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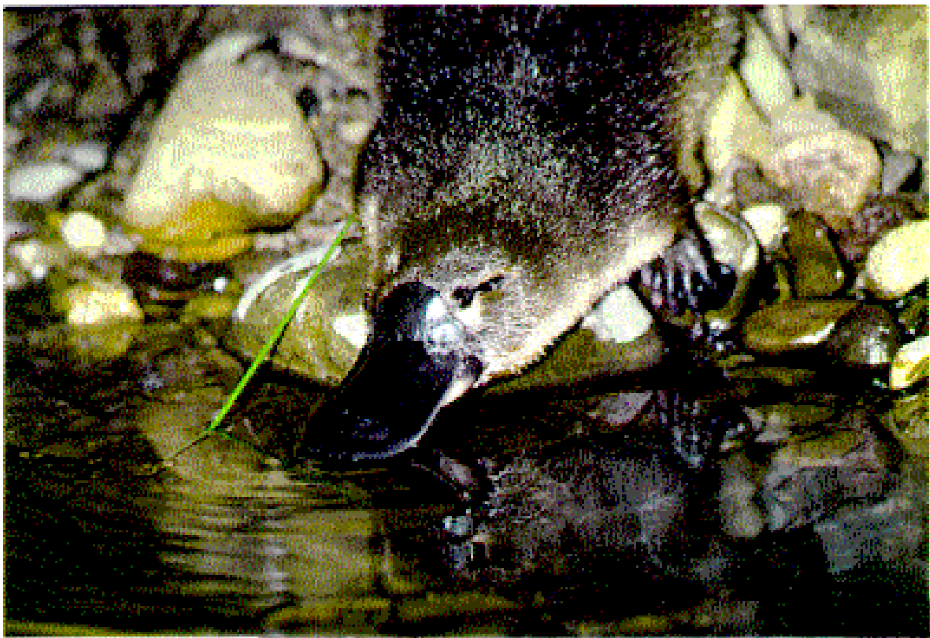
by **Anthony Scott** and **Tom Grant**



Technical Report 23/97; November 1997

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Cover Photos; Platypus entering the water (Ford Kristo, Animal Image Photography);
Water Rat in the Culgoa River (Robert W G Jenkins, Nature Focus)

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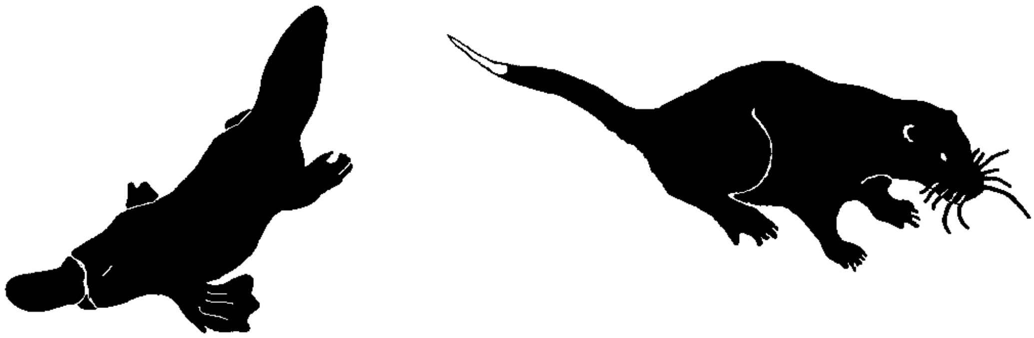
Abstract

The platypus (*Ornithorhynchus anatinus*) and the water rat (*Hydromys chrysogaster*) are amphibious mammals that inhabit rivers of the Murray-Darling Basin.

In the past, both these animals have been hunted for their fur and numbers declined. Many were also drowned in nets set by commercial fishermen. Although the numbers of both the platypus and water rat appear to have recovered from these past activities, other potential threats still exist.

The instream habitat utilised by both species has changed in the past few decades due to the impacts of river regulation and the associated dams and weirs. Habitat quality has also been reduced by the loss of riparian vegetation.

This report reviews the habitat requirements of both the platypus and water rat and discusses the likely impacts of water management practices within the Murray-Darling Basin.



Part 1. The platypus

1. Introduction

The platypus (*Ornithorhynchus anatinus*) is a unique mammal found only in inland water bodies of eastern Australia. It is one of three monotremes (egg-laying mammals) that exist in the world, the other two being the long-beaked and short-beaked echidnas. Although distinctly a mammal, as indicated by warm bloodedness, the habit of suckling its young with milk and the presence of fur, it also has a number of reptilian affinities such as the laying of eggs. Other interesting features of the platypus are adaptations to its specialised mode of life; the duck-like bill, dorsal nostrils, paddle-like tail and webbed feet.

2. Present distribution and abundance

The distribution of the platypus in south-eastern mainland Australia is shown in Figure 1. Within the Murray-Darling Basin, they are most common in the headwaters of rivers and streams along the Great Dividing Range and are less common on the western slopes (Grant 1992a). The species is generally rare or absent as these rivers traverse the western plains. Very occasional sightings however, are reported along the lower reaches of the Murrumbidgee River and also along the Murray River as far west as Renmark in South Australia (Grant 1992a).

Population densities within its present distribution vary markedly. For instance, along the lower sections of the Murray River, from Tocumwal to Swan Hill, there were only 12 reported sightings between 1980 and 1990 (Grant 1992a). In more suitable habitat, abundance can be a lot higher, for instance Gust and Handasyde (1995) caught 120 individuals (over a three year period) along a 3.5 km stretch of the Goulburn River in Victoria. No-one has yet attempted to calculate the total population of platypuses throughout its entire range, although it is safe to say that there must be many thousands.

3. Changes in abundance and distribution since European settlement

Until the turn of the century, platypuses were hunted for their skins and this had a considerable impact on their abundance (Grant 1995). They were given legal protection in Victoria in 1892, followed by NSW (1901), Queensland (1906) and South Australia (1912). Many would also have been drowned by the netting activities of the early freshwater fishery (Grant 1993). The fishery was based mainly on the Murrumbidgee and Murray Rivers, but extended into many other inland river systems. Today, the freshwater fishing industry is considerably smaller although there is still an overlap between platypus distribution and commercial fishing in the lower Murrumbidgee and lower Murray. Restrictions on the mesh size of nets has also reduced (but not eliminated) the chance of platypuses being caught (Grant 1993).

Over the last few decades, the distribution and abundance of platypuses appear to have recovered in most rivers, although the commercial fishery and illegal netting might still be suppressing numbers in the lower Murrumbidgee and Murray rivers (Grant 1993). There is also evidence that in some Victorian streams, platypus abundance is being reduced by the use of eel nets and fyke nets. The platypus is now considered to be common but vulnerable (Carrick 1995, Grant 1991).

Another potential threat to the platypus is river regulation and water extraction for irrigation. A large number of dams and weirs have been constructed on most rivers within the Murray-Darling Basin, and in many instances the natural flow regimes have been completely changed. However, historical records indicate that river regulation has had little effect on the distribution of the platypus. They can still be found immediately downstream of large water storages such as Burrinjuck and Blowering (Grant 1995), and are also occasionally sighted in the lower reaches of the Murrumbidgee and Murray Rivers, both of which are highly regulated. Although there is evidence which indicates that river regulation has not caused a decline in platypus distribution, it is difficult to tell if it has caused a significant impact on abundance.

