27°50'32"	153°22'37"	mangrove	80	1.7	mud	2; 2 @ 0cm	*A. marina*, live, Ht 6m, CBH 1.1m
80	Coomera R	27°50'35"	153°22'19"	mangrove	86	1.6	mud	3; 3 @ 0cm	*A. marina*, live, Ht 5m, CBH 0.57m
81	Coomera R	27°50'35"	153°22'19"	mangrove	indet.	2.0	mud	4; 0cm, 2 @ 15cm, 30cm (tree hole)	*A. marina*, live, Ht 6m, CBH 0.68m
92	S Stradbroke	27°51'27"	153°25'01"	mangrove	75	1.8	mud/grey-black sand	undetected	*E. tereticornis*, dead, Ht 3m, CBH 1.25m
93	S Stradbroke	27°51'30"	153°25'00"	mangrove	66	3.5	mud/grey-black sand	2; 30cm, 40cm	*E. tereticornis*, dead, Ht 2.1m, CBH 1.3m
94	S Stradbroke	27°51'30"	153°25'00"	mangrove	63	2.6	mud/grey-black sand	2; 2 @ 63cm	*E. tereticornis*, dead, Ht 4m, CBH 1.7m
96	S Stradbroke	27°51'35"	153°25'01"	mangrove	72	3.1	mud/grey-black sand	3; 3 @ 0cm in buttresses	*E. tereticornis*, dead, Ht 1.9m, CBH 1.25m
97	S Stradbroke	27°51'36"	153°25'07"	mangrove	56	4.7	mud/grey-black sand	5; 4 @ 0cm, 20cm	*E. tereticornis*, dead, Ht 1m, CBH 1m
98	S Stradbroke	27°51'37"	153°25'02"	mangrove	25	1.1	mud/grey-black sand	2; 2 @ 0cm under logs	*E. tereticornis*, dead, Ht 1.6m, CBH 1.9m
99	S Stradbroke	27°51'37"	153°25'03"	mangrove	65	3.1	peat/grey sandy mud	2; 2 @ 25cm	*E. tereticornis*, dead, Ht 1.3m, CBH 1.2m
100	S Stradbroke	27°51'38"	153°25'04"	mangrove	54	3.0	mud/grey sand	2; 0cm, 40cm	*E. tereticornis*, dead, Ht 2.8m, CBH 1.5m

TABLE 5 (*Cont.*)

Ref. No.	Locality	Lat (S)	Long (E)	Veg. Zone	H (cm)	Circ. (m)	Material	Holes	Tree Species
101	S Stradbroke	27°51'38"	153°25'04"	mangrove	62	4.2	mud/grey sand	8; 8 @ 0-32cm	*E. tereticornis*, dead, Ht 2.5m, CBH 1.6m
104	S Stradbroke	27°51'40"	153°25'04"	mangrove	35	2.7	mud/grey-black sand	5; 0cm, 4 @ 10cm	*E. tereticornis*, dead, Ht 9m, CBH 1m
105	S Stradbroke	27°51'41"	153°25'04"	mangrove	60	3.1	mud/grey sand	4; 3 @ 0cm, 15cm	*E. tereticornis*, dead, Ht 2.5m, CBH 1.5m
107	S Stradbroke	27°51'42"	153°25'05"	mangrove	60	3.1	mud/grey sand	2; 2 @ 0cm	*E. tereticornis*, dead, Ht 3m, CBH 2.1m
108	S Stradbroke	27°51'42"	153°25'05"	mangrove	60	2.5	mud/grey-black sand	5; 5 @ 0-25cm	*E. tereticornis*, dead, Ht 3m, CBH 2.3m
109	S Stradbroke	27°51'44"	153°25'04"	mangrove	85	4.3	grey sand	5; 5 @ 0cm (1 in buttress)	*E. tereticornis*, dead, Ht 8m, CBH 1.55m

small diameter trees mud plugging of knot holes and other gaps in the tree's outer walls were sometimes seen at considerable heights. In one case at Coomera River (#81), a plugged knothole was noted 1.75m above ground, while other holes at heights of 1.4m and 1.1m were also blocked with mud.

Up to eight entrance holes were recorded in tree trunk nests but, given the number of exposed 'buttress' roots through which access to some nests might have been gained, this total was probably an underestimate. Other tree nests had no visible access points in the trunk or roots but did possess mud mounds with entrance tunnels constructed against the base of the trunk. Recorded examples of such mounds ranged in height from 10-42cm and contained 1-3 access holes, sometimes with fluted entrances. These mounded structures were of insufficient height to represent nests themselves but appeared to provide access to one or more holes in the nest tree at or near ground level. This was not confirmed in any of the documented cases because it would have necessitated destroying the associated mound.

Because of the location of many of this extraordinary range of tree trunk nests deep within the mangrove community (up to 265m from the landward mangrove zone edge), most experienced longer periods of inundation and deeper moating than other *X. myoides* nest types. The only tree trunk nests recorded that did not receive 360° moating during the tidal cycle (Noosa North Shore #11; Rainbow Channel #52) involved trees standing on the supralittoral bank. In both cases, the maximum extent of moating experienced at high tide was 180°.

5. Spoil Heap Nests. Spoil heap nests were those constructed in human-made piles of excavated or bulldozed earth (Fig. 14), soil clods among roots of bulldozed trees or in the bund walls associated with drainage or flood mitigation works (Fig. 15). Such artificially created features provided elevation above the surrounding intertidal communities and the level of spring tides.

FIG. 11. Mounding at the base of a living (hollow) *Avicennia marina* (nest #81, Coomera River, November 2001). Photo Ian Gynther.

FIG. 12. Details of mud plugging of hole in trunk of same living *Avicennia marina* depicted in Fig. 11 (nest #81, Coomera River, August 2001). Photo Ian Gynther.

Eighteen nests were recorded in human-made bund walls or spoil piles (Table 6). Spoil heap nest heights ranged from 40-89cm (mean = 56cm, SD = 15cm, n = 18). Although examples of Type 5 nests were discovered within each intertidal vegetation community, the majority was in *Sporobolus* grassland, a community that receives a high incidence of human-related impacts because of closer proximity to adjacent land uses. All spoil heap nests identified during this study would have experienced 360° moating during spring high tides.

At Maroochy River (Fig. 14) and Donnybrook, nests #13 and #46, respectively, were constructed in combined soil and tree stump waste that had been bulldozed to near the landward edge of the mangrove woodland, presumably during construction of vehicle tracks. The spoil heap associated with the nest at White Patch on Bribie Island (#47) resulted from a firebreak being bulldozed through the wallum vegetation to the edge of the intertidal zone. Similarly, all nine Type 5 nests discovered on the north bank of the Coomera River were in spoil piles created during past clearing of the site for a development that was then temporarily abandoned. Some of the piles included rock, gravel and even concrete debris (nest #s 86,88,90,91).

At Steiglitz, four nests were found in spoil heaps originating from the soil associated with the exposed roots of upturned trees or from excavation activity during the construction of a high-banked drainage channel. All piles were thickly covered with Marine Couch. Large heaps with circumferences of 7.3-7.6m (nest #s 65, 67) were richly pocked with access holes (19 and 20 holes, respectively) and heavily scored (beneath the couch) with mud tracks created by the animals (see Fig. 20). These nests were close (approximately 130m) to the site of an intensive marina development. The structurally simple mangrove community associated with the Steiglitz nests was probably not older than thirty years. In the mid-1960s, elevation of the nearby existing main road (90m to the southwest), together with the introduction of tidal gates on the

FIG. 13. Mounding on dead, hollow, horizontal trunk of living *Avicennia marina* (nest #80, Coomera River, November 2001). Photo Ian Gynther.

FIG. 14. Spoil heap nest in bulldozed material (nest #13, Maroochy River, March 1996). Photo Ian Gynther.

Behm's Creek bridge (700m to the southeast) resulted in the site undergoing an ecological succession from a *Casuarina glauca/Sporobolus virginicus* community to one dominated by *Avicennia marina/S. virginicus* (G. Leiper, pers. comm.). Numerous dead *C. glauca* stags remain today. The 1m-high drainage channel wall, approximately 10m north of the spoil pile nests did not show any evidence of nesting activity. This was not the case at the Pimpama River locality, where the single recorded nest (#69), discovered by Peter Lehmann during a radio-telemetry study, was constructed in the spoil bank created during excavation of a drainage channel (Fig. 15). This channel emptied directly into the Pimpama River, 33m from the nest site.

All Type 5 nest sites were within highly disturbed areas or in close proximity to such areas. In addition to the White Patch and Coomera River sites mentioned above, the Maroochy River nest (#13) was approximately 16m from a road skirting a sugar cane plantation, nest #46 (Donnybrook) was approximately 5m from a vehicle track and a now felled, exotic pine plantation, and all Steiglitz nests occurred in an area less than 200m wide between an artificial channel draining an abandoned sugar cane plantation and a road bordering a marina development. Nest #68 (Jacobs Well) was built in a large (9m x 11m) spoil heap, 17m from the boundary of a commercial nursery on the main Jacobs Well Road.

NEST RECOGNITION. With some experience, most active or recently active *X. myoides* nests belonging to each nest class described above could be identified with confidence by considering a combination of the following features: the overall height of the nest, the size and shape of any associated mounding, the existence of additional workings including mud or peat plastering and tracks, and the presence and nature of access holes. The small percentage of *X. myoides* nests that could not be detected or reliably identified using visual search techniques included those constructed in the supralittoral bank without any additional associated mounding. It was necessary to locate these using radio-telemetry techniques because the profusion

FIG. 15. Spoil heap nest in material excavated from a drainage channel (nest #69, Pimpama River, July 1995). Photo Ian Gynther.

TABLE 6. Spoil heap nests (Type 5) of *Xeromys myoides* from southeast Queensland. Abbreviations: H, height of the spoil heap plus any additional mounding; Circ., basal circumference of the spoil heap.

Ref. No.	Locality	Lat (S)	Long (E)	Veg. Zone	H (cm)	Circ. (m)	Material	Holes	Veg. Cover
13	Maroochy R	26°38'20"	153°04'18"	*Sporobolus*	67	16	stump/clay/loam	8; 4 @ 0cm, 2 @ 18cm, 20cm, 22cm	nil
46	Donnybrook	27°01'22"	153°03'12"	chenopod	89	24	stump/clay (later burnt)	7; 2 @ 25cm, 30cm, 56cm, 70cm, 2 @ 89cm	*S. virginicus*
47	White Patch	27°01'40"	153°06'59"	sedgeland	45	6.8	peat/loam	9; 3 @ 0cm, 8cm, 2 @ 10cm, 30cm, 34cm, 40cm	*J. kraussii, Phragmites australis*
64	Steiglitz	27°45'20"	153°20'29"	*Sporobolus*	44	3.0	peat/sand	12; 2 @ 4cm, 5cm, 2 @ 10cm, 3 @ 13cm, 14cm, 15cm, 17cm, 21cm	*S. virginicus*
65	Steiglitz	27°45'21"	153°20'28"	*Sporobolus*	60	7.6	sand/loam	19; 5 @ 0cm, 7cm, 8cm, 9cm, 2 @ 10cm, 2 @ 11cm, 2 @ 12cm, 15cm, 20cm, 30cm, 37cm, 42cm	*S. virginicus*
66	Steiglitz	27°45'21"	153°20'28"	*Sporobolus*	53	2.6	sand/loam	7; 5cm, 7cm, 2 @ 8cm, 11cm, 14cm, 15cm	*S. virginicus*
67	Steiglitz	27°45'24"	153°20'25"	*Sporobolus*	80	7.3	stump/peat/sand	20; 0cm, 2 @ 8cm, 2 @ 14cm, 3 @ 15cm, 16cm, 2 @ 17cm, 2 @ 18cm, 3 @ 20cm, 21cm, 22cm, 53cm, 64cm	*S. virginicus, C. glauca* (4m)
68	Jacobs Well	27°46'22"	153°21'16"	*Sporobolus*	50	2.6	peat/sand	4; 10cm, 15cm, 21cm, 45cm	*S. virginicus*
69	Pimpama R	27°48'18"	153°20'21"	mangrove	45	12.6	peat/mud	8; 5 @ 0cm, 3 @ 45cm	nil
82	Coomera R	27°50'35"	153°22'20"	mangrove	47	3.6	peat/mud/sand	3; 15cm, 30cm, 33cm	*S. virginicus*
83	Coomera R	27°50'39"	153°22'17"	mangrove	45	3.0	peat/mud/sand	2; 24cm, 32cm	*S. virginicus, S. quinqueflora*
84	Coomera R	27°50'39"	153°22'19"	mangrove	44	3.1	peat/mud/sand	1; 0cm	*S. virginicus, S. quinqueflora*
85	Coomera R	27°50'51"	153°22'20"	*Sporobolus*	40	3.8	peat/mud/sand	2; 2 @ 0cm	*S. virginicus*
86	Coomera R	27°50'51"	153°22'22"	*Sporobolus*	45	3.3	clay/mud/gravel	7; 0cm, 5cm, 19cm, 20cm, 24cm, 2 @ 29cm	*S. virginicus*
88	Coomera R	27°50'54"	153°22'26"	*Sporobolus*	62	8.1	mud/gravel/rock	8; 3 @ 10cm, 40cm, 43cm, 2 @ 49cm, 55cm	*S. virginicus*
89	Coomera R	27°50'55"	153°22'21"	*Sporobolus*	40	4.5	heavy loam	4; 2 @ 0cm, 15cm, 30cm	*S. virginicus*
90	Coomera R	27°50'55"	153°22'26"	*Sporobolus*	64	7.2	mud/gravel/rock	6; 12cm, 17cm, 25cm, 30cm, 36cm, 47cm	*S. virginicus*
91	Coomera R	27°50'56"	153°22'28"	Sporobolus	80	11.1	mud/gravel/debris	3; 5cm, 21cm, 31cm	*S. virginicus, S. quinqueflora*

of crab holes that occurred in supralittoral banks made positive visual identification of nest entrances impossible. Also, nests that had been abandoned for a long period of time were difficult to identify with confidence because all external signs of occupation (holes, tracks, plastering, etc.) had disappeared. As an illustration of this, only one abandoned nest (a free-standing mound designated as Stockyard #63) could be reliably attributed to *X. myoides* during this study. This was because its history of occupation was known.

The various features that aid in the identification of *X. myoides* nesting structures are described in more detail here.

Overall Nest Height and Moundings. For all *X. myoides* nest types, a plot of the overall heights of nests above the surrounding substrate of the intertidal zone revealed an approximately normal distribution. The mean height of extant nests across all nest classes was 53cm (range = 25-89cm, SD = 16cm, n = 101). Two-thirds of these occupied nests had heights within the range of 31-60cm, with only 7% and 27% of nests being smaller or larger, respectively. This typical size

FIG. 16. Diagram of intertidal community zonation from the supralittoral bank (top) to the marine mudflats showing the variety of *Xeromys myoides* nesting strategies documented from the 110 nests encountered during this study. The numbers represent totals for each nest type recorded within each zone.

range provides a useful guide when assessing whether potential nest structures encountered during survey work belong to *X. myoides*.

All nest types involved, or could incorporate, characteristic moundings of mud or other substrate material. The mound structures associated with free-standing nests ranged up to 66cm in height and were often conspicuous in their surroundings because the mound accounted for the nest's total height. However, those found in association with island, supralittoral bank or spoil heap nests were generally smaller in all dimensions because the raised substrate on which the nest was located already provided substantial elevation and, therefore, protection of the nest against high tides. In all cases, however, the overall profile of the mounded structure was similar — approximating an inverted paraboloid.

In situations of tall or dense vegetation, mounded structures created by *X. myoides* were much easier to detect and identify where fires had recently burned the survey area. This was true for mounds associated with island nests (Fig. 17) but was particularly so for the large mud mounds of free-standing nests and those on the supralittoral bank that would otherwise have been concealed by surrounding sedgeland (Fig. 18).

In the area of southeast Queensland in which this study focused, the naturally occurring structures most likely to be mistaken for *X. myoides* nests were various mounds made by intertidal crab species. The most frequently encountered were the low, irregular mud mounds found in the outer (more seaward) portions of the mangrove community, usually amongst stands of *Rhizophora stylosa*. These were created by *Neosarmartium trispinosum* and *Perisesarma messa*. Two main indicators that these were not Water Mouse nest structures were the abundance of such mounds (at times covering large areas amid the mangroves) and their limited height (most <25cm). Given their position in the intertidal zone, it was quite apparent that even the tallest of these structures would be entirely inundated at high tide. Nevertheless, such crab mounds may offer valuable protection to *X. myoides* because many

FIG. 17. A mound associated with an island nest exposed by fire (nest #42, Donnybrook, September 1996). Photo Ian Gynther.

FIG. 18. A mound associated with a supralittoral bank nest exposed by fire (nest #61, Rainbow Channel, North Stradbroke Island, September 1997). Photo Steve Van Dyck.

captured individuals ran into these holes upon release from our traps.

Plastering and Tracks. The tops of mounded structures associated with active *X. myoides* nests often bore signs of recent 'earthworks' in the form of plastering or daubing. This frequently involved additions of a mud or peat slurry that, over time, gradually served to increase the mound's overall height. In other cases, the material added was not as fluid, instead forming a peaty layer in which small (<1cm diameter), roughly spherical balls of substrate were compacted together (see Fig. 18). In whatever form it took, the fresh daubing was often worked into and among the bases of living stems of sedges or *Sporobolus* to a height of many centimetres (see Fig. 18).

The style of plastering used by Water Mice to add height to their mound structures was also used to repair any damage to the top or sides of the mound. For example, where Feral Pigs *Sus scrofa* had breached the side of a free-standing nest at Pumicestone Passage (#21), the resulting hole was plugged with newly added peat material of a markedly different colour and texture to the surrounding mound, indicating it had come from a different source and was added later. Another example from Gallagher Point, Bribie Island is shown in Fig. 19.

Plastering and daubing were also features of tree trunk nests. In fact they were often the only visible evidence of nesting activity in trees because the very nature of such nests often made it impossible to see the full extent of the workings within the hollow trunk or stump. At times, mud or peat packing could be seen inside the tree's hollow chamber when viewed from above (see Fig. 10) or by examining knot holes or openings left where trunks or branches had broken off. The use of plastering in such situations was similar to the plugs constructed following damage to other *X. myoides* nest types. Mud workings associated with tree trunk nests also included mounds with access holes constructed against the trunk at ground level (Fig. 11, see above). Nest #80 at Coomera River, with its small mound of mud adorning the upper surface of a horizontal section of trunk well above ground (Fig. 13), represented a more exaggerated example of plastering.

FIG. 19. Repair work to damaged nest mound (nest #24, Gallagher Point, Bribie Island, March 1999). Photo Steve Van Dyck.

FIG. 20. Free-standing nest showing slurry track leading from access hole to mound top (nest #17, Pumicestone Passage, November 1996). Photo Steve Van Dyck.

FIG. 21. Multiple slurry tracks on top surface of nest mound (nest #29, Bullock Creek Conservation Park, March 1999). Photo Ian Gynther.

The material used by *X. myoides* to plaster the tops of nest mounds or repair breaches to mound structures was brought from one or more access holes and then smeared to the site where additions were being made. This action, which in captivity was observed (by SVD) to involve the animal pushing the substrate along with its forefeet, resulted in clearly defined, slurry tracks 5-10cm wide leading to the top of the nest mound (Fig. 20). Breaches in the nest structure were also observed being plugged using the mouth only, with a captive individual putting a plug in place with the bottom of the snout. Often each mound possessed multiple tracks (Fig. 21). By parting the Marine Couch or sedges growing on the mound, these obvious tracks could be traced back to the hole from which the mud, peat or other material had come. The plastering action that must be associated with construction of such slurry pathways was apparent from the way the material used overlaid the bases of grass and sedge stems along the route. Once the track substrate had dried and hardened following application, these tell-tale signs of energetic building activity persisted long after the work was actually performed.

A further feature of *X. myoides* nests useful for confirming identification is the frequent inclusion in the daubing and tracks of whole or partial carapaces of small crabs, particularly *Parasesarma erythrodactyla* and *Helice leachii*, upon which this rodent feeds (Van Dyck, 1997). Although this was most likely an inadvertent action on the part of the Water Mouse, the carapaces would have reinforced the 'mortar' formed by mud, peat or other substrates used in nest construction.

Finally, very fresh tracks, as well as mud or peat daubing, often possessed a distinctive, somewhat acrid aroma characteristic of *X. myoides*. Whether this smell, detectable to us only at close range, was due to the animal's droppings or to deliberate scent marking using secretions from its anal glands was not determined, nor was it ascertained whether fresh workings always bore this odour. Nevertheless, this olfactory evidence proved useful in identifying nests of this species.

Access Holes. All active *X. myoides* nests possessed external holes to provide the animals with entry and exit points. The size, shape, number and positioning of these holes offered clues indicating a potential nest structure did indeed belong to the Water Mouse. The occasional exceptions to this were supralittoral bank nests where no additional mound structure was associated with the nest and some tree trunk nests where ground level access was most likely achieved via existing tunnels in hollow buttress roots. Where present and visible, nest access holes were generally larger in overall diameter than those created by the various southeast Queensland intertidal crabs encountered during this study. They were usually circular or horizontally elliptical. Hole dimensions were not recorded for each nest observed in this study and so summary statistics on size variation are not available. Nevertheless, typical dimensions were 35-38mm in diameter for circular access holes and 35mm wide x 28mm high for elliptical holes. Access holes used by *X. myoides* always gave the appearance of being open, although observations made in captivity revealed that at least some tunnels leading into the nesting chamber within the mound were blocked some way down with a plug of mud 5-8cm in thickness (SVD, pers. obs.). This blockage was not visible from outside the nest. On occasion we discovered holes that had dome-shaped caps of mud or peat sealing the external entrance, but in all such instances the animal responsible was determined to be a crab.

The number of access holes per nest ranged from one to 25. Across all nest types, however, the majority (64%) of nests possessed between one and five access holes, with a further 25% of nests having six to ten holes. Of the remaining nests, 5% had 11-15 holes, 4% had 16-20 holes, and nests with 21-25 holes accounted for only 2% of the total recorded. Based on this frequency distribution, one would only occasionally expect to encounter nests of *X. myoides* with more than ten access holes when conducting nest searches.

Although access holes could be present at any height from ground level to the nest top, the distribution of hole heights for all nest types involving mounded or elevated structures was skewed towards the lower third section of the nest. Consequently, where a structure suspected of being a nest of *X. myoides* possessed multiple holes, additional evidence supporting these suspicions was provided by a higher proportion of holes near the base of the structure.

Access holes showed no obvious difference in size or shape according to their position on the nest. Those at ground level or near the base of a nest structure, however, usually led to tunnels filled with water. As was frequently observed (by SVD) in the captive situation, animals negotiated these flooded passages before entering the nest chambers within. Visible pathways with *X. myoides* footprints leading away from the nest were sometimes detected at ground level access holes, particularly when the surrounding substrate was boggy. These pathways, created through frequent usage by resident animals, often coursed beneath tree roots, dead fall or timber flotsam.

Confusion with other Rodent Activity. It was possible to mistake nests of two other rodent species occupying saltmarsh and mangrove habitats for those of *X. myoides*. Nests of the introduced Black Rat *Rattus rattus* were regularly encountered in the hollow branches and trunks of mangrove trees at heights well above the level of high tide. These nests usually involved obvious collections of dried mangrove leaves, which could be seen through knot holes, broken ends of branches and occasionally down the hollow centres of trunks. Mud, peat or other substrate was never associated with nests of *R. rattus*, but nests often contained crab claws and carapaces. Collections of these crab remains were also encountered in knot holes, branch forks and other recesses in trees thought to represent regular feeding stations used by Black Rats. This suspicion was supported by the identification of hair samples collected from such places as *Rattus* sp. (B. Triggs, pers. comm.). These sites were distinguished from the feeding middens created by *X. myoides* by their presence above ground and by the inclusion of the eaten remains of claws belonging to the crab *Helice leachii*. With a carapace up to 25mm across, this species is probably near the upper size limit of crustaceans preyed upon by Water Mice. Observations in captivity revealed that although *X. myoides* attacked and devoured similar sized species (e.g. *Perisesarma messa*), it did not usually consume the claws, which consequently remained intact (SVD, pers. obs.).

Evidence of activity of a second rodent species, the Swamp Rat *R. lutreolus*, was occasionally discovered in the landward portion of the sedgeland and on the supralittoral bank. This species typically made obvious runways through sedgeland that could be traced for considerable distances among dense ground layer vegetation.

FIG. 22. A pile of spoil created by tunnelling or feeding activity of *Rattus lutreolus* in sedgeland (Coomera River, November 2001). Photo Ian Gynther.

The runways were made more distinct by the Swamp Rat's habit of chewing rushes or sedges along the path, leaving only the stem bases behind. In addition, low mounds or piles formed from *R. lutreolus* tunnel spoil were sometimes encountered. These consisted of a coarse mixture of balls of often peaty substrate and short lengths of chewed sedge stems. The resulting mixture was always much more loosely packed and friable than the substrate found on nests of *X. myoides* (Fig. 22).

DISCUSSION

During our investigation of the Water Mouse's southeast Queensland distribution, we successfully discovered at least one nest structure at all localities at which the species was trapped. This illustrates the considerable value of employing nest search techniques when conducting field surveys. Although the approach is not entirely foolproof, careful searching for evidence of nesting activity of *X. myoides* may represent a more convenient and efficient survey method by comparison to the usual technique of Elliott trapping.

To our knowledge, no other small rodent constructs conspicuous and relatively immense mud nesting mounds after the manner of *X. myoides*. Although comparison of nesting techniques can only be made within a limited field of semi-aquatic rodent genera (see Van Dyck, 1997), it is very likely the preference of *Xeromys* for low altitude, still water, saline conditions and regular tidal fluctuations in water level that has led to the evolution of this unique nesting strategy. In some broad principles of nest construction, however, there are counterparts in lodge-building beavers *Castor canadensis* and muskrats *Ondatra zibethica* from the Northern Hemisphere. Both species gather vegetation into sizeable nesting piles (up to 1.8m and 60-90cm above water level, respectively), which are accessed through underwater tunnels. Of even greater relevance, where earth banks are high enough for dens to be well above water level, or where streams are swift with an accompanying increase in erosional force, both beavers and muskrats dig tunnels into the bank rather than building mounded lodges (Walker, 1964; Burt & Grossenheider, 1976).

Considering the small size of *X. myoides* and the inconvenience that high tides must bring to initial mound construction in the littoral zone, we hypothesise that in situations with a normal tidal range and influence most nests begin in any suitable ground offering sufficient height above the upper tidal level. This would explain the propensity of *X. myoides* for not only colonising the supralittoral bank when one exists, but also raised islands or hummocks, spoil piles, bund walls and clods of earth amongst the roots of upturned trees wherever such features occur in the intertidal zone. However, in exposed situations where minimal buffering is offered by the mangrove community and where no sedges or Marine Couch occur seaward from the supralittoral bank (e.g. Canalpin Creek with its 25m-wide, structurally open mangrove zone), tunnels in the high supralittoral bank may be the only type of nest present. The protection from savage erosion provided by a broad mangrove zone (up to 385m) and abutting zone of sedgeland (up to 32m wide) in locations such as Donnybrook and Rainbow Channel gives the animals time to respond to minor erosion and wet nest chambers by slowly building up nest height with the repeated plastering of mud or peat. Thus examples of additional daubing that formed small mounds atop the nest were recorded from all nest types encountered during the study. On occasions of extreme high tides, these additions were sometimes the only part of the nest above water level (e.g. free-standing nest #s 76, 87, Coomera River; tree trunk nest #105, South Stradbroke Island) and, by observing through access holes, one or more individuals could be seen occupying these most elevated chambers within the nest structure. During an unusually high daytime tide associated with wind and storm surge at Coomera River, an animal was observed by one of us (SVD) escaping from the hole at the top of the nest and being forced to swim to find alternative shelter. Nearby, an adult female and two young were seen sitting under *S. virginicus* cover on the top of a second nest.

The 'islands' with which Type 2 nests are associated very likely form through erosion of the supralittoral bank. Presumably, the life of such supralittoral offcuts is dependent upon their stabilisation by vegetation cover and their capacity to endure further erosion. When such 'islands' are eventually carved from the supralittoral bank, only those sufficiently consolidated by the roots of trees, shrubs and ground cover may remain as high points, maintaining their integrity in the face of spring tides, wind-induced waves and storm surge. Type 2 nests may then originate through colonisation of such newly available high ground within the tidal zone following the island's formation. Conceivably, though, pre-existing supralittoral bank nests may be sufficiently consolidated within the root mass of trees to be able to persist with the island as it is carved off. This would offer a second possible origin of these island nests.

In highly sheltered locations (e.g., Pumicestone Passage), where spring tides fail to establish a supralittoral bank, free-standing nests, constructed slowly in the absence of frequent inundation or tide damage, predominate. This strategy of constructing large, mounded nests in an area lacking terrain features that would provide sufficient height to offer protection against tides enables *X. myoides* to colonise otherwise uninhabitable locations.

Plastering of nests appears to be performed in response to wet nesting chambers or breaching of the nest's outer wall. This conclusion is supported by the infrequency with which such mud-daubing occurs once a nest is established. Plastering of approximately 20cm diameter increased the height of a bank nest (#53) at Rainbow Channel from nothing to 6cm in 17months. More dramatic plastering events were also noted. On Bribie Island, the height of a mound structure on a spoil pile nest (White Patch #47) increased some 15cm over a maximum period of four months, and perhaps over a time span as short as 3-4 weeks (D. Cameron, pers. comm.). This remarkable rate of construction may have been in response to a period of prolonged inundation due to the combined effects of high rainfall (531.5mm) and tide heights of up to 2.51m in February 1999. Although the rate at which plastering and daubing of a nest structure occurs is undoubtedly dependent upon the number of nest occupants, such events as this at Bribie Island are probably atypical and large, free-standing mounds (e.g., nest #s 14,17,57) may represent decades of effort by generations of mice.

Based on the quantity of substrate that would be required to construct a large, mounded structure, we speculate that most, if not all, of the material used to create the tracks and daubing on the nest's top must originate from substrate layers beneath ground level, i.e. below the nest itself. This would also account for the sometimes different nature of the mound and plastering material as compared to the surface substrate immediately surrounding the nest. The observations of Magnusson et al. (1976) support this hypothesis — in the Melville Island *X. myoides* nesting mound, tunnels 3-5cm in diameter were noted to extend as much as 90cm below ground level. The significant volume of material that must have been excavated during their construction was presumably added to the above-ground mud mound.

The use of spoil piles, clods of soil associated with the roots of fallen trees and hollow tree trunks for nesting provided an insight into the opportunistic way *X. myoides* uses structures that provide nest elevation in situations where it is otherwise in short supply. In addition, tree trunk nesting demonstrated that if a durable framework of support were available Water Mice would occupy the littoral zone well out into the mangrove community. It was apparent, though, that not all hollow trunks offer suitable nesting locations for this rodent. Fourteen of the 31 tree trunk records came from one location on South Stradbroke Island, and these were all from *Eucalyptus* stags. The 'stranding' within the mangrove zone of these large upright stumps, up to 125m from the marine/terrestrial boundary, can be attributed to the rise in water level within the Southport Broadwater and subsequent erosion and flooding of the low-lying terrestrial community caused by sand sedimentation inside the Broadwater after the breaching of the hitherto connected North and South Stradbroke Islands at Jumpinpin in 1896 (Connah, 1946; Brooks, 1953). That the present day substrate level is lower than it was previously is readily apparent from the exposed root systems of the dead eucalypts. Presumably, by the time the trunks were hollow and accessible to *X. myoides*, the rise in seawater level had not been so great as to prevent nest mounds being initiated within the trees' protective walls. Furthermore, the ongoing rise in water level must have been gradual enough for the mud mounding process to keep abreast of it.

Although the hard-wearing nature of the eucalypt trunks at this South Stradbroke Island site still protects nests today from daily tidal exacerbations, the building of mud structures from 'scratch' in a regularly and deeply flooded location such as this is probably only possible under the special circumstances in which a particular tree offers safe refuge above high tide to a *X. myoides* individual prior to and during the process of nest construction. Of the 12 cases of nests in mangroves reported here, one (Noosa North Shore #11) occurred in the stump of a Milky Mangrove, which, as is typical of this species, was growing at the marine/terrestrial boundary, landward of the main mangrove community. As a consequence, it would have been inundated only very occasionally during the highest of spring tides. The other mangrove nests were, without fail, either in small to large diameter, sloping trunks or in vertical trees of small diameter. In both situations, the nature of the internal hollows presumably enabled the non-arboreal *X. myoides* to scramble up inside, thereby providing dry shelter to the nest-building individuals during the intervening periods of tidal inundation when mound construction within the trunk (or the stopping up of knot holes and other gaps in the tree) could not be undertaken. This may explain why so many apparently suitable mangrove trunks, particularly those of *Avicennia marina*, are not utilised for nesting by *X. myoides*. Their large diameter, hollow bases are usually vertical and simply don't provide opportunities for *X. myoides* individuals to climb up inside.

Although it was obvious when larger diameter nest trees were either mud-filled or contained a mounded mud structure that could house a nesting chamber, it was never unequivocally ascertained whether Water Mice also filled the internal cavities of small diameter trees with mud or other substrate material for this purpose. It is possible that the only mud workings associated with such nests are the plugged external holes that provide nest security whereas the concealed spaces within the narrow diameter trunks and limbs of the tree itself serve as a nesting chamber. This was suggested by the one tree nest example (Coomera #80) where it was possible to view a leaf-filled chamber within a horizontal trunk following damage to the small mud mound that had previously capped the roof. By contrast to large, free-standing mound structures, which would involve considerable effort to build and maintain, the use of such trees that require relatively little mud plastering or packing to convert them into suitable nest sites may make it possible for individual *X. myoides* to occupy nests on a temporary basis or to maintain multiple nest trees within a single home range. Such simple refuges may be utilised by males or newly recruited individuals, i.e. those animals simply seeking shelter rather than somewhere to raise young. Observations in captivity indicated that, in stark contrast to an adult female, a male *X. myoides* used a very basic nest with a chamber lacking any leaves or grass for lining (SVD, pers. obs.). Similarly, an adult male individual caught by hand under a piece of corrugated iron beside the Tomkinson River, Arnhem Land (Magnusson et al., 1976) may have been using the site as a temporary refuge since no nest was found. The fact that certain tree nests were ephemeral in nature was demonstrated by the finding that they were no longer active on our subsequent visits, with some trees even lacking their once tell-tale signs of mud daubing. Presumably not long after a tree nest is abandoned any mud additions fall into disrepair, particularly when these are incapable of being consolidated by vegetation and are submerged and subjected to tidal currents on a frequent basis.

The same gradual rise in sea level that very likely led to the proliferation of tree trunk nests in the eucalypt stags of South Stradbroke Island may also account for the origin of the free-standing mounds (nest #s 95,102,103) that stand amid the sedges and mangrove fern landward of the mangroves at this site, despite the now regular inundation of this section of the intertidal zone. Here, mound construction may also have been able to keep pace with the long term, incremental change in water height that occurred following the break at Jumpinpin. The extra shelter afforded by the seaward mangrove community, together with the decreased period and extent of tidal inundation in the sedgeland areas as compared to the mangroves, may have allowed nests with no external structural framework, i.e. free-standing mounds, to be built.

Curiously, none of the nests encountered during this study closely matched the description of the original *X. myoides* nest structure from Melville Island provided by Magnusson et al. (1976). It involved a 60cm-high mud mound, containing a nesting chamber, constructed at ground level against the trunk of a living mangrove (*Bruguiera parviflora*) tree. The nest from southeast Queensland that most closely resembled this Northern Territory example was tree trunk nest #81 from Coomera River in which a 42cm-high mud mound was built against the base of a living *Avicennia marina*. Other tree trunk nests with smaller mud mounds were also discovered. However, given the limited size of these mounds, as well as the position of the trees in the littoral zone, the mounds associated with these nests would have been entirely inundated during high tide and so could not serve as nests in their own right. Rather, the purpose of these ancillary mounds may either have been to provide secure access through mud tunnels to the nest proper within the adjacent tree or to serve as a buffer against the tide and thereby prevent mud or organic matter within the tree from washing out through any ground level hole in the trunk. Both explanations may be true. Alternatively, it is interesting to speculate about whether these small mounds built alongside tree nests serve any useful function at all. Because natural selection will have favoured those *X. myoides* individuals that build nest structures above the height of spring tides (the dominant external factor that ultimately must govern nest heights in any region), perhaps animals construct mounds even in situations in which they are not required. Based on our hypothesis about the requirements for nest construction to begin within the mangrove zone, we would assume that the *B. parviflora* adjacent to the nest structure described by Magnusson et al. (1976) was hollow and so able to afford the Water Mice individuals refuge during the mound-building phase.

Trapping and radio-tracking studies have revealed that *X. myoides* regularly follows the receding tide out into the mangrove zone where it feeds until rising water forces it back to the shelter of its nest site (Van Dyck, 1997). This apparent preference for foraging among mangroves suggests this is where food resources for the species occur in the highest densities. This conclusion is supported by studies showing that substrate-dwelling fauna of the mangrove zone is richest in species at the lower tide levels where regular inundation by tides occurs (McCormick, 1978). On first appearances, it would appear sensible for *X. myoides* to nest within the mangrove zone but additional factors come into play. Of all the vegetation communities in the littoral zone, the resource rich mangrove community is the first to be inundated on the flooding tide, and the last to be exposed when the water recedes. Furthermore, the depth of inundation is greater there than anywhere else in the intertidal zone. As a consequence, the time available for a mangrove-nesting *X. myoides* to forage between tides is more limited. We suggest that, overall, nest location, and therefore nest type is a resultant compromise between proximity to the most productive resources of the mangrove zone and a suite of complicating factors, namely the difficulty (or practicality) of nest building in a regularly flooded site, the ability of the nest to withstand tides, particularly spring tides, and the period available for foraging.

In addition to proximity to rich food resources, what other selective advantages may offset the effort in constructing and maintaining large mounds or tree trunk nests within or as close as possible to the productive mangrove zone as opposed to digging simple tunnels into the supralittoral bank near the woodlands and wallum? One possibility is that offspring survival might be higher in complex nest structures attached to high-yielding foraging areas as a consequence of the cumulative effect of home range defence by related adults. This is supported by the incidence of agonistic encounters witnessed between individuals away from nest sites (SVD, pers. obs.). Bank nests, unlike other nest types out in the intertidal zone, are not fully moated at high tide and so may offer less protection from snakes and more opportunities for disruptive intrusion from conspecifics. Additional disturbance may be caused by the foraging activity of *Rattus lutreolus* and predation by *R. rattus* and *Hydromys chrysogaster*. The evening journey between the supralittoral bank and foraging areas within the mangroves may also produce higher losses to nocturnal raptors, Red Foxes *Vulpes vulpes* and Cats *Felis catus*. Finally, fire, the dramatic event that revitalises wallum and coastal woodland by triggering germination, may select those mice that nest far