National recovery plan for the water mouse (false water rat) *Xeromys myoides*

Queensland Government

Northern Territory Government

Australian Government

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Cover photograph: Water mouse (false water rat) *Xeromys myoides* (image by Totally Wild, Network 10)

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Abbreviations:

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
EPBC	Environment Protection and Biodiversity Conservation Act 1999
DEEDI	Queensland Department of Employment, Economic Development and Innovation
DERM	Queensland Department of Environment and Resource Management
DPIFM	Northern Territory Department of Primary Industries, Fisheries and Mines
GIS	Geographic Information Systems
NCA	Queensland Nature Conservation Act 1992
NRETAS	Northern Territory Department of Natural Resources, Environment, the Arts and Sport
SEQ	South East Queensland
TPWC	Territory, Parks and Wildlife Conservation Act 2000
VMA	Queensland Vegetation Management Act 1999
WildNet	A centralised, searchable database of Queensland's flora and fauna that is maintained by the Queensland Department of Environment and Resource Management
WPSQ	Wildlife Preservation Society of Queensland

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1. Executive Summary

Species description and taxonomy
The water mouse or false water-rat *Xeromys myoides* Thomas 1889 is a small native rodent recorded from coastal saltmarsh including samphire shrublands, saline reed-beds and saline grasslands, mangroves and coastal freshwater wetlands. The water mouse has small eyes and small, rounded ears. The dorsal coat is slate-grey and the belly is white. It has a maximum head and body length of 126 mm and maximum weight 64 g. The water mouse is a specialised mammal and is distinguished from other species that may be encountered in similar habitat because of its overall size and appearance. The species is also known as the false water rat and yirrkoo.

Current species status
The species is listed as 'Vulnerable' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Queensland *Nature Conservation Act 1992* (NCA) (listed as false water-rat). In the Northern Territory *X.myoides* is listed under the *Territory Parks and Wildlife Conservation Act 2000* (TPWC Act) as 'Data Deficient'. The species is recorded on Appendix I of CITES[1]. Currently, the common name used is water mouse and for the purposes of this report, *X. myoides* will be referred to as the water mouse.

Habitat and distribution
The water mouse has been recorded in coastal saltmarsh, mangrove and adjacent freshwater wetland habitats in the Northern Territory, Queensland and New Guinea. In Queensland, the species is known from the Proserpine area south to near the Queensland/ New South Wales border. In the Northern Territory, it has been recorded from widely separated sites in Arnhem Land, the South Alligator River, Daly River and Melville Island.

Threats to species' survival
In Queensland, habitat loss, through clearing and fragmentation, and habitat degradation due to altered hydrology are the most significant threatening processes for the water mouse. In addition, site-specific impacts from introduced animals, recreational vehicles, habitat modification including by changes in soil chemistry due to disturbance of acid sulphate soils, and pesticide applications may contribute to local population extinctions. Reflecting the very different development pressures across its disjunct range, the main threats in the Northern Territory are quite different and include coastal habitat change due to saltwater intrusion, spread of exotic pasture grasses, impacts of feral animals and livestock (especially associated with intensification of pastoral activities), and possibly predation by feral cats.

Recovery objective
The overall objective of the recovery plan is to improve the conservation status of the water mouse and its habitat through habitat protection, reducing threats to species' survival, research and increasing public participation in recovery activities.

[1] Appendix I includes those species that are most endangered among CITES listed animals and plants. They are threatened with extinction and CITES prohibits international trade in specimens of these species except where the purpose of import is not commercial.

Summary of actions
Key actions required for the recovery of the water mouse include confirming and documenting the current distribution of the species; mapping known populations and their habitat; assessing the impact of known threatening processes; developing and implementing a threat management plan to rehabilitate habitat at priority sites; engaging the community in efforts to protect existing populations by establishing voluntary agreements with relevant land owners and managers; and coordinating the recovery process.

Evaluation and review
This is the first national recovery plan for the species. The plan will be reviewed within five years from adoption as a national recovery plan. Relevant experts will review implementation actions and their effect on the recovery of the water mouse.

2. General Information

The water mouse (false water-rat) *Xeromys myoides* Thomas 1889 is a small native rodent recorded from coastal saltmarsh including samphire shrublands, saline reed-beds and saline grasslands, mangroves and coastal freshwater wetlands. The water mouse, also known as the false water rat and yirrkoo, is the only member of the genus and, together with the water rat *Hydromys chrysogaster*, comprises the Tribe Hydromyini in Australia (Walton and Richardson 1989).

Conservation status
The water mouse is listed as 'Vulnerable' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act 1999) and the Queensland *Nature Conservation Act 1992* (NCA). It is listed as Data Deficient in the Northern Territory under the *Territory Parks and Wildlife Conservation Act 2000* (TPWC).

International obligations
The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) lists *X. myoides* (as False Water Rat) on Appendix I.

Affected interests
Australian Government
Department of the Environment, Water, Heritage and the Arts
Department of Defence

Queensland Government
Department of Environment and Resource Management
Department of Employment, Economic Development and Innovation
Queensland Museum

Local government
Local government areas throughout the range of the species in Queensland

Land councils (and the Traditional Owner groups they represent)
Queensland South Native Title Services Ltd
Central Queensland Land Council Aboriginal Corporation
Gurang Land Council Aboriginal Corporation
Northern Land Council
Tiwi Land Council

Regional natural resource management (NRM) boards
Reef Catchments Mackay Whitsunday
Fitzroy Basin Association
Burnett Mary Regional Group for Natural Resource Management Inc
SEQ Catchments
Natural Resource Management Board (NT) Inc

Non-government organisations and the community
Landcare groups
Conservation organisations and natural history groups
Research institutions
Private landholders and leaseholders

Northern Territory Government
Department of Natural Resources, Environment, the Arts and Sport
Department of Resources

Local government
Local government areas throughout the range of the species in the Northern Territory

Non-government organisations and the community
Landcare groups
Indigenous ranger groups
Conservation organisations and natural history groups
Research institutions
Private landholders and leaseholders

Consultation with Indigenous peoples
The water mouse occurs in coastal saltmarsh, mangrove and adjacent freshwater wetland habitats in coastal areas of central and south-east Queensland, the mainland and near-shore islands of the Northern Territory and in New Guinea. As a consequence of this broad distribution, implementation of components of this recovery plan will require assistance and input from a range of Indigenous peoples who either have management responsibility for affected lands or have a cultural connection to lands critical for the conservation of the water mouse.

Consultation with Indigenous stakeholders in the development of actions for the recovery of this species was sought in Queensland and the Northern Territory. Implementation of the actions within this plan includes consideration of the role and interests of Indigenous peoples in the water mouse's conservation. It may also require training and the development of appropriate education and information materials. All activities will be undertaken in a manner that respects the cultural traditions of Aboriginal peoples throughout the species' range.