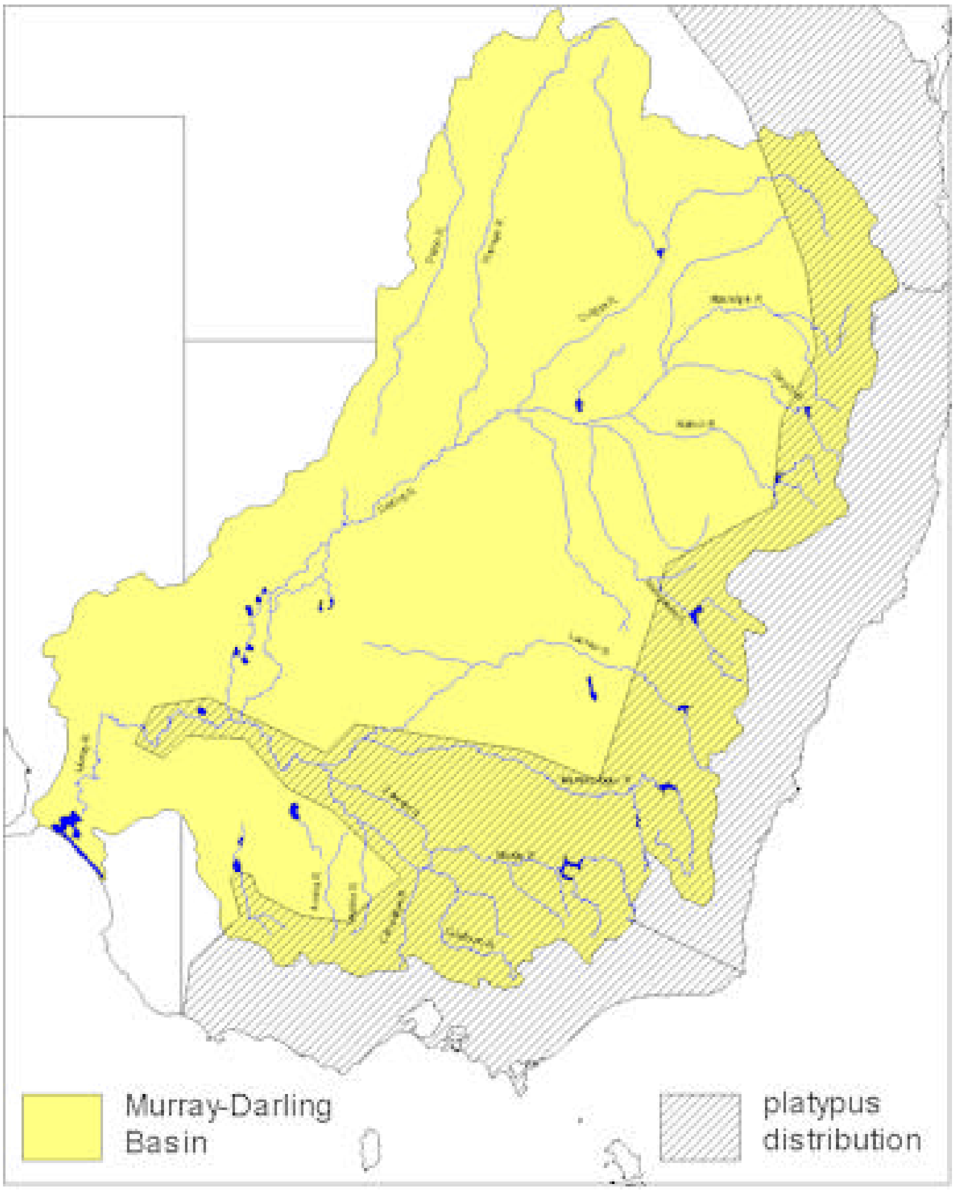


Figure 1. Present distribution of the platypus in south-east mainland Australia.
Based on information from Grant (1992) and Menkhorst (1995)

4. Habitat

Ideal habitat for the platypus is a fairly shallow river or stream with relatively steep earth banks consolidated by the roots of native vegetation and with its growth overhanging the bank. The river should have a diversity of habitats for benthic invertebrates (the main food source), including aquatic vegetation and logs, and consist of a series of distinct pools of less than 5 metres depth, with little sand accumulation and separated by cobbled riffle areas (Grant 1995). Riparian vegetation is an important component for a number reasons. Firstly, the roots help consolidate the banks and hence protect the platypus burrows from collapsing, and secondly, the overhanging vegetation provides cover from predators when they enter or leave their burrows. Riparian vegetation also creates suitable habitat in the stream for benthic invertebrate food species by providing shade, food material and habitat diversity (Riding and Carter 1992, Cummins 1993).

Platypuses can also inhabit natural and artificial lakes, particularly if they are connected to a nearby stream and are not too deep. Most large water storages within the Murray-Darling Basin do not provide suitable habitat since they tend to be too deep for the platypus to dive to the bottom for food. Furthermore, the supply of food is limited as benthic productivity declines with increasing water depth. This is due to the reduced light penetration with increasing water depth which in turn limits primary production in the lower water layers (and hence benthic productivity). However, platypuses

Platypuses are known to utilise a number of short (3-5 metre long) resting burrows, (Burrell 1927, Gust and Handasyde 1995) which are thought to be important as protection from predators and from the extremes of ambient temperature. Burrows used for nesting tend to be more elaborate and are generally 3-8 metres in length but may be as long as 30 metres and have numerous side branches. The burrows are generally inclined upwards, with the end of the burrow close to the ground surface. This provides greater protection from rises in water level. Studies in the Yarra River catchment, Victoria, found that undercut banks were favoured for burrows, although some were also found in banks with vertical or convex profiles (Serena pers. comm.). It was also observed that burrows were only located in banks where the burrow chamber could be sited at least 0.5 metres above the water level.

Increasing amounts of bank rock, boulder and cobble cover also decreases the suitability for construction of burrows (Woon and Laxdal 1993). As an increasing proportion of the river bank is taken up with rock there is a decreasing amount of bank potentially available for digging burrows. Bank soil composition will determine how easy it is to excavate a burrow and also whether the burrow is liable to collapse. The soil type might also affect the gas and moisture exchange characteristics of the burrow.

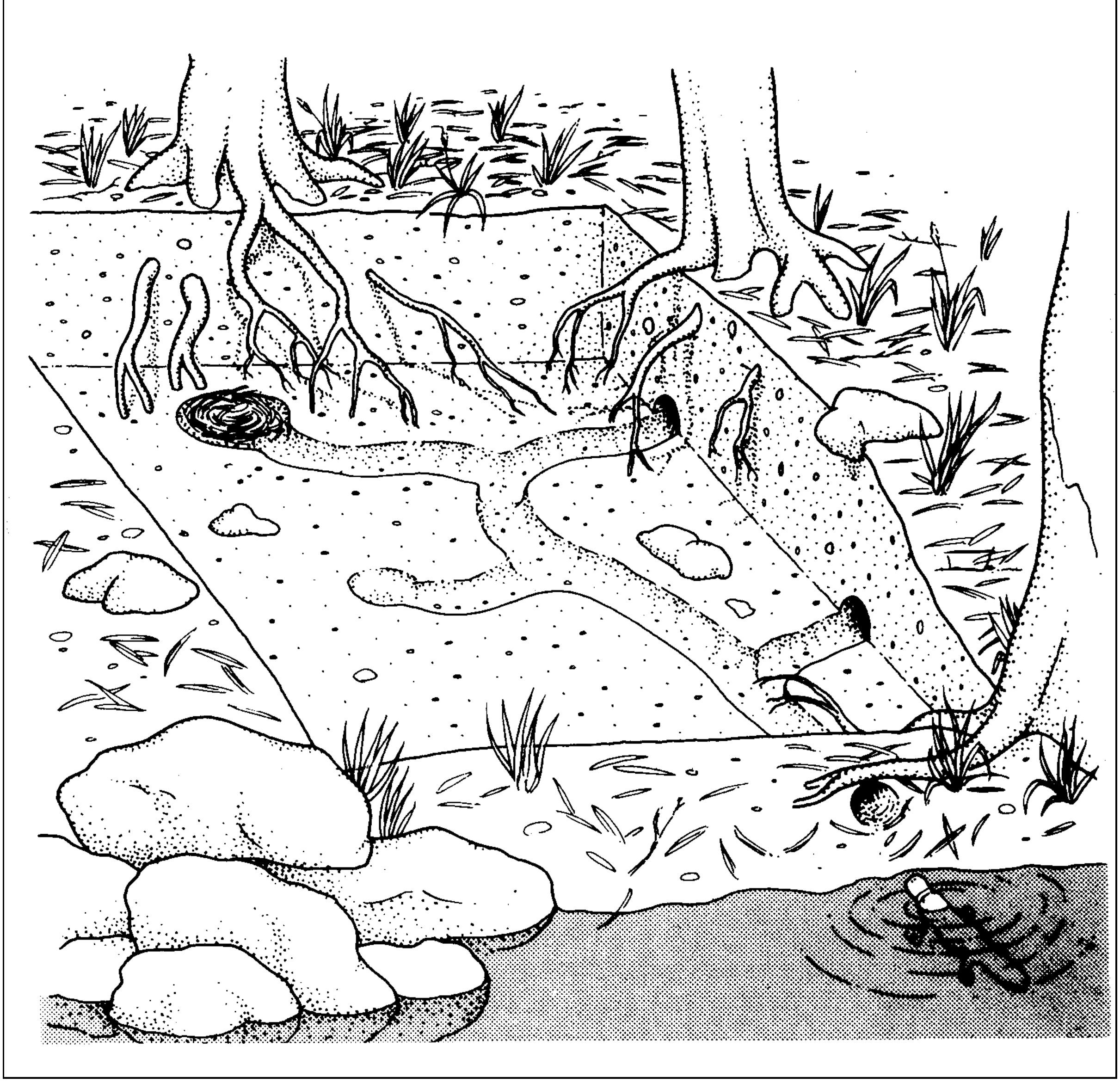


Figure 2; The nesting burrow; *This may be quite a complex affair and is constructed by the female. They are often built around tree roots, which help to consolidate the soil and prevent collapse. Platypuses also construct resting burrows and these tend to be much simpler structures.*

5. Movement and dispersal

It seems that most platypuses have a definite home range which may include one or a number of adjacent pools along a stretch of river. In a study along the upper Shoalhaven river in the southern tablelands of NSW, only 32% of adults were recaptured outside the pool in which they were originally netted (Grant 1992b, Grant 1995). Of these, less than half had moved distances of more than one kilometre and only 6% had moved a distance greater than 3km. Similar results have been obtained from rivers and streams in Victoria where home ranges have been estimated from 0.35 to 2.6 km in the Goulburn river (Gust and Handasyde 1995) and 0.3 to 2.3 km along tributaries of the Yarra River (Serena 1994). On occasions, however, adults, and in particular males, have been found to move outside their normal home range, with distances of up to 15km having been recorded (Serena 1995).

Mark and recapture studies in both Victoria and New South Wales have found that after juvenile platypuses emerge from the nesting burrows in January to March, they are caught for a number of months in their 'home' area, but then their recaptures decline (Grant 1995). Juveniles may disperse in search of new places to live and might be forced to do so by competition for food with the resident population.

Small weirs (with wall heights of 3 metres or less) do not prevent the dispersal or movement of platypuses, as shown by studies on the Barnard river in NSW (Grant and Denny 1987). Platypuses are capable of moving around the wall by walking overland, although they are more prone to predation while doing so. Larger structures however, such as Burrinjuck Dam on the Murrumbidgee River, create a significant barrier that platypuses find difficult to negotiate and these inhibit both the movement of adults and the dispersal of juveniles.

6. The life cycle of the platypus

Platypuses are seasonal breeders (Temple-Smith 1973) and do not require any particular flow regime to attain breeding condition. Within a population, there is a spread in the times when individuals actually breed, with some individuals mating earlier than others. Grant (1995) suggests that within the Murray-Darling Basin breeding occurs earliest in Queensland, later in New South Wales, and latest in Victoria, with the eggs being laid some time between the beginning and middle of spring (Figure 3). Young platypuses do not appear to breed until they are at least two years old and some females do not breed until their fourth year or later (Grant 1995). Also, not all adult females in a population will breed each year.

Females lay up to three eggs (most often two) at a time but do so only once per year. The length of incubation is probably about 10-11 days. Lactation occurs for about 3-4 months and usually the young emerge from the burrows between late January-March in NSW (Grant and Griffiths 1992). At this time they have grown to about 80-90% of their adult length. In captivity platypuses have lived for up to 21 years (Whittington 1991), and in the wild, one individual originally marked as a juvenile, has been recaptured 13 years later (Grant, unpublished).

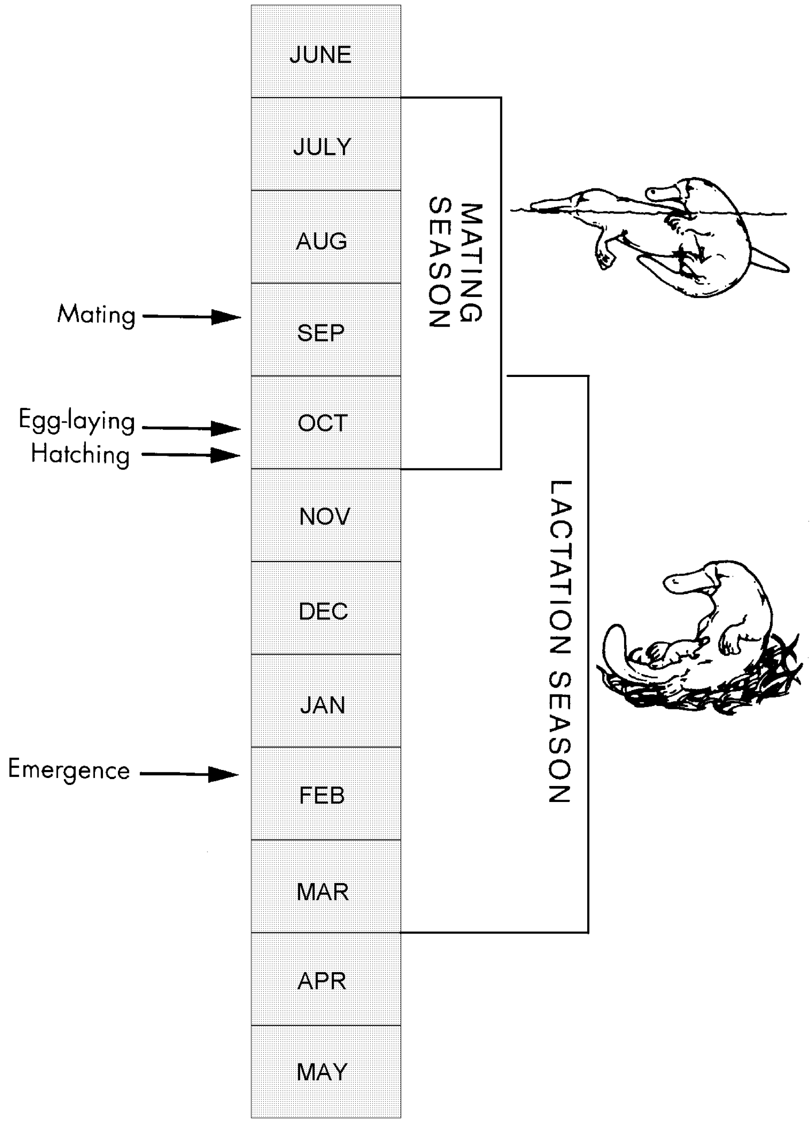


Figure 3; The breeding season. *This diagram is representative of platypuses in the southern highlands of NSW. In Queensland, breeding would commence slightly earlier, and in Victoria slightly later (from Grant 1995).*

7. Diet and feeding habits

The abundance of food within a river is one of the major determinants of platypus abundance. Most platypuses emerge from their burrows after dusk, spend much of the night feeding and then return at dawn. Occasionally some animals will also feed during the day. They search for food by fossicking with their bills along the river bottom and will collect food from both the slow moving and rapid (riffle) areas of streams. The bill is equipped with a sensory system that includes both an array of touch receptors (Bohringer and Rowe 1977; Rowe and Bohringer 1992) and electroreceptors capable of detecting the tiny electrical fields emitted by muscle contractions of their prey (Scheich *et al.* 1986, Gregory *et al.* 1987).

Most of their diet consists of insect larvae such as caddis fly (Trichoptera), fly (Diptera) and mayfly (Ephemeroptera), along with other bottom dwelling (benthic) macroinvertebrates such as shrimps and molluscs (Faragher *et al* 1979, Grant 1982). They tend to be opportunists to the extent that their diet varies depending on the availability of different food types.

Many instream factors are related to the productivity and structure of the benthic community, including pH, turbidity, nutrient loading, conductivity, water temperature, sedimentation and leaf litter input, and these may therefore indirectly affect platypus abundance.

8. Surviving floods

In the headwaters of rivers in southern half of the Murray-Darling Basin, rain tends to fall (and the snow starts to melt) during late winter and spring and this is the time during which floods are most likely to occur. In the northern half of the Basin (northern NSW and southern Queensland) floods can occur at any time of the year, but with a slightly higher incidence in the summer months.

Although some mortality of platypuses associated with flooding has been reported (Grant 1995), particularly if there is river bank erosion (and hence destruction of burrows), it appears that most survive and many are not even displaced from their home range. It is not fully understood how they cope with flooding, but some evidence indicates that they will move away from the river into billabongs and backwaters until the waters have subsided (Gust and Handasyde 1995). Grant (1995) also observed that platypuses avoided the strong currents during periods of peak flow by foraging close to the bank.

9. Bankfull flows during the irrigation season

Under natural flow conditions, the middle and upper reaches of rivers in the Murray-Darling Basin that are inhabited by platypuses, generally experience floods that last for a few days or occasionally a couple of weeks. Many of these rivers are now regulated to provide drinking and irrigation water, and downstream of the water storages some of these rivers now flow bankfull from late spring to early autumn every year. Very little research has been carried out on the effects of river regulation on platypus populations, although there is evidence to suggest that it has some detrimental effects.

During the irrigation season bankfull flows will tend to flood most of the platypus burrows along the main channel for many months and this could reduce breeding success. Not only are burrows flooded, but the high flows can also result in the platypus expending more energy swimming against the strong current while feeding. Over a period of months, this increased energy requirement could reduce the condition of the platypus. Also, when high flows are sustained for long periods, the availability of benthic invertebrates in the main channel can be reduced, particularly in riffle areas where there are high velocities (Grant and McDonald in press, see Appendix 2 for abstract). These negative effects of bankfull flows on the platypus can be exacerbated by the release of cold water, which forces the animal to spend extra energy maintaining its body temperature.

Despite the drawbacks of bankfull flows during irrigation season, platypuses are still sighted below many of the major water storages, but whether their abundance has been reduced is uncertain. At a site on the Goulburn River below the Eildon weir, Gust and Handasyde (1995) observed no negative impacts caused by extended bankfull flows. However, this was probably due to the availability of backwaters which the platypuses could move to during high flows, and these provided excellent foraging habitat. In rivers where platypuses cannot seek refuge in calm backwaters, the impacts of bankfull flows during the irrigation season are likely to be greater.

To ensure suitable habitat for platypus breeding, extended periods of bankfull flow in late spring and summer should be avoided whenever possible. Bank collapse can be minimised by avoiding sudden falls in water level. There should also be sufficient calm water so that the platypuses are not continuously swimming against a strong current. The flow regime should also be designed to ensure an abundance of invertebrates for food.

10. Droughts and low flows

Under natural flow conditions, summer is often a time of reduced river flows, particularly in the southern half of the Murray-Darling Basin. As flows decrease, riffle areas between pools shrink and this leads to a reduction in the area available to the platypus for foraging. In most years this effect is probably offset by the larger number of invertebrates available during the warmer months and the lower metabolic demand for body temperature regulation. However, in drought years this may not be the case. At these times, rivers may be reduced to isolated pools and the valuable riffle feeding areas might not exist. There is some evidence from studies in the upper Shoalhaven River to suggest that drying up of parts of the river during the 1982/83 drought, reduced reproduction during that breeding season (Grant *et al*. 1983). Presumably however, populations recover during the wetter years.

The regulation of many rivers within the Murray-Darling Basin has changed the natural flow conditions and many sections of rivers immediately below large water storages now experience very low flows each year from late autumn through to early spring rather than during summer. These low flow conditions over the cooler months result in a reduction in foraging area for the platypus at a time when invertebrate abundance is also low. Ideally a minimum flow should be released through the winter months to cover the riffle areas of streams to maintain invertebrate productivity and to increase the foraging area for the platypus. The flow should also provide enough water so that the platypus can swim up through the riffle areas without having to come out of the water. This allows it to move safely between pools and provides a continuity of habitat.

11. Effect of reduced temperature of water released from storages

Releases from the lower levels of water storages can result in depressed water temperatures downstream. Although the platypus can tolerate very cold water (Grigg *et al.* 1992), it does force the animal to spend extra energy maintaining its body temperature. Also, the sudden release of cold water might have indirect effects by reducing the abundance of benthic invertebrates (Marchant 1989, Doeg 1984) and hence the availability of food for the platypus.

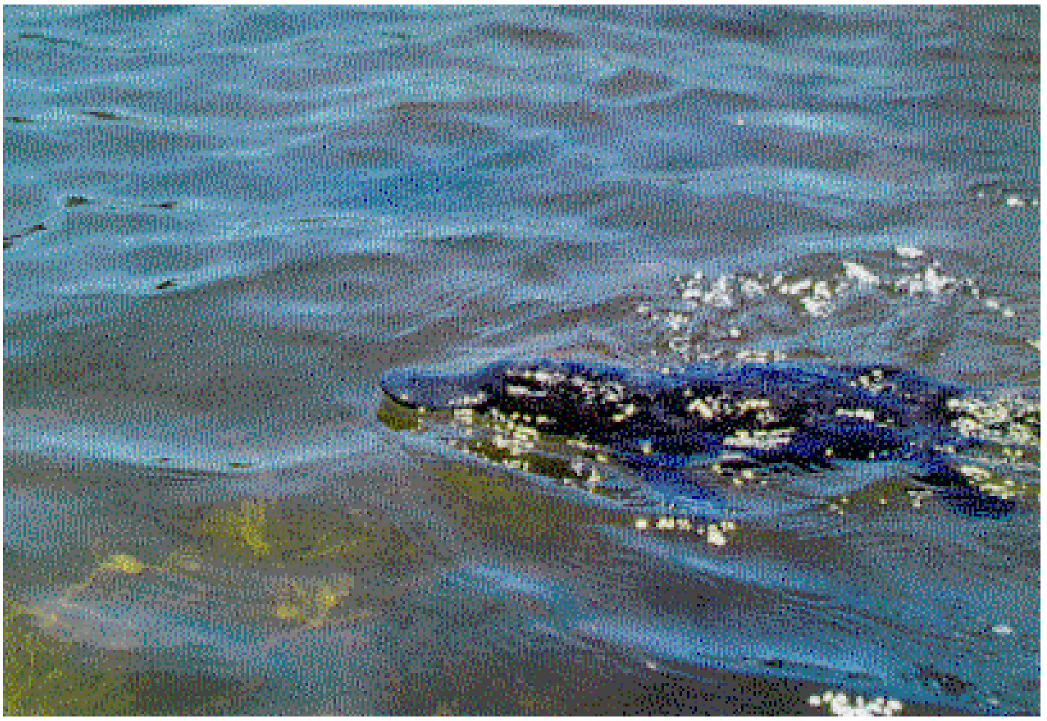
12. Water Quality

No work has been undertaken to investigate the effects of water quality on platypuses. They are however found in quite eutrophic streams, for instance downstream of some sewage treatment works, and they have been seen in rivers where the nutrient levels are so high that there are large mats of algae growing. High nutrient levels might alter the types of benthic invertebrates present, but generally don't reduce the abundance of invertebrates, and hence the amount of food available to the platypus.

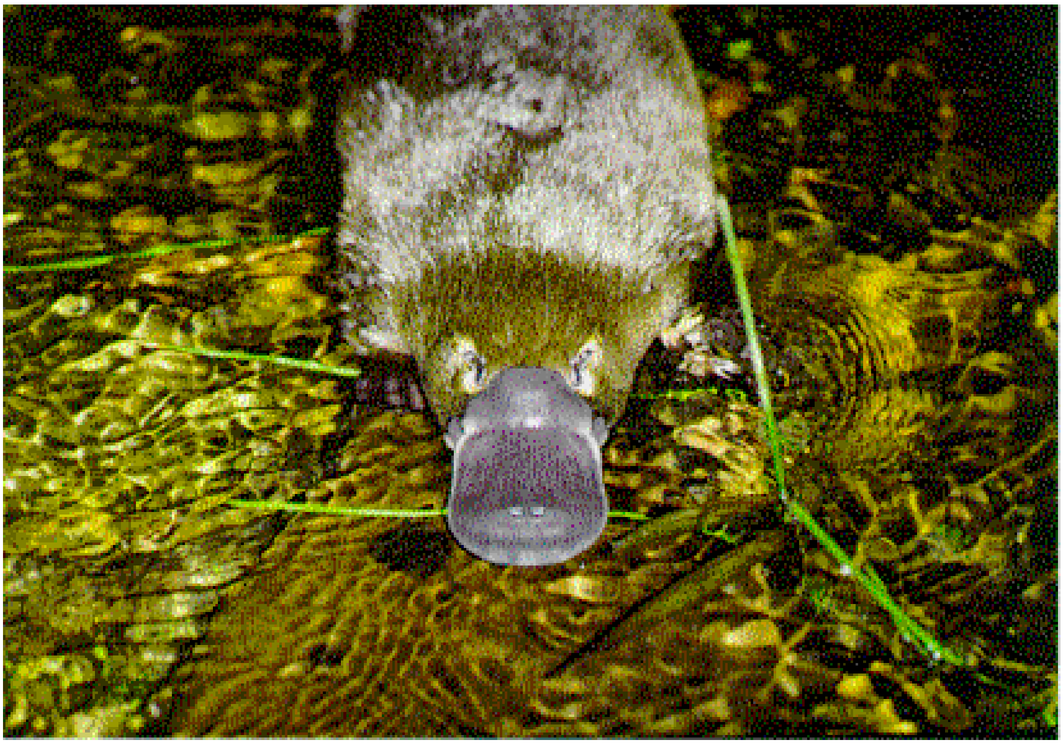
The effects of other pollutants such as pesticides and heavy metals are poorly known. Some tests have been done for the presence of organochlorine pesticides in platypus tissue, and the highest level recorded, of 3.4 mg/L was for a liver sample (Aust. Academy of Science 1972). Further studies on the impacts of toxic chemicals is required, particularly in streams near urban or industrial areas.

High turbidity is unlikely to affect platypus feeding since it is not a visual feeder. High turbidity may however have an indirect effect by limiting light penetration through the water column and reducing primary productivity. This in turn reduces benthic productivity and hence the abundance of food for the platypus. The very high turbidity of the Darling River is one possible reason why it is not suitable habitat for the platypus.

Some of the middle and lower reaches of rivers in the Murray-Darling Basin, including some within the current distribution of the platypus, have increased in salinity over the last few decades due to extensive clearing of native vegetation (Williamson *et al.* 1997). The tolerance of the platypus to these increasing salinity levels is not known, although Woon and Laxdal (1993) reported observing platypuses in sections of the Hunter River on the NSW coast, where electrical conductivity (which is a measure of the salinity) can be as high as 850-880 µS/m. This is similar to the levels recorded in the more degraded rivers of the Murray-Darling Basin. However, although the platypus might be able to tolerate such high salinities it would not be the preferred habitat. Manger (pers comm, cited by Woon and Laxdal 1993) suggested that the electroreceptors in the platypus bill would locate food items more effectively in water with a low conductivity.



Platypus *(Tom Grant)*



Platypus *(Ford Kristo, Animal Image Photography)*

13. Methods for determining suitable flow regimes for the platypus

The best scenario for environmental management of rivers is to reflect the natural pattern of flows. For the rivers of the Murray-Darling Basin there is considerable natural variation from year to year in both the floods and low flows, and these variations are essential if species diversity is to be maintained.

In highly regulated rivers, however, it is difficult to maintain the natural elements of the flow regime. In such cases, a different approach is needed, and the determination of suitable flows for platypuses has relied on qualitative approaches such as the 'Expert Panel Approach'. Grant and Bishop (in press) have proposed a more quantitative method which involves measuring the availability of habitat at various flows in order to determine a suitable flow regime (see appendix 1). The habitat variables that would be measured are mainly associated with providing suitable benthic habitat to ensure a good food supply of invertebrates, and the availability of river banks for burrowing. This would include the measurement at a range of different flows, of stream attributes such as; riffle areas, wetted perimeters and size of pools. The determination of flow velocities through riffle and pool areas would also be required to assess the availability of calm water sections for resting, and to ensure easy movement through riffle areas.

Perhaps the most difficult aspect of this method is understanding the relationships between invertebrate abundance and different flow regimes (for both natural and regulated flow patterns), and how these might vary between different rivers. This information can only be obtained by undertaking field studies.

The proposed quantitative method was tested for the Wingecarribee River in the Southern Tablelands of NSW (Grant & McDonald in press) which is used for transferring water from the Shoalhaven River to the Hawkesbury-Nepean system (Appendix 2). The response of both the platypus and the invertebrate populations were monitored under a range of different flow conditions, and this helped determine suitable flow scenarios.

14. Other factors that might affect platypus abundance

<u>Exotic species</u>

There are a large number of introduced plants and animals that have impacted on freshwater ecosystems within the Murray-Darling Basin. For instance, in many upland areas of NSW and Victoria, the original riparian vegetation has been replaced with willows (*Salix* spp.). Although often blamed for choking narrow streams with a mass of roots and branches, the roots of these trees do appear to provide good consolidation of earth banks used for burrowing by the platypus. Whether the abundance of platypuses would be higher if willow infested streams were instead lined with native vegetation has not been determined.

European carp (*Cyprinus carpio*) are an introduced fish species that have spread throughout the Murray-Darling Basin relatively recently (McDowall 1996). Their distribution covers the western plains and slopes of the Basin and includes some stretches of river which are also inhabited by platypuses, particularly along the Murray and its tributaries. Although there is an overlap in the diets of the two species, the impact of carp on platypuses is not yet fully understood.

Trout (*Salmo trutta* and *Oncorhynchus mykiss*) are introduced fish species that are found in many of the upland streams inhabited by the platypus. Although there is some overlap in food sources of trout and platypuses (Faragher *et al.* 1979), the platypus tends to be a bottom feeder whereas the trout forages throughout the water column. Trout and platypuses have appeared to cohabit successfully in many upland rivers of NSW for up to 100 years (Faragher 1986). It is also worth noting that during one study, platypuses were observed to supplement their diet over winter by consuming trout eggs (Grant 1982).

Diseases.

There is a fungal infection (*Mucor amphibiorium*) that infects and kills platypuses in the Tamar River system in Tasmania. Currently it has not been reported in platypuses from other areas of Tasmania or from mainland Australia, although the infection has been isolated from cane toads in Queensland (Grant 1995, Obendorf *et al* 1993). Platypuses do suffer from other diseases as well, and most carry ticks. For instance, there is a bacterial disease of cattle, Leptosporosis, which has been found to infect 50% of platypuses in the upper Shoalhaven River. The effect of this disease on platypuses is not yet known, although the animals that have tested positive appear quite healthy (Grant 1995).

Impacts of stock and removal of riparian vegetation

Uncontrolled stock access to riparian land can lead to bank erosion, compaction of soil, overgrazing of riparian vegetation and trampling of regeneration (LWRRDC 1996a). The removal of riparian vegetation and the subsequent erosion of stream banks, reduces the number of sites suitable for platypus burrows. There have also been anecdotal reports of platypus burrows collapsing due to cattle trampling. Removal of riparian vegetation also reduces the protection available to the platypus when it is entering and leaving its burrow, thus making it more prone to predation.

Loss of riparian vegetation affects the quality of instream habitat due to the decrease in shading, and the reduction in leaf litter, insects and other organic debris which is food for aquatic species (Riding and Carter 1992). Large trees along the river bank also provide woody debris when large limbs (or whole trees) fall into the stream. Tree branches and trunks provide niches and habitats for small invertebrates and are an important natural component of river systems (LWRRDC 1996c).

Livestock can also reduce water quality by the addition of urine and faecal material, which increase nutrient levels and introduce bacteria and viruses to the water (LWRRDC 1996b).

The impacts of grazing stock along rivers and streams leads to a reduction in the quality of both the riparian and the instream habitat and large stretches of river eventually become unsuitable for the platypus. Restoration of the riparian zone can be achieved by restricting the access of stock and by revegetating the stream banks with native species.

Sedimentation of pools

The preferred habitat for the platypus consists of a series of distinct pools, with little sediment accumulation and separated by cobbled riffle areas (Grant 1995). This type of habitat supports an abundance of platypus food in the form of benthic invertebrates. However, many catchments have suffered from extensive land clearing and the subsequent high erosion rates have led to the sedimentation of rivers and streams. Sedimentation tends to reduce the quality of the instream habitat for benthic invertebrates and could impact on the abundance of platypuses.

Fragmented distribution

Human activities resulting in bank erosion, the removal of riparian vegetation and sediment accumulation in river channels has reduced the availability of suitable habitat for the platypus. This has lead to the fragmentation of local platypus distributions in coastal rivers of NSW and Victoria (Grant, in press; Lunney *et al.*, in press), and also within the Murray-Darling Basin. Although the platypus is still widespread, the animals occur at low population densities in much of their habitat, and thus even in big streams, platypus populations are unlikely to be big enough to persist in isolation from others (Serena 1995). This emphasises the importance of conserving platypus habitat throughout catchments, and not just in isolated sections of streams (Serena pers. comm.).

15. Research Priorities

The following are considered to be the research priorities for obtaining a better understanding of how different flow regimes in rivers of the Murray-Darling Basin affect platypus survival.

a) Study the effects on platypus habitat caused by changes in the geomorphology of rivers, particularly sedimentation of deep pools and riverbank erosion.

b) Quantify methods for determining flow regimes suitable for the platypus as proposed by Grant and Bishop (see Appendix 1). This involves a description of instream habitat with the aim of determining
   - benthic productivity,
   - the suitability of the pools and riffles for foraging, resting and daily movements and
   - the availability of suitable sites for burrowing.

   Potential benthic productivity would be assessed by measurements of habitat diversity, total riffle area, total pool area and wetted perimeter. The suitability of pool and riffle areas would be assessed by determining the flowrate in terms of velocity and the resulting depth of water over the riffles. The availability of suitable sites for burrowing is determined by the distance of earth banks (which are consolidated by roots of vegetation and suitable for burrowing by platypuses), from the water's edge at the various flows and also by the available height of earth banks above the water level.

c) Set up long term monitoring sites to detect any changes in health or abundance of platypuses and determine if these are related to changes in their habitat, such as flow regime or invertebrate abundance. This will help provide long term data that can be used to better define what aspects of platypus (and invertebrate) biology are the best indicators of sustainable management practices for platypus populations (Serena pers. comm.).

d) Determine the effects of contaminants such as pesticides and heavy metals on the health of the platypus. Also investigate any indirect effects these contaminants might have on platypus food sources, ie benthic invertebrates.

16. Concluding remarks

The regulation of many rivers within the Murray-Darling Basin has changed the natural flow conditions and many sections of rivers immediately below large water storages now experience very low flows each year from late autumn through to early spring. These low flow conditions over the cooler months result in a reduction in foraging area for the platypus at a time when invertebrate abundance is also low. Ideally a minimum flow should be released through the winter months to cover the riffle areas of streams in order to maintain invertebrate productivity and to increase the foraging area for the platypus. The flow should also provide enough water so that the platypus can swim up through the riffle areas without having to come out of the water. This allows it to move safely between pools and provides a continuity of habitat.

During the warmer months (irrigation season), many of the regulated rivers in the Murray-Darling System run bankfull below the major storages. These high flows would flood many of the platypus burrows along the main channel for many months at a time and could reduce breeding success. The high flows can also result in the platypus expending more energy swimming against the strong current while feeding, and over a period of months, this increased energy requirement might reduce their condition. This can be exacerbated by the release of cold water, which forces the animal to spend extra energy maintaining its body temperature. Despite all these drawbacks, platypuses are still sighted below many of the major water storages, although their abundance could have declined.

To ensure suitable habitat for platypus breeding, extended periods of bankfull flow in late spring and summer should be avoided whenever possible. Flows should be kept below a level which allows sufficient bank space for burrows and minimises bank collapse. There should also be sufficient calm water so that the platypus is not continuously swimming against a strong current.

Of course, the best scenario for managing rivers is, if possible, to reflect the natural pattern of flows, since this is what the (native) aquatic life has adapted to over many thousands of years. For the rivers of the Murray-Darling Basin there has always been considerable variation from year to year in both the flood flows and low flows, and these natural variations are also essential if species diversity is to be maintained.

The removal of riparian vegetation and the degradation of instream habitat through poor land management practices is another important issue. Eventually this results in the fragmentation of local platypus populations along rivers and threatens their long term survival.

The conservation of the platypus in the Murray-Darling Basin will only be achieved through the better management of both land and water resources on a catchment-wide basis to ensure that there is suitable platypus habitat throughout catchments, and not just in isolated sections of streams.

Part 2. The water rat

1. Introduction

The water rat (*Hydromys chrysogaster*) is an amphibious rodent which is native to Australia and New Guinea. It is a placental mammal (not a marsupial) with a body length of about 30cm and a long white tipped tail (Olsen 1995). Among its adaptations for aquatic life are broad, partially webbed hindfeet and water repellent fur. The dense, soft fur has in the past led to its commercial exploitation (Fleay 1964). It is the only amphibious Australian mammal other than the platypus.

2. Present distribution

The water rat is widely distributed throughout Australia including some offshore islands, and also occurs in New Guinea (Olsen 1995). In the Murray Darling Basin it is found in permanent water bodies across a wide range of habitats from upland streams along the Great Dividing Range to lowland rivers and wetlands in the west (Figure 4). In other parts of Australia it is also found along some beaches and estuaries.

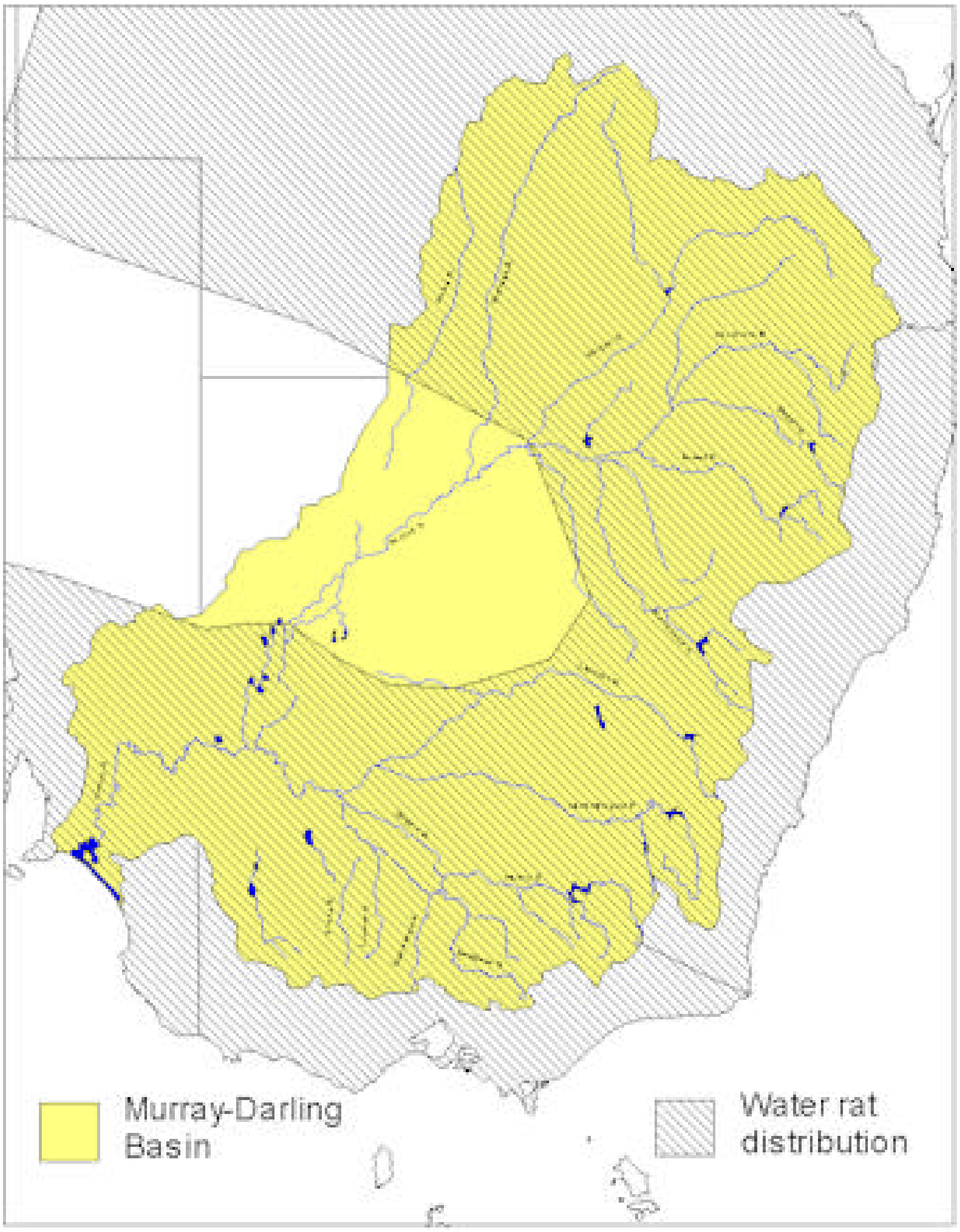


Figure 4 Present distribution of the water rat in south-east mainland Australia.
Adapted from Olsen (1995).

3. Changes in abundance and distribution since European settlement.

At first numerous, populations declined in certain areas following its exploitation for fur during the first half of this century. Destruction as vermin in irrigation areas probably contributed to the decline. Legislation now protects the species and populations have recovered. Swamp reduction and flood mitigation practices have removed some habitat but the construction of permanent wetlands, particularly in irrigation areas, appears to have compensated for these losses.

The overall distribution of the water rat does not seem to have changed much since European settlement. On a national scale, water rats have recently been assessed as 'secure' but with an overall decline in abundance estimated at 10-50% (Lee 1995). Within the Murray-Darling Basin, however, it is still common in areas where there is suitable habitat, such as irrigation areas and permanent wetlands. For instance, during field studies over the period 1969 to 1976 at Lake Cowal in NSW, Vestjens (1977) observed a total of several hundred water rats, and on one day alone, 34 were seen.

4. Habitat

The water rat usually lives in the vicinity of permanent bodies of fresh or brackish water and even on some marine beaches (Olsen 1995). The highest numbers of water rats are generally seen in irrigation canals and permanent wetlands, but appear to be less common along inland rivers (Olsen 1995). It is also an occasional vagrant to temporary waters (Olsen 1995). Watts and Aslin (1981) suggested that the water rat may be one of the few native mammals to have profited from human activities in some areas. Although it is usually found close to water, the water rat is able to survive on dry land and may range far from water in search of prey (Woollard *et al.* 1978). Nests are made at the end of tunnels in banks or occasionally in logs (Olsen 1995).

5. Tolerance to cold water environments

Given that water rats obtain most of their food from the aquatic environment, and that their wide geographical range includes mountain areas, it is surprising to learn that they cannot maintain their body temperature in cold water (Fanning and Dawson 1980, Dawson and Fanning 1981). Water rats can tolerate a water temperature of 5 ^{o}C for between 30-100 minutes without suffering noticeable impairment of activity or metabolic function. However, for periods longer than this, they slowly becomes hypothermic. Observations of behaviour, indicate that when they are feeding and foraging, a considerable amount of time is spent out of the water, on logs and weed clumps and at 'feeding tables' to which the prey is carried for eating (Woollard *et al* 1978). Gardner and Serena (1995) also observed that they periodically return to their burrows during the night, allowing them to warm up before re-entering the water in search of more food. This explains how the water rat can inhabit regions with low winter temperatures without becoming hypothermic.

6. Movement and dispersal

The water rat maintains a home range and has no migratory patterns. Gardner and Serena (1995) reported a home range of 3.9 km of river for an adult male fitted with a radio tracking collar. Harris (1978) reported home ranges for three adult males ranging from 0.9-2.2 km of river . Adult males tend to occupy the largest home ranges and they often overlap with the home ranges of one or more females.

Dispersal of young to surrounding waterbodies presumably occurs after each successful breeding season. Dams and weirs would not inhibit the dispersal of water rats since they can move considerable distances across dry land. They are however, more prone to predation while moving around these structures.

7. The life cycle of the water rat

Studies undertaken in the ACT (Olsen 1982) indicated that breeding can occur throughout the year, although most litters are born between September and March, with peak activity in early spring. McNally (1960) reported a slightly shorter season of September to January for water rats in irrigation districts of northern Victoria. He also observed that during late summer, autumn, and early winter the female rats were anoestrus. In south-eastern Queensland, Harris (1978) reported a slightly longer breeding season, from August through to the following May; presumably due to the warmer climate. Populations in arid regions probably breed whenever suitable conditions exist, rather than seasonally.

A female may become sexually mature at the age of 4 months and breed in the same season of its birth. Commonly however, breeding does not begin until the following season. Gestation occupies about 34 days (Olsen 1982) and the litter size can range from 1 to 7, with the average size being about three (Olsen 1982, McNally 1960). Apparently one litter per season is normal (McNally 1960) but when food and water are abundant, up to three litters are possible (Williams 1983, McNally 1960). In dry years breeding is irregular and litters are smaller. The female suckles the young for about 4 weeks, after which they remain with her for another 4 weeks, gradually attaining independence (Olsen 1995).

Olsen (1982) observed that females never bred in more than three consecutive breeding seasons even when they survived as many as six seasons. None produced a litter when aged more than about 3.5 years.

8. Diet and feeding habits

The water rat is unusual among Australian rodents in not being entirely nocturnal. The most active period is for 2 to 3 hours immediately after sunset (Harris 1978, Gardner and Serena 1995) but animals may forage in full daylight (Woollard *et al* 1978, Olsen 1995). Most food is gathered from the water with movements being primarily along the shoreline. The eyesight of the water rat is keen in discerning movement, and the eyes are kept open under water (Woollard *et al* 1978). They will also collect food from the land if it is readily available.

The water rat eats little plant material, being essentially an opportunistic predator on large aquatic insects, fishes, crustaceans and mussels. Frogs, lizards, small mammals, and waterbirds may also be taken (Woollard *et al* 1978). Prey is often carried to a regularly used feeding site (Olsen 1995). Water rats have also been reported to have raided poultry runs (Troughton 1967) and fisherman's nets (McNally 1960, Frith 1973). Fresh carrion, including edible domestic rubbish, dead waterbirds and dead domestic livestock, is also readily eaten (Woollard *et al* 1978).

With the ability to detect and capture a large range of food items, from mosquitoes to ducks, the water rat appears to be an opportunist governed by changing availability and in times of abundance, by preference. Versatility and broad resource utilisation would appear to ideally suit the water rat to the dynamically changing waterways of Australia (Woollard *et al* 1978).

9. Effects of water regime on the ecology of the water rat

Bankfull flows during irrigation season

Bankfull flows in rivers, for extended periods of time during the irrigation season reduces the availability of riparian sites for burrows during the breeding season. However other nesting sites might still be available further away from the main channel and whether bankfull flows have an impact on water rat abundance or not, has yet to be reported in the literature. Another possible impact of bankfull flows might be the increased water velocity throughout summer which could increase the energetics of food collection as the water rat swims up and down the edges of the river.

Rivers however, are only one type of waterbody occupied by water rats. Large numbers are also found in permanent wetlands, lakes and in irrigation areas. Therefore, while bankfull flows during the irrigation season might have negative impacts on some water rat populations, they do not pose a serious threat to the survival of the species as a whole.

Floods and droughts

Although the flooding of rivers or wetlands in spring or summer may lead to some mortality of young in burrows, the water rat is capable of producing a second and possibly even a third litter in the same season. This ability to produce more than one litter per season enables the water rat to tolerate changes in flow better than many other aquatic vertebrates. Although there might be some short term mortality of young, on a long term basis floods are most likely to benefit the water rat since the floodwaters result in an increase in suitable feeding habitat. This is supported by anecdotal reports of increases in abundance in Barmah forest during major floods in 1975 (Chesterfield *et al.* 1984) and along the Lachlan river during extended wet periods (Roberts and Sainty 1996, 1997).

During extended droughts, many wetlands and waterholes dry up and this might lead to a temporary decline in the water rat population. However, when conditions improve, water rats in the more permanent water bodies can rapidly breed and the dispersal of the young allows these areas to be re-inhabited.

Minimum flows in rivers

Water rats do not require the flow in a river to be maintained above some minimum value. Even if the river ceases to flow, they can move across land to gain access to upstream or downstream pools (although there might be slightly higher mortality due to predation).

Permanent inundation of wetlands

In some areas of the Murray-Darling Basin, temporary wetlands have been used for storing water for irrigation purposes and are now permanently inundated. This tends to favour the water rat, as shown by the high numbers present in Barren Box Swamp in the Murrumbidgee Irrigation Area (Woollard *et al* 1978).

Effect of cold water releases from storages

Releases from lower levels of water storages can result in depressed water temperatures downstream. Since the water rat cannot maintain its body temperature in cold water, cold water releases would reduce the amount of time it could hunt for food instream. The release of cold water might also have indirect effects on the water rat's food supply by altering the abundance or composition of aquatic invertebrates. However, the water rat is known to be a readily adaptable animal and it could probably change its feeding patterns to compensate for any negative impacts. No studies addressing this topic have yet been published.

10. Effect of water quality

Pesticides, heavy metals and other pollutants can reduce or kill populations of invertebrates which are food items for the water rat. Water rats however, are found in irrigation drainage channels which can often have high nutrient levels and can also contain low levels of pesticide residues. In the early 1970s, when organochlorines were still being extensively used, Olsen and Settle (1979) detected residues of DDT in all samples of livers, kidneys, mammary glands and foetuses of water rats collected from the Murrumbidgee Irrigation Area. The ability to survive in irrigation channels is an example of the adaptability and opportunism of water rats. If certain food items, such as crustaceans or mussels are unavailable due to the poor water quality, the water rat can switch to other food items such as fish (including exotics such as carp), lizards, waterbirds or even domestic rubbish. However, at very high pollution levels, the water rats themselves may be poisoned.

High salinity levels are clearly not a problem for the water rat since it not only occurs in freshwater habitats but is also found in brackish and marine habitats.

Perhaps one of the more important parameters is the turbidity of the water. The water rat hunts under water with its eyes open (Woollard *et al.* 1978) and high turbidity might make food collection more difficult than it would be in clear water. Nothing has yet been published on this issue.

11. Other factors that might affect water rat populations

Exotic species - carp

Since carp are benthic feeders whereas water rats hunt for food across a wide range of habitats, there is probably little competition for food. In fact the water rat might have benefited from the large increase in carp numbers since small fish form an important part of their diet. Chesterfield et al (1984) provided anecdotal evidence of water rats feeding on large numbers of carp in Barmah forest during a major flood in 1975.

Predators

Snakes and various birds of prey are the natural predators of water rats (McNally 1960), however feral cats and foxes also feed upon them (Williams 1983, Olsen 1983). The impact of these introduced predators is not known.

Extermination

The water rat was regarded by some as a pest of inland fisheries and its burrows were said to cause damage to irrigation structures (McNally 1960). However, even greater damage would be caused by burrowing freshwater crayfish if water rats were not present to prey upon these animals (Olsen 1983). Extermination of water rats as vermin contributed to the initial decline of water rats earlier this century. However, legislation now protects the species and populations have recovered.

Although Vestjens (1977) reported water rats drowning in fish nets, it is likely that this problem has declined since the commercial inland fishing industry is now quite small. Restrictions on the mesh size of nets has also reduced (but not eliminated) the chance of water rats being caught. The impact of recreational fishing and illegal nets is not known and would be difficult to determine.

Removal of riparian vegetation

Removal of riparian vegetation reduces the amount of cover available to the water rat as it moves around the river banks, thus making it more prone to predation. A dense cover of riparian vegetation is an important aspect of water rat habitat.

Loss of riparian vegetation also affects the quality of instream habitat due to the decrease in shading, and the reduction in leaf litter, insects and other organic debris which is food for aquatic species such as macroinvertebrates and fish. Large trees along the river bank also provide woody debris when large limbs (or whole trees) fall into the stream. Tree branches and trunks provide niches and habitats for small invertebrates and are an important natural component of river systems (LWRRDC 1996c).

12. Further research

There is still very little ecological information on the water rat and there is good justification for setting up some long term monitoring studies within the Murray-Darling Basin. This would improve our knowledge on habitat requirements, movement and dispersal, diet, and life cycle. Such monitoring would also help detect any long term changes in their abundance, or threats to their survival.

13. Concluding remarks

The water rat is an opportunistic and highly adaptable species, capable of occupying a wide range of habitats from small inland waterways to swamps and lakes and coastal estuarine waters. Within the Murray-Darling Basin it is common in areas where there is suitable habitat, and appears to have benefited from the increase in permanent waterbodies associated with irrigation areas. It is an opportunistic predator and will consume a wide range of foods including crustaceans, fish, large insects, frogs and even domestic garbage or carrion. Throughout most of its distribution, breeding is on a seasonal basis and does not appear to be triggered by any change in water regime such as flow rate or water depth. In arid areas however, where the amount of suitable habitat declines during dry periods, breeding might be delayed until sufficient water (and hence food) are available.

Although flooding might temporarily drown out their burrows, water rats appear to benefit from floods since the floodwaters result in an increase in suitable feeding habitat. During droughts, many wetlands and waterholes dry up and this leads to a temporary decline in the water rat population. However when conditions improve, water rats in the more permanent water bodies can rapidly breed and the dispersal of young will allow these areas to be re-inhabited.

The adaptability of the water rat to conditions in a wide range of habitats and the high level of transience are of primary significance in ensuring the survival of the species.

Platypus references

Australian Academy of Science (1972) The use of DDT in Australia. Reports of the Academy of Science, No. 14, 72pp.

Bohringer R.C. and Rowe M.J. (1977) The organisation of sensory and motor areas of the cerebral cortex of the platypus (*Ornithorhynchus anatinus*). *J. Comparative Neurology* **174**: 1-14.

Burrell H. (1927) The platypus. Angus & Robertson , Sydney. (reprinted in 1974 by Rigby Ltd, Adelaide.)

Carrick F.N. (1995) Platypus. In 'The mammals of Australia'. (ed.) R Strahan. Reed Books, Chatswood, 35-38. (Note; the distribution map for platypus presented in this article is incorrect for S-W NSW and most of Victoria).

Cummins K.W. (1993) Riparian stream linkages: In-stream issues. In 'Ecology and management of riparian zones in Australia'. (eds.) S.E. Bunn, B.J. Pusey & P. Price. Occasional paper No. 05/93, Land & Water Resources Research & Development Corporation, Canberra, 1-20

Doeg T.J. (1984) Response of the macroinvertebrate fauna of the Mitta Mitta River, Victoria, to the construction and operation of Dartmouth Dam. 2. Irrigation release. *Occasional Papers from the Museum of Victoria* **1**: 101-108.

Faragher R.A. (1986) Trout in New South Wales. *Agfact* F3.2.2: 1-8, Department of Agriculture, NSW.

Faragher R.A., Grant T.R. and Carrick F.N. (1979) Food of the platypus (*Ornithorhynchus anatinus*) with notes on the food of brown trout (Salmo trutta) in the Shoalhaven River, NSW. *Aust. J. Ecology*, **4**: 171-179.

Grant T.R. (1982) Food of the platypus, *Ornithorhynchus anatinus* (Monotremata: Ornithorhynidae), from various water bodies in New South Wales. *Australian Mammalogy*, **5**: 235-236.

Grant T.R. (1991) The biology and management of the platypus (*Ornithorhynchus anatinus*) in NSW. Species Management Report No. 5, National Parks and Wildlife Service NSW.

Grant T.R. (1992a) Historical and current distribution of the platypus, Ornithorhynchus anatinus, in Australia. Pp232-254 in 'Platypus and echidnas' (ML Augee, ed.). The Royal Zoological Society of NSW, Sydney.

Grant T.R. (1992b) Captures, movements and dispersal of platypuses, *Ornithorhynchus anatinus*, in the Shoalhaven River, New South Wales, with evaluation of capture and marking techniques. Pp255-262 in 'Platypus and echidnas' (ML Augee, ed.). The Royal Zoological Society of NSW, Sydney.

Grant T.R. (1993) The past and present freshwater fishery in New South Wales and the distribution and status of the platypus *Ornithorhynchus anatinus*. *Australian Zoologist*, **29**(1-2): 105-113.

Grant T. (1995) The platypus: a unique mammal. (revised edition) University of New South Wales Press Ltd, Sydney.

Grant (in press) Current and hostorical occurrence of platypuses (*Ornithorhynchus anatinus*) around Sydney. Paper presented at "Platypus Biology", a National Symposium held at Charles Sturt University, Bathurst, November 1996. To be published in *Australian Mammalogy.*

Grant T. and Bishop K. (in press) Instream flow requirements for the platypus: I. Low Flows. An assessment strategy. Paper presented at "Platypus Biology", a National Symposium held at Charles Sturt University, Bathurst, November 1996. To be published in *Australian Mammalogy.*

Grant T.R. and Denny M.J.S. (1987) The Barnard River water supply project: studies of the platypus population in the project area: post construction study. Unpublished report to the Electricity Commission of NSW, Sydney.

Grant T.R. and Griffiths M. (1992) Aspects of lactation and determination of sex ratios and longevity in a free ranging population of platypuses, *Ornithorhynchus anatinus,* in the Shoalhaven River, NSW. In 'Platypus and Echidnas' (ML Augee, ed.), Royal Zoological Society of NSW, Sydney, pp80-89.

Grant T.R., Griffiths M. and Leckie R.M.C. (1983) Aspects of lactation in the platypus, *Ornithorhynchus anatinus,* in the rivers of eastern Australia. *Aust. J. Zool.* **31**: 881-889.

Grant T. and McDonald G. (in press) Instream flow requirements for the platypus: II. High flows. Studies of water transfers from the Shoalhaven River System to the Hawkesbury-Nepean River System. Paper presented at "Platypus Biology", a National Symposium held at Charles Sturt University, Bathurst, November 1996. To be published in *Australian Mammalogy.*

Gregory J.E., Iggo A., McIntyre A.K. and Proske U. (1987) Electroreceptors in the platypus. *Nature* **326**: 386-387.

Grigg G., Beard L., Grant T. and Augee M. (1992) Body temperature and diurnal activity patterns in the platypus (Ornithorhynchus anatinus) during winter. *Aust. J. Zoology* **40**: 135-142.

Gust N. and Handasyde K (1995) Seasonal variation in the ranging behaviour of the platypus (*Ornithorhynchus anatinus)* on the Goulburn River, Victoria. *Aust. J. Zoology* **43**: 193-208.

Lunney et al. (in press) A community-based assessment of the distribution of the platypus (*Ornithorhynchus anatinus)* in the Eden region of south-east NSW. Paper presented at "Platypus Biology", a National Symposium held at Charles Sturt University, Bathurst, November 1996. To be published in *Australian Mammalogy.*

LWRRDC (1996a) Managing riparian land. Fact sheet No. 1 of 'Riparian management', compiled by M Asky-Doran *et al*. and edited by W Tubman, Land & Water Resources Development Corporation, Canberra.

LWRRDC (1996b) Water Quality. Fact sheet No. 3 of 'Riparian management', compiled by M Asky-Doran *et al*. and edited by W Tubman, Land & Water Resources Development Corporation, Canberra.

LWRRDC (1996c) River Ecosystems. Fact sheet No. 4 of 'Riparian management', compiled by M Asky-Doran *et al*. and edited by W Tubman, Land & Water Resources Development Corporation, Canberra.

Marchant R. (1989) Changes in the benthic invertebrate communities of the Thompson River, south-eastern Australia, after dam construction. *Regulated Rivers* **4**: 71-88.

McDowall R. (1996) Freshwater fishes of south-eastern Australia. Reed Books, Sydney

Menkhorst (1995) Mammals of Victoria; distribution, ecology and conservation. Oxford University Press, Melbourne.

Obendorf D.L., Peel B.F. and Munday B.L. (1993) *Mucor amphibiorum* infection in platypus (*Ornithorhynchus anatinus*) from Tasmania. *Journal of Wildlife Diseases*, **29:** 485-487.

Riding T. and Carter R. (1992) The importance of the riparian zone in water resource management. A literature survey. Department of Water Resources, NSW.

Rowe M.J. and Bohringer R.C. (1992) Functional organisation of the cerebral cortex in monotremes. Pp 69-74 in 'Platypus and Echidnas' (ML Augee, ed.) The Royal Zoological Society of NSW, Sydney.

Scheich H., Langner G., Tidemann C., Coles R.B. and Guppy A. (1986) Electroreception and electrolocation in the platypus. *Nature* **319**: 401-402

Serena M. (1994) use of time and space by platypus (*Ornithorhynchus anatinus*: Monotremata) along a Victorian stream. *J. Zool., Lond.* **232**: 117-131.

Serena M (1995) Platypus pursuits. *Nature Australia*, spring edition, pp55-61.

Temple-Smith P.D. (1973) Seasonal breeding biology of the platypus, *Ornithorhynchus anatinus*, with special reference to the male. PhD Thesis, Australian National University, Canberra.

Whittington R.J. (1991) The survival of platypuses in captivity. *Aust. Vet. J*. **68**: 32-35.

Williamson D.R., Gates G.W.B., Robinson G, Linke G.K., Seker M.P. and Evans W.R. (1997) Salt trends: historic trend in salt concentration and saltload of stream flow in the Murray-Darling Drainage Division. Dryland Technical Report No. 1, Murray Darling Basin Commission

Woon P.M.N. and Laxdal D. (1993) Platypus (*Ornithorhynchus anatinus*) habitat criteria. Final report to the Australian Nature Conservation Agency (Project no. 109), prepared on behalf of the Zoological Parks Board of NSW.

Water rat references

Chesterfield E.A., Loyn R.H. and Macfarlane M.A. (1984) Flora and fauna of Barmah State Forest and their management. Biological Survey Branch, Forests Commission Victoria, Research Branch Report 240, 73pp+App. (unpubl.)

Dawson T.J. and Fanning F.D. (1981) Thermal and energetic problems of semiaquatic mammals: a study of the Australian water rat, including comparisons with the platypus. *Physiological Zoology* **54**: 285-296

Fanning F.D. and Dawson T.J. (1980) Body temperature variability in the Australian water rat, *Hydromys chrysogaster*, in air and in water. *Australian Journal of Zoology* **28**: 229-238.

Fleay D. (1964) The rat that mastered the waterways. *Wildl. Aust.* **1**(4): 3-7.

Frith H.J. (1973) Wildlife conservation. Angus & Robertson, Sydney.

Gardner J.L. and Serena M. (1995) Observations on activity patterns, population and den characteristics of the water rat *Hydromys chrysogaster* along Badger Creek, Victoria. *Australian Mammalogy* **18**: 71-75.

Harris W.F. (1978) An ecological study of the Australian water-rat (*Hydromys chrysogaster*: Geoffroy) in southeast Queensland. Masters thesis, University of Queensland.

Lee A.K. (1995) The action plan for Australian rodents. Australian Nature Conservation Agency, Canberra. 62pp.

McNally J. (1960) The biology of the water rat, *Hydromys chrysogaster* Geoffrey (Muridae: Hydromyinae) in Victoria. *Aust. J. Zool*. **8**: 170-180.

Olsen P.D. (1982) Reproductive biology and development of the water rat, *Hydromys chrysogaster*, in captivity. *Aust. Wildl. Res*. **9**: 39-53

Olsen P.D. (1983) Water-rat. In 'The Australian Museum complete book of Australian mammals', (ed) R Strahan, Angus and Robertson Publishers, 367-368.

Olsen P.D. (1995) Water-rat, *Hydromys chrysogaster*. In 'The mammals of Australia'. (ed.) R Strahan. Reed Books, Chatswood, 628-629.

Olsen P and Settle H (1979) Pesticide contamination of water rats in the Murrumbidgee Irrigation areas, New South Wales, Australia, 1970-72. *Pesticides Monitoring Journal*, **12**(4): 185-188.

Roberts J. and Sainty G. (1996) Listening to the Lachlan. Sainty & Associates P/L, Sydney.

Roberts J. and Sainty G. (1997) Oral history as a tool in historical ecology: Lachlan river as a case study. CSIRO Land & Water Consultancy Report 97-20, June 1997.

Troughton E. (1967) Furred animals of Australia. Angus & Robertson, Sydney.

Vestjens W.J.M. (1977) Status, habitats and food of vertebrates at Lake Cowal. CSIRO Division of Wildlife Research Technical Memorandum No. 12.

Watts C.H.S. and Aslin H.J. (1981) The rodents of Australia. Angus and Robertson, Sydney.

Williams W.D. (1983) Life in inland waters. Blackwell Scientific Publications, Melbourne. 114-117

Woollard P., Vestjens W.J.M. & MacLean L. (1978) The ecology of the eastern water rat *Hydromys chrysogaster* at Griffith, NSW: food and feeding habits. *Aust. Wildl. Res*. **5**: 59-73.

Appendix 1

"Instream flow requirements for the platypus (*Ornithorhynchus anatinus*): An assessment strategy." by Tom Grant and Keith Bishop, presented at "Platypus Biology", a National Symposium held at Charles Sturt University, Bathurst, November 1996. (To be published in *Australian Mammalogy*)

Abstract; A number of human activities have the potential to impact on platypus populations by removing water from streams or by increasing flows. A number of studies, which have indicated low impact on downstream platypus populations, have been carried out before and after projects involving water extractions or releases. However, it would be much more satisfactory to be able to predict minimum and/or maximum flow requirements for platypuses in specific water bodies. It is proposed that a number of known habitat requirements of the platypus could be incorporated into a simple and practical rapid assessment methodology to make assessments of flow requirements for the species. Measurement and visual estimations, followed by graphing of such characteristics over a range of natural flows, within the predicted flow regime during water extraction and/or release, should provide numerical information on which minimum and/or maximum flow recommendations could be based. Platypuses are dependent on suitable banks for burrowing and a supply of benthic invertebrate food species. It is proposed that measurements be made at representative pool and/or riffle transects which indicate potential benthic productivity and suitability and availability of banks. Potential benthic productivity would be assessed by measurements of habitat diversity, total riffle area, total pool area and wetted perimeter. Distance of earth banks, consolidated by roots of vegetation