Benefits to other species and communities

Protecting habitat critical to the survival of the water mouse will benefit a range of listed threatened and migratory (as recognised under the JAMBA[2] ,CAMBA[3] and ROKAMBA[3] bilateral agreements) species as well as 'Endangered' and 'Of concern' regional ecosystems. These include Illidge's ant-blue butterfly *Acrodipsas illidgei*, swamp orchid *Phaius australis*, *Durringtonia palidosa* and coastal lowland vegetation communities such as inter-tidal mangrove, saltmeadow, paperbark (*Melaleuca*) wetland, and coastal heathland (wallum). Table 1 lists these species and communities.

Conserving and protecting these species and habitat areas will result in a number of positive flow-on effects for terrestrial and aquatic ecological processes.

[2] JAMBA: Agreement between the Government of Australia and the Government of Japan for the protection of migratory birds in danger of extinction and their environment. (Australian Treaty Series 1981 No. 6).

[3] ROKAMBA: Agreement between the Government of Australia and the Government of the Republic of Korea on the protection of migratory birds and exchange of notes. (Australian Treaty Series 2007 ATS 24).

Table 1. Significant biodiversity benefits from protecting habitat critical to survival of *Xeromys myoides*

Common Name	Scientific Name	Habitat	Legislation	Status
Illidge's ant-blue butterfly	Acrodipsas illidgei	Coastal wetland and mangrove	NCA	Vulnerable
Latham's snipe	Gallinago hardwickii	Coastal, inter-tidal and freshwater wetlands	EPBCA	Migratory
Australian painted snipe	Rostratula australis	Coastal, inter-tidal and freshwater wetlands	EPBCA/NCA	Migratory Vulnerable
common greenshank	Tringa nebularia	Coastal, inter-tidal and freshwater wetlands	EPBCA	Migratory
lesser sand plover	Charadrius mongolus	Coastal and inter-tidal wetlands and rocky reefs	EPBCA	Migratory
grey plover	Pluvialis squatarola	Inter-tidal wetland and rocky reefs	EPBCA	Migratory
grey-tailed tattler	Heteroscelus brevipes	Coastal wetland and rocky inter-tidal	EPBCA	Migratory
bar-tailed godwit	Limosa lapponica	Coastal, inter--tidal and freshwater wetlands	EPBCA	Migratory
eastern curlew	Numenius madagascariensis	Coastal and/or inter-tidal wetlands	EPBCA NCA	Migratory Near threatened
whimbrel	Numenius phaeopus	Coastal and/or inter-tidal wetlands	EPBCA	Migratory
Pacific golden plover	Pluvialis fulva	Coastal and inter-tidal wetlands and rocky reefs	EPBCA	Migratory
terek sandpiper	Xenus cinereus	Coastal and inter-tidal wetlands	EPBCA	Migratory
yellow chat (Alligator Rivers subspecies)	Epthianura crocea tunneyi	Coastal wetland	EPBCA/ TPWCA	Endangered/ Vulnerable
Cooloola sedgefrog	Litoria cooloolensis	Coastal and freshwater 'acid' wetlands	NCA	Near threatened
wallum rocketfrog	Litoria freycineti	Coastal and freshwater 'acid' wetlands	NCA	Vulnerable
wallum sedgefrog	Litoria olongburensis	Coastal and freshwater 'acid' wetlands	EPBCA/NCA	Vulnerable
wallum froglet	Crinia tinnula	Coastal and freshwater 'acid' wetlands	NCA	Vulnerable
grey-headed flying-fox	Pteropus poliocephalus	Eastern coastal vegetation	EPBCA	Vulnerable
estuarine crocodile	Crocodylus porosus	Coastal, estuarine and	NCA	Vulnerable

Common Name	Scientific Name	Habitat	Legislation	Status
		freshwater wetlands		
Oxleyan pygmy perch	Nannoperca oxleyana	Coastal and freshwater 'acid' wetlands	EPBCA/NCA	Endangered Vulnerable
honey blue-eye	Pseudomugil mellis	Coastal freshwater wetland	EPBCA/NCA	Vulnerable
swamp orchid	Phaius australis	Coastal and freshwater wetlands	EPBCA/NCA	Endangered
	Garcinia warreni	Inter-tidal wetland (mangroves)	TPWCA	Endangered
	Monocharia hastata	Coastal wetland	TPWCA	Vulnerable
	Utricularia dunstaniae	Coastal wetland	TPWCA	Vulnerable
	Utricularia singeriana	Freshwater wetland	TPWCA	Vulnerable
durringtonia	Durringtonia paludosa	Coastal and freshwater wetlands	NCA	Near threatened
Regional Ecosystem 12.1.1[4]		*Casuarina glauca* open forest on margins of marine clays	VMA	Endangered
Regional Ecosystem 12.2.7		*Melaleuca quinquenervia* or *M. viridiflora* open forest to woodland on sand plains	VMA	Of Concern

VMA – Vegetation Management Act 1999 (Queensland)
EPBCA – Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
NCA – Nature Conservation Act 1992 (Queensland)
TPWCA – Territory Parks and Wildlife Conservation Act 2000 (Northern Territory)

Social and economic impacts

It is not expected that the implementation of recovery actions will have any significant adverse social or economic impacts. Implementation of this recovery plan will have advantages in improved land management of a range of regional ecosystems. Any management actions to conserve the water mouse to be undertaken on private land will be in consultation with and with the approval of the landholders. Required changes to

[4] From the *Regional Ecosystem Description Database* that lists the status of regional ecosystems as gazetted under the Queensland *Vegetation Management Act 1999* (their vegetation management status), and their biodiversity status. This database is maintained by the Queensland Department of Environment and Resource Management. Available from: http://www.epa.qld.gov.au/nature_conservation/biodiversity/regional_ecosystems/introduction_and_status/ Accessed 2009-06-04

land use or restriction of activities recommended within this recovery plan may be offset by the support and incentives provided by voluntary conservation mechanisms.

3. Biological information

Species description
The water mouse is a relatively small, specialised mammal (Ball 2004) and is distinguished from other species that may be encountered in similar habitat because of its overall size and appearance. Body dimensions from a Northern Territory specimen (Magnusson et al. 1976) and detailed studies of populations from south-east and central Queensland are summarised in Table 2 and provide an indication of adult characteristics (Gynther and Janetzki 2008).

Table 2. Body characteristics of adult *Xeromys myoides*

Feature	Male (average)	Female (average)
Head and body length (mm)	72-126 (105)	74-124 (102)
Tail length (mm)	62-94 (85)	63-99 (82)
Weight (g)	32-64 (42)	32-64 (42)

The water mouse has small eyes and small, rounded ears. The dorsal coat is slate-grey in colour whereas the belly is clearly defined and white (Van Dyck 1997). Sparse, white speckling has been observed on some adult individuals.

Life history and ecology:
Nesting strategies
The water mouse is probably entirely nocturnal, sheltering during the day and between tidal cycles in constructed nesting mounds and natural or artificial hollows. *Xeromys myoides* is also known to utilise artificial structures where no other suitable sites exist (Van Dyck et al. 2003). The first published description of an active nest was of a structure built against the base of a small-leaved orange mangrove *Bruguiera parviflora* on Melville Island, Northern Territory (Magnusson et al. 1976).

A range of nesting strategies for the water mouse has been identified at mainland and island locations in south-east Queensland (Van Dyck and Gynther 2003). Five different strategies are described from four different vegetation communities. Nesting structures are summarised broadly by Van Dyck and Gynther (2003) as being:

- free-standing
- small elevated sedgeland ‘islands’
- within living or dead trees
- within the bank above the high water mark
- within human-made spoil heaps.

In the Mackay region of Queensland *X. myoides* was only observed using sloping mud nests constructed among the buttress roots of mangrove trees, although nests excavated in banks may have gone undetected (Ball 2004).

A two-year survey of water mouse populations in the Great Sandy Strait and Wide Bay/Burnett regions of Queensland identified 207 nest structures at 22 sites across these previously poorly sampled areas, with the highest concentration of nests being found in the Kauri Creek catchment and Tin Can Inlet (Burnham 2002).

Diet and foraging activity
From observational accounts in tidal areas, the water mouse utilises exposed mangrove substrata to hunt for invertebrate prey amongst pneumatophores (roots rising above the ground or water) and in shallow pools. These activities occur nocturnally when individuals follow the tide out to the low water mark and forage until advancing waters inundate the mangrove community (Van Dyck 1997). The ecology of *X. myoides* utilising non-tidal environments has not been investigated.

Food preference studies have not been conducted for the water mouse. However, the species is known to frequent regular feeding locations, depositing the remains of previous meals in middens (Van Dyck 1997). From these, fragments of shell and other remains have been collected and identified to provide information on the range of organisms targeted for feeding. These comprise a number of invertebrates including grapsid crabs, other inter-tidal crustaceans, pulmonate snails and marine gastropods (see Newman and Cannon 1997, Van Dyck 1997 for all known prey species). These species are common in inter-tidal saltmarsh habitats in south-east Queensland (Breitfuss et al. 2004).

Reproductive biology
To date, little is known about the reproductive biology of the water mouse, although the species has been successfully held in captivity for short periods (S Van Dyck pers. comm. 2007). A study by Van Dyck (1997) on North Stradbroke Island (Queensland) found up to eight animals of mixed age and gender may share a mound, however, there is generally only one sexually active male present. The nest may also be used by successive generations of water mouse over a number of years.

Distribution
In Australia, the water mouse is currently known from coastal areas of central and south-east Queensland from Proserpine south to the Queensland/New South Wales border region (Van Dyck and Gynther 2003; Ball 2004) and a small number of near-coastal sites in the top end of the Northern Territory (McDougall 1944; Redhead and McKean 1975; Magnusson et al. 1976, Van Dyck 1997; Woinarski et al. 2000). A map illustrating known records of the species is provided in Appendix 1.

In Queensland the water mouse has been recorded on the mainland from the Proserpine region, at Mackay, an area south of Gladstone, and from south-east Queensland between Hervey Bay and the Coomera River (50 km south-east of Brisbane). Additional records are from Fraser Island, Bribie Island, North Stradbroke Island and South Stradbroke Island.

In the Northern Territory, the water mouse has been recorded from widely separated sites on the Glyde River and Tomkinson River in Arnhem Land and the South Alligator River, Daly River and Melville Island (Woinarski 2006; Woinarski et al. 2007), although most of these records are now very dated. The species has also been recorded from Papua New Guinea (Hitchcock 1998). Specimens were collected close to a seasonally inundated freshwater wetland surrounded by *Melaleuca* forest on the Bensbach River floodplain (Hitchcock 1998).

Within Queensland different survey strategies appear to be more suited to particular sections of the species' range. For example, nest site surveys that enable a convenient and relatively rapid assessment of the presence/absence of the species in southern Queensland (Burnham 2002, Van Dyck and Gynther 2003) are not as useful along the central Queensland coast where free-standing nests have not been encountered and other nest types are detected infrequently (Ball 2004). Most records of the water mouse in the latter area have resulted from Elliott trapping. Interestingly pitfall trapping has

proved successful in the Northern Territory at sites where previous cage and Elliott trapping did not capture the species (Woinarski et al. 2000). Pitfall trapping is seldom used by workers targeting the water mouse in Queensland.

Exploratory surveys for the water mouse have been conducted at locations in addition to those at which the species is known to occur (Van Dyck and Gynther 2003; S Van Dyck and I Gynther pers. obs). In particular, wetland habitats directly south of the New South Wales/Queensland border and in Brisbane have been surveyed, with no positive records to date. Currently, the distribution of *X. myoides* is patchy but the reasons are unclear for the species' apparent absence from areas that possess similar habitat to occupied sites. The water mouse may also fail to be detected during re-survey of sites that had known populations (Ball 2004) or may be captured where earlier efforts were unsuccessful (Woinarski et al. 2000). The cause of such temporal changes in distribution and abundance are unknown. There has been no targeted survey for this species across its Northern Territory range.

To date, only a preliminary, inconclusive investigation of the extent of genetic variation within *X. myoides* has been undertaken, based on a small sample size (Vitalone 2002). A more detailed analysis is required to determine whether the current, fragmented populations that occur over the species' essentially linear range in Australia and New Guinea are genetically distinct. The value of such an investigation is that it could reveal the existence of cryptic species or some form of population structuring, and determine if the pattern of fragmentation is a result of historical or contemporary and/or anthropogenic influences. The results of such research would have implications for the conservation management of the water mouse, identifying whether recovery action should be targeted at the species as a whole or at separate demographic units or distinct taxa.

Habitat critical to the survival of the species

The characteristics of vegetation communities and landforms associated with areas where the water mouse has been captured are detailed in a number of published and unpublished reports (e.g. Woinarski et al. 2000; Burnham 2002; Van Dyck and Gynther 2003; Ball 2004). These accounts describe nests or capture of individuals from both freshwater and saline habitats associated with various coastal and freshwater flora assemblages and a range of landform features. Vegetation types utilised by the water mouse include sedgeland composed mainly of freshwater vegetation, chenopod shrubland including succulents and dwarf shrubs, *Sporobolus* grassland and salt meadows, and a range of mangrove communities.

Habitat modelling has not been conducted for any part of the national distribution of the water mouse. However, habitat suitability maps or maps indicating locations of significant water mouse populations have been produced for the Central Queensland Coast and Southeast Queensland bioregions. Ecological information and expert knowledge was used to demarcate 'essential habitat' for the species as part of the Queensland DERM Biodiversity Planning Assessments. These assessments function as biodiversity and nature conservation information tools to assist land use and land management decision-making, e.g. assessment of clearing applications under Queensland's *Vegetation Management Act 1999*. Due to the paucity of water mouse records, no detailed mapping has been undertaken in the Northern Territory.

Important populations

The water mouse is recorded from a number of protected areas in central and south-east Queensland. These include:

- Cape Palmerston National Park, Cape Hillsborough National Park and Sandringham Bay Conservation Park in central Queensland

- Eurimbula National Park, Great Sandy National Park, Poona National Park, Great Sandy Conservation Park, Beerwah Forest Reserve and Bribie Island National Park in south-east Queensland
- Protection zones within the Southern Moreton Bay Marine Park in south-east Queensland.

Within the Great Sandy Strait, south-east Queensland, some populations of water mouse are located within the Fraser Island World Heritage Area, and others occur within the Wide Bay Military Reserve.

A large percentage of the water mouse populations in the Great Sandy Strait and Moreton Bay areas of south-east Queensland occur in inter-tidal habitats within the Great Sandy Strait and Moreton Bay Ramsar[5] Sites.

In south-east Queensland, high density populations of *X. myoides* occur within the Great Sandy Strait (including Tin Can Bay), Pumicestone Passage and southern Moreton Bay (including the western shores of North and South Stradbroke Islands).

In the Northern Territory, land on which the water mouse is known to occur on Melville Island and the mainland is managed by Traditional Owners. Access to these sites is by permit, through the Tiwi Land Council and the Northern Land Council respectively.

One Northern Territory population is known from Kakadu National Park, but there is no knowledge of this population other than a broad location described at the time of its discovery in 1903 (Woinarski 2004).

Threats to Species' Survival

Physical

The most important issues for the water mouse are the loss, degradation and fragmentation of freshwater and inter-tidal wetland communities utilised by the species. Whilst clearing results in the obvious loss of habitat structure, processes that degrade or fragment core elements of a habitat can reduce potential feeding resources and nesting opportunities, extend edge effects, promote weed invasion and increase predatory pest densities or their impacts on native fauna.

In some parts of Queensland, water mouse habitats are often within areas of significant urban expansion and have been cleared to accommodate human development and infrastructure. For example, certain areas of mangrove and adjacent saltmarsh and freshwater wetland habitats have been cleared and/or modified for development in the Southeast Queensland bioregion. As an illustration, approximately 94% remains of the pre-clearing mappable area of 53,499 ha of mangroves (Regional Ecosystem 12.1.3), while the equivalent figure for tidal saltmarsh communities (Regional Ecosystem 12.1.2) is 87% of a pre-clearing extent of 32,713 ha (Accad et al. 2008).

[5] *The Convention on Wetlands* (Ramsar 1971) is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. These sites are included on the List of Wetlands of International Importance.

At a local level, habitats important for the water mouse are influenced by a number of natural and artificial physical processes. Natural physical processes include:

- fluctuations in sea level that result in altered patterns of vegetation zoning between mangrove, saltmarsh and terrestrial communities
- subsidence and accretion of inter-tidal sediments that results in modified community distribution, structure and composition
- natural flooding events that directly limit or reduce the distribution of the water mouse.

More broadly, much of the floodplain wetlands of northern Australia are likely to be highly susceptible to change arising from even small rises in sea levels associated with global climate change. Such saltwater intrusion will cause losses of productive freshwater habitats and their replacement by saline systems. Too little is currently known about the habitat requirements of the water mouse in this region to assess whether this environmental change will be detrimental, neutral or beneficial to this species.

Other potential threats to the survival of *X. myoides* include:

- changes in hydrology, including increased freshwater inflows and sedimentation from stormwater runoff as a result of adjacent residential development
- physical changes to saltmarsh such as runnelling or bundwall construction that modify tidal amplitude and frequency of inundation
- reclamation of inter-tidal and terrestrial habitats as a result of deposition of dredge spoil
- use of recreational vehicles in inter-tidal areas due to the long-lasting damage they cause through destruction and degradation of habitat
- modified water levels and salinity in tidal waterways resulting from installation of flow control gates for flood mitigation
- drainage of coastal and terrestrial wetlands for urban and industrial developments
- inappropriate burning of sedgeland, grassland and adjacent *Melaleuca* wetland communities.

Artificial physical processes may also impact on the water mouse indirectly. For example, changes to salinity and sediment loads caused by increased stormwater runoff from expanding urbanisation are detrimental to populations of grapsid crabs, a major food source for *X. myoides* (Ball et al. 2006).

Biological

Direct biological impacts on the water mouse include predation pressures from native and introduced fauna, competition for food resources and modification of suitable habitat by feral and hard-hoofed animals such as pigs.

Predation pressures from feral and domestic dogs, foxes and feral and domestic cats are likely to pose significant threats to populations of the water mouse, particularly those located close to urban environments in parts of coastal Queensland. However, these pressures have not been quantified for isolated populations. Remains of the water mouse have been detected in dingo scats on Fraser Island (K Twyford pers. comm. 2007), although the population-level significance of predation of *X. myoides* by dingoes is unknown.

Destruction or degradation of habitat by feral and hard-hoofed animals (e.g. pigs) has been recorded from a number of populations of the water mouse (Burnham 2002; S Van Dyck and I Gynther pers. obs). In the Northern Territory, much of the lowland wetland

communities of this species is being deliberately or inadvertently transformed by the spread of exotic plant species, including *Mimosa pigra* and exotic pasture grasses (such as para grass and olive hymenachne). The impacts of such changes on the status of the water mouse are uncertain.

Chemical

In south-east and central Queensland, saltmarsh and mangrove habitats occur adjacent to agriculture (e.g. sugar cane lands) and urban development. Herbicides and pesticides are employed for pest management, but may also persist in natural environments (Zimmerman et al. 2000), possibly impacting non-target populations and potentially affecting the water mouse and/or its prey and habitat.

Changes in soil chemistry, for instance the development of acid sulphate soils as a result of disturbance and exposure to air of 'at risk' soils, may disrupt mangrove habitat, e.g. mangrove and saltmarsh communities near Tweed Heads in the late 1980s (C Easton pers. comm. 2002).

Off-shore pollution events such as oil spills have the potential to negatively influence the function and health of mangrove and saltmarsh communities. As a result, the cumulative impacts from these activities may result in secondary effects on populations of the water mouse and/or its primary food sources.

Populations under threat

Local reductions and disappearances of water mouse populations have been recorded both in Queensland and the Northern Territory in the past 30 years and at least one local extinction event has been recorded at Coomera Waters adjacent to the Coomera River, Gold Coast (Van Dyck et al. 2006.). Exploitative reclamation of coastal habitats for urban development is a primary factor involved in the loss of habitat important for the water mouse. The impacts from these types of habitat loss are difficult to quantify, however, some populations in south-east Queensland are known to have been affected, whether directly or indirectly, by development activities (Van Dyck et al. 2006). For example, monthly trap censuses demonstrated the decline and eventual disappearance of a robust population of *X. myoides* over a five-year period coincident with the development of the adjacent 118 ha, 1100-allotment Coomera Waters canal estate (Van Dyck et al. 2006). No further captures of water mouse were recorded despite increased trap effort over the subsequent 16 months. The precise cause of this local extinction is unclear but may be the result of one or more factors associated with the estate's development (Van Dyck et al. 2006).

4. Recovery objectives, performance criteria and actions

Overall objective
The overall objective of the recovery plan is to improve the conservation status of the water mouse and its habitat through habitat protection, reducing threats to species' survival, research and increasing public participation in recovery activities.

Specific objectives

Specific objective 1: Identify habitats supporting populations of the water mouse and map the current distribution.

Action 1.1: Conduct surveys to confirm the current distribution of the water mouse.

- Based on live trapping and/or positive nest identification, conduct surveys of all previously known populations across the range of the water mouse to confirm the species' continued presence.
- Wherever captures are made, collect relevant DNA samples (ear clip, tail tip or blood) from individuals in each subpopulation to contribute to an investigation of genetic variation within the species. Genetic researchers should be contacted to determine the appropriate samples to be collected and to ensure optimal sampling strategies are implemented. Investigate the potential to use non-intrusive sampling methods, e.g. hair samples.
- Record key habitat features and biological associations for all survey locations.

Performance criteria: Historic and other previously known sites are surveyed to confirm the species' continued presence.

Potential contributors: NRETAS, QMuseum, Regional NRM boards (i.e. Reef Catchments Mackay Whitsunday Burnett Mary Regional Group for Natural Resource Management Inc, SEQ Catchments, Natural Resource Management Board [NT] Inc), research institutions, volunteers, DERM.

Action 1.2: Consolidate existing Queensland and Northern Territory water mouse databases to form a comprehensive national dataset, including survey results and sites supporting extant populations.

- Produce an up-to-date and verified national database of all records of water mouse on *WildNet* including historical, specimen-backed and contemporary records. The database will record information on survey locations, survey effort, habitat type, tenure and disturbance history, as well as presence/absence of the species. This will serve as a register of sites with extant populations and will assist in directing future survey effort, reassessing conservation status of the water mouse, prioritising sites for active management and targeting areas for habitat protection through conservation agreements.
- Maintain and review the database on an ongoing basis to ensure the data remain current and accurate.

Performance criteria: Within two years, record on *WildNet* accurate, comprehensive details of all sites supporting extant populations.

Potential contributors: DERM, NRETAS

Action 1.3: Produce high-quality GIS mapping and undertake spatial analysis of habitat supporting extant populations, particularly for sites under most severe threat.

- Review existing maps of historical capture and nesting locations to provide a baseline for further mapping.
- Evaluate and improve existing GIS habitat models to assist in planning field surveys of new areas covered by these models under Action 1.4.
- Ascertain the most appropriate GIS habitat modelling techniques to be applied to areas not covered by the existing habitat models to enable the occurrence of the water mouse elsewhere to be predicted.
- Based on the outcome of this work, integrated with the results of Actions 1.1-1.2 and 1.4, produce up-to-date mapping of extant populations and their geographic extent, relating the status of current and historical sites to key landscape types, habitat features, vegetation associations, tidal inundation regimes and land use.
- Determine whether habitat corridors link occupied sites.
- From this new mapping, identify sites protected under State or Commonwealth legislation and those on other land tenures.

Performance criteria: GIS maps produced by Year 3 and updated annually. Local maps of extant populations are produced within two years.

Potential contributors: DERM, NRETAS

Action 1.4: Conduct surveys and ecological assessments of potential water mouse habitat.

- Following an evaluation of existing GIS habitat models and the development of additional GIS habitat modelling for other areas within the range of the water mouse (Action 1.3), conduct targeted trapping and nest surveys at predicted new sites, particularly those possessing a high correlation of key characteristics to known water mouse locations.
- Target areas adjacent to known populations to determine the geographic extent of the species. In particular, areas of extensive mangrove and saltmarsh vegetation between previously identified locations across the range of the species should be surveyed. In south-east Queensland, survey effort should be extended on river systems such as the Noosa and Maroochy Rivers to more fully define the distribution and upstream extent of occurrence of the water mouse.
- Where appropriate, collect genetic samples as in Action 1.1.
- Update *WildNet* with the results of these surveys and habitat assessments.

Performance criteria: For each locality, at least one additional site with potential habitat is surveyed annually.

Potential contributors: QMuseum, Regional NRM boards, research institutions, conservation groups, volunteers, DERM, NRETAS

Specific objective 2: Describe key biological and ecological features of the water mouse and its habitat.

Action 2.1: Determine whether genetic differentiation exists across populations of the water mouse.

- Conduct a genetic analysis of the DNA samples collected from subpopulations of the water mouse from Actions 1.1 and 1.4 to investigate the degree of genetic variation inherent within the species. Ideally, the sampling would represent the entire distribution of the species in Australia. This analysis may possibly demonstrate the existence of cryptic species or determine the extent of population structuring present within what is essentially a fragmented, linear distribution around the northern and eastern coasts of Australia. The potential for the existence of more than one species or genetically identifiable population has significant implications for the conservation status, as well as for managing the species and individual populations to ensure the maintenance of genetic diversity.
- Consult genetic researchers to determine the appropriate samples to be collected (e.g. tail tips or ear clips for mtDNA; blood for allozymes) and to ensure optimal sampling strategies are implemented. Investigate the potential to use non-intrusive sampling methods (e.g. hair samples).

Performance criteria: The degree of genetic variation within the overall distribution of the water mouse is determined and a report produced within three years of the commencement of the investigation. Paper(s) detailing findings of the research produced by the plan's fifth year.

Potential contributors: QMuseum, research institutions, NRETAS

Action 2.2: Understand the reproductive biology of the water mouse.

- Focus research efforts towards providing a greater understanding of basic reproductive features of the water mouse. This information will be important for determining the species' capacity for recovery once threatening processes are ameliorated. Current knowledge of the reproductive biology of the species is minimal. Data are required about: breeding behaviour, mating characteristics, nesting structures and their function, development to sexual maturity, external genitalia, gestation period, fecundity, foetal development, brood size and reproductive seasonality in the wild.
-

Performance criteria: Research plan is developed during the recovery plan's first year of implementation and paper(s) produced within five years of commencement of the recovery plan, to detail findings of this research.

Potential contributors: research institutions, DERM, NRETAS

Action 2.3: Investigate selected field populations to describe poorly known ecological features of the water mouse.

- Investigate characteristics of field populations, such as home range, feeding/foraging areas, population structure and inter/intra-specific competition. The focus should be towards basic biological and ecological characteristics that are currently little understood. This study should be site-specific and based on information gaps, and should include targeted monthly work on at least two field populations over three years.
- Although selection of potential locations for regular investigation will depend upon factors such as ease of access and size of the water mouse population, sites should be chosen from different parts of the known range of the species to encompass any variation in life history characteristics across the distribution. In south-east Queensland, suitable populations would be those from Pumicestone Passage (e.g. Donnybrook) or southern Moreton Bay (e.g. McCoys Creek).

Performance criteria: Research plan developed during the first year of implementation of the recovery plan. Regular study of at least two populations conducted for three years. Reports and paper(s) produced within five years of commencement of the recovery plan, detailing findings of the research.

Potential contributors: NRETAS, research institutions

Specific objective 3: Monitor population trends and identify and manage threats to species' survival.

Action 3.1: Conduct a monitoring program of selected representative water mouse populations to measure trends in abundance of the species and efficacy of management actions.

- Develop a robust monitoring protocol and establish a long-term monitoring program at representative sites, especially where such monitoring can measure the efficacy of management actions and/or the responses of this species to environmental change or the impacts of known or putative threats.

Performance criteria: Consistent monitoring protocols developed during the recovery plan's second year of implementation. Monitoring program trialled and results analysed. Robust monitoring program implemented for at least three representative sites. Resulting trend data are reported annually.

Potential contributors: NRETAS, Regional NRM boards, research institutions, DERM

Action 3.2: Assess the impact of known threats to species' survival on extant populations of the water mouse.

- Assess the impact of identified processes that threaten species' survival, including: habitat destruction and fragmentation from development (e.g. Sunshine Coast and northern Gold Coast of south-east Queensland); direct and indirect effects of stormwater runoff from residential developments (e.g. Mackay region of central Queensland); damage to habitat caused by recreational vehicle usage (e.g. Tin Can Bay/Great Sandy Strait area of south-east Queensland); habitat degradation by feral and hard-hoofed animals (e.g. pigs); predation by native and introduced fauna (e.g. saltmarsh areas of Pumicestone Passage, south-east Queensland); cattle grazing and trampling (e.g. Coomera River, Gold Coast; Daly River floodplains, Northern Territory); inappropriate fire events that may directly threaten individuals nesting structures and expose foraging water mice to a greater risk of predation by removing vegetation cover in sedgeland, grassland and adjacent *Melaleuca* communities (e.g. Pumicestone Passage); and impacts of weed invasion on aspects such as the viability of extant water mouse populations and the restriction of re-colonisation of populations into adjacent habitats.
- Use the results of site-specific studies to formulate and guide future management actions.

Performance criteria: Report produced within three years of commencement of recovery plan detailing results, implications and recommendations for all extant populations of the water mouse.

Potential contributors: NRETAS, Regional NRM boards, research institutions, DERM

Action 3.3: Investigate the relative impact of potential threats to species' survival.

- Model the likely impacts on habitat suitability of factors arising from global climate change (particularly change in seawater levels).
- Study the potential direct and indirect impacts of chemical pesticide treatments on field populations of the water mouse, in particular, products employed for mosquito control in coastal wetlands that affect non-target invertebrate populations. Possible areas for study include wetlands adjacent to higher density human populations on the Gold and Sunshine Coasts of south-east Queensland, particularly where housing developments have recently been completed or construction is due to commence.
- Through a desk-top review of available literature, examine the possible indirect impacts on the water mouse of chemical pesticide treatments used to control mosquitoes.
- Investigate pesticides registered for use in sugar cane production (e.g. in the Mackay area of central Queensland and the Maroochy River area of the Sunshine Coast) to determine whether they have adverse impacts or indirect impacts on the water mouse.
- Assess the potential direct and indirect impacts on the water mouse of major changes to soil chemistry and water quality. Potential study locations include the Gold and Sunshine Coasts of south-east Queensland where industrial, residential, marina or other significant developments are planned or have commenced. If possible, review the impact on the water mouse of sand quarrying operations at Donnybrook on the western side of Pumicestone Passage in south-east Queensland, where an important population of water mice occurred prior to extraction activities commencing.
- Study the foraging ecology of feral predators in and adjoining inter-tidal vegetation communities (e.g. foxes and cats in the Pimpama River to Coomera River corridor of the Gold Coast) to determine the significance of impacts on the water mouse.

Performance criteria: Report produced within five years of commencement of this recovery plan, detailing results, identifying additional confirmed threats and providing recommendations for mitigating threats to species' survival.

Potential contributors: NRETAS, research institutions, DERM

Action 3.4: Develop and implement a threat management plan.

- Based on the recommendations from Actions 3.1-3.3, produce a threat management plan to identify threats to species' survival and outline measures to mitigate these threats, e.g. control of feral predators; creating conservation reserves; encouraging land holders and land managers to protect and conserve habitat (e.g. by fencing to exclude cattle; instigating appropriate and carefully planned fire regimes for habitat adjacent to occupied sites, etc.); and enhancing the quality of habitat adjacent to extant populations including through use of buffer zones.
- Identify and implement management actions to reduce or remove threats to species' survival at five priority locations for the water mouse.

Performance criteria: Production of a threat management plan and annual reports detailing work undertaken at five selected sites.

Potential contributors: NRETAS, local governments, Regional NRM boards, landholders

Specific objective 4: Rehabilitate habitat to expand extant populations.

Action 4.1: Regenerate habitat corridors at five sites.

- Based on the findings from Actions 1.1-1.4 and the results of Actions 2.1 and 3.1-3.4, develop a site rehabilitation plan and establish active regeneration programs at selected sites adjacent to and linking extant water mouse populations, working in collaboration with interested landowners or land managers wherever possible. Exclusion fencing, revegetation, removal of introduced species (plants and animals), restoration of natural hydrology and modification of stormwater inflows from residential areas may facilitate natural regeneration of sites. Results of survey and monitoring efforts conducted previously suggest possible sites for rehabilitation in south-east Queensland could include the lower Noosa and Maroochy Rivers; the western shore of Pumicestone Passage; and the Behms Creek to Pimpama River corridor and Coomera River area of southern Moreton Bay. On the central Queensland coast, potential areas for such work include the Glen Isla/Goorganga area; McCready's Creek, Reliance Creek and unallocated land along Rocky Dam Creek.
- Monitor rehabilitated sites at three-monthly intervals and conduct assessments against criteria detailed in the rehabilitation plan.

Performance criteria: Rehabilitation plan developed within first year of recovery plan implementation, and regeneration programs commenced at five sites within two years. Progress of site regeneration is reported annually thereafter.

Potential contributors: DERM, NRETAS, local governments, Regional NRM boards, conservation groups, volunteers

Action 4.2: Evaluate the potential for artificial nesting structures to encourage re-colonisation of suitable habitat by the water mouse.

- Investigate the degree to which artificial nesting structures (based on previously published, successful designs; see Van Dyck et al. 2003) are used by the water mouse. If determined to be viable and practical, installation of these structures may encourage animals to take up residence in sites that lack natural opportunities for nesting but which otherwise possess suitable habitat. This approach may facilitate the expansion of existing water mouse populations. Such work could be undertaken in conjunction with habitat rehabilitation projects at south-east Queensland sites identified in Action 4.1 (e.g. at Behms Creek, or Pimpama River).
- Use the results of the investigation to refine the design of the artificial nesting structures so as to enhance colonisation under field conditions.

Performance criteria: Trials utilising artificial nest structures are conducted at two sites. Results and recommendations, including any refinements in design of artificial nest structures, reported within four years of commencement of recovery plan.

Potential contributors: QMuseum, research institutions, conservation groups

Specific objective 5: Increase public awareness of, and involvement in, water mouse conservation.

Action 5.1: Collaborate with Indigenous landowners to exchange knowledge about the water mouse, its environment, threats to species' survival and management.

- Improve current understanding of the species' biology and ecological requirements, as well as knowledge of threats to species' survival. This approach will enhance the conservation management of the water mouse.
- Develop communication products to facilitate this information exchange.

Performance criteria: Relevant Indigenous landowners have an appreciation of the conservation significance of this species, and are supportive of its conservation management. Relevant Indigenous knowledge of this species is applied where appropriate to guide management actions.

Potential contributors: DERM, NRETAS, landholders, Land Councils, Traditional Owners

Action 5.2: Investigate opportunities for protecting the habitat of extant populations on freehold land and land managed by local, State and Commonwealth governments through establishment of voluntary conservation agreements.

- Use the findings from the survey and mapping activities conducted in Actions 1.1-1.4 to identify landowners or land managers who have *X. myoides* on their properties or lands adjacent to mapped sites.
- Investigate opportunities to protect this habitat through various voluntary mechanisms (such as nature refuges, voluntary conservation agreements, *Land for Wildlife*) involving the landowners or managers and the relevant level of government.
- Consider employing incentives schemes to secure habitat critical for the protection of extant populations.

Performance criteria: Voluntary conservation agreements to protect land supporting (or adjacent to) extant populations are established within five years of commencement of this recovery plan.

Potential contributors: DERM, Department of Defence, DEEDI, local governments, landholders

Action 5.3: Develop and implement management plans for populations of water mouse occurring on land that is subject to voluntary conservation agreements.

- Establish extension programs for landowners and land managers who have entered into a voluntary agreement to protect *X. myoides* under Action 5.2, with the aim of explaining how to manage the species and its habitat.
- Apply the results of Actions 3.2-3.4 to identify relevant threats to the water mouse population and determine how these threats are best mitigated at specific sites.
- Working with the relevant parties, develop site-specific management plans for the water mouse populations for land covered by voluntary conservation agreements.

- Assist landowners and land managers in securing funding to implement the property-specific management plans for the water mouse.

Performance criteria: Management plans are developed and implemented within five years of recovery plan implementation for all land covered by voluntary conservation agreements representing known habitat or potential habitat of the water mouse.

Potential contributors: local government, Regional NRM boards, landholders

Action 5.4: Develop and implement a community awareness and education program focusing on the water mouse.

- Formulate and implement a community extension and education program in local government areas where the water mouse is known to exist, with the aim of increasing public awareness of issues relevant to the survival of the species. Previously, the Wildlife Preservation Society of Queensland (WPSQ) conducted a program involving community training in water mouse survey and nest identification techniques, followed by field days and community-based surveys in locations including the islands of southern Moreton Bay in south-east Queensland. As part of this program, an educational brochure was produced and information on the water mouse made available on the WPSQ web site (refer http://www.wildlife.org.au).
- Review this earlier program and the existing brochures, posters etc, with the aim of producing new or revised materials, holding additional field days or guided walks, and developing novel approaches to broaden the audience receiving the educational message about the water mouse. So as to build community awareness and capacity to support the recovery effort it will be important to identify the appropriate target audience and design the materials and approaches accordingly,.

Performance criteria: Community awareness and education program for key local government areas is developed and implemented within five years.

Potential contributors: local governments, Regional NRM boards

Summary table

Table 3 outlines the recovery actions described above, including the relative priority of each action, and potential stakeholders.

Table 3. Summary of recovery implementation

Action	Performance criteria	Potential contributors	Priority*
Specific objective 1: Identify habitats supporting populations of the water mouse and map the current distribution			
1.1: Confirm current distribution of the water mouse	Surveys of previously known water mouse populations conducted and DNA samples collected	NRETAS, QMuseum, Regional NRM boards, research institutions, volunteers, DERM	1
1.2: Consolidate data concerning all water mouse records and survey results	Comprehensive database of water mouse information incorporated on *WildNet* within two years of recovery plan implementation and data regularly maintained and updated.	DERM, NRETAS	2
1.3: Produce GIS mapping and undertaken spatial analysis of water mouse habitat	GIS database produced within two years. Maps of extant populations produced within two years of implementation of recovery plan.	DERM, NRETAS	1
1.4: Conduct surveys and ecological assessments of potential water mouse habitat	For each locality, at least one additional site with potential water mouse habitat is surveyed annually.	QMuseum, Regional NRM boards, research institutions, conservation groups, volunteers, DERM, NRETAS	2
Specific objective 2: Describe key biological and ecological features of the water mouse and its habitat			
2.1: Determine whether genetic variation exists across populations of the water mouse	Genetic variation across overall distribution of the water mouse determined, and a report produced within three years of commencement of the investigation. Paper(s) detailing findings of research produced within five years of recovery plan implementation.	QMuseum, research institutions, NRETAS	1
2.2: Understand the reproductive biology of the water mouse	Research plan developed within one year of implementation of the recovery plan and paper(s) produced detailing findings of the research within five years	Research institutions, DERM, NRETAS	3

2.3: Investigate selected field populations of the water mouse	Research plan developed within one year of implementation of the recovery plan. Regular monitoring of two populations conducted for three years. Reports and paper(s) detailing findings of the research produced within five years	NRETAS, research institutions	2
Specific objective 3: Identify and manage threats to species' survival			
3.1. Monitor representative populations	Consistent monitoring protocols developed during the plan's second year. Monitoring program trialled and results analysed. Robust monitoring program implemented for at least three representative sites. Resulting trend data reported annually.	NRETAS, Regional NRM boards, research institutions, DERM	1
3.2: Assess impact of known threats to species' survival	Report results, implications and recommendations within three years of commencement of recovery plan.	NRETAS, Regional NRM boards, research institutions, DERM	1
3.3: Investigate relative impact of potential threats to species' survival	Report produced within five years of commencement of this recovery plan, detailing results, identifying additional confirmed threats and providing recommendations for mitigating threats to species' survival.	NRETAS, research institutions, DERM	2
3.4: Develop and implement threat management plan	Production of a threat management plan and annual reports detailing work undertaken at five sites.	NRETAS, local governments, Regional NRM boards, landholders	1

Specific objective 4: Rehabilitate habitat to expand extant populations			
4.1: Regenerate habitat corridors at five sites	Rehabilitation plan developed within first year of recovery plan implementation, and regeneration programs commenced at five sites within two years. Annual progress reports prepared thereafter.	DERM, NRETAS, local governments, NRM boards, conservation groups, volunteers	3
4.2: Evaluate the potential for artificial nesting structures to encourage re-colonisation of suitable habitat by the water mouse	Trials utilising artificial nest structures conducted at two sites, with results and recommendations reported within four years of commencement of recovery plan.	QMuseum, research institutions, conservation groups	2

Specific objective 5: Increase public awareness of, and involvement in, water mouse conservation			
5.1: Collaborate with Indigenous landowners to exchange knowledge about the water mouse, its environment, threats to species' survival and management	Relevant Indigenous landowners have an appreciation of the conservation significance of this species, and are supportive of its conservation management. Relevant Indigenous knowledge of this species is applied where appropriate to guide management actions.	DERM, NRETAS, landholders, Land Councils, Traditional Owners	2
5.2: Investigate opportunities for protecting the habitat of extant populations through voluntary conservation agreements	Voluntary conservation agreements to protect land supporting (or adjacent to) extant populations established within five years of commencement of this recovery plan.	DERM, Department of Defence, DEEDI, local government, landholders	1
5.3: Develop and implement management plans for populations of water mouse occurring on land that is subject to voluntary conservation agreements	Management plans developed and implemented within five years of recovery plan implementation for all land covered by voluntary conservation agreements that is known habitat or potential habitat of the water mouse.	Local government, Regional NRM boards, landholders	1
5.4: Develop and implement a community awareness and education program focusing on the water mouse	Community awareness and education program about the water mouse developed for key local government areas and implemented within five years of recovery plan commencement.	Local government, Regional NRM boards	2

*** Priority ratings are: 1 - action critical to meeting plan objectives; 2 - action contributing to meeting plan objectives; 3 - desirable but non-essential action.**

5. Management Practices

Appropriate management of the habitat of the water mouse is critical to the survival of the species. Issues that are known or considered to impact negatively upon *X. myoides,* based on current knowledge of the biology of the species include:

- clearing, drainage and/or other modification of coastal freshwater and inter-tidal wetland communities utilised by the species to accommodate human development, infrastructure and extractive industry;
- reclamation of inter-tidal and terrestrial habitats due to deposition of dredge spoil;
- fragmentation of coastal vegetation communities due to the direct impacts (e.g. loss of habitat, limited dispersal opportunities, reduced genetic exchange) and indirect impacts (e.g. increased feral predation, increased weed invasion);
- disturbance/exposure to air of potential acid sulphate soils due to potential for changes in soil chemistry, e.g. acidification that may adversely the health of mangrove, saltmarsh and other vegetation communities;
- changes to natural hydrology that adversely impact on inter-tidal communities (including prey species) or the adjacent terrestrial community;
- activities that threaten the integrity of the supralittoral bank, a physical feature of the inter-tidal habitat commonly used for nesting by the water mouse;
- mechanical changes (e.g. runnelling, construction of bundwalls) to saltmarsh that modifies tidal amplitude and frequency of inundation;
- presence of recreational vehicles on inter-tidal wetland areas;
- degradation of habitat through grazing and trampling of wetland, saltmarsh and mangrove areas;
- discharge of wastes (stormwater runoff from residential areas, thermal effluents, sewage, and industrial and urban wastes) into estuaries;
- offshore oil pollution events, which have the potential to damage the function and health of mangrove communities;
- installation of flow control gates for flood mitigation, which modify water levels and salinity in tidal waterways;
- spread of exotic pasture grasses on floodplain and other wetland habitats;
- chemical (fertiliser, herbicide and pesticide) usage on land adjacent to water mouse habitat.

6. Cost of recovery

The estimated costs associated with implementing this National recovery plan for the water mouse *Xeromys myoides* are provided below:

Table 4. Costs of water mouse recovery

Action	Year 1 ($)	Year 2 ($)	Year 3 ($)	Year 4 ($)	Year 5 ($)	Total per action
Action 1.1	36 000	36 000	0	0	0	$72 000
Action 1.2	12 000	12 000	12 000	12 000	12 000	$60 000
Action 1.3	16 000	16 000	16 000	16 000	16 000	$80 000
Action 1.4	4400	4400	4400	4400	4400	$22 000
Action 2.1	0	15 000	10 000	10 000	0	$35 000
Action 2.2	0	15 000	15 000	15 000	0	$45 000
Action 2.3	0	15 000	15 000	15 000	0	$45 000
Action 3.1	10 000	20 000	10 000	10 000	10 000	$60 000
Action 3.2	0	72 000	50 000	0	0	$122 000
Action 3.3	12 000	12 000	12 000	12 000	12 000	$60 000
Action 3.4	35 000	20 000	20 000	20 000	20 000	$115 000
Action 4.1	14 000	44 000	44 000	44 000	44 000	$190 000
Action 4.2	0	12 000	12 000	12 000	0	$36 000
Action 5.1	0	10 000	10 000	0	0	$20 000
Action 5.2	Indirect costs only					—
Action 5.3	0	4000	4000	4000	4000	$16 000
Action 5.4	40 000	10 000	10 000	10 000	10 000	$80 000
Total per year	**$179 400**	**$317 400**	**$244 400**	**$184 400**	**$132 400**	**$1 058 000**

7. Evaluation of recovery plan

Relevant experts will review implementation actions and their effect on the recovery of the water mouse. A full review of progress will be conducted within five years from adoption as a National recovery plan.

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- External Consultants: Adrian Caneris (Biodiversity Assessment and Management P/L)
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10. Appendices

Appendix 1. Known current and recent historical records for *Xeromys myoides* in Australia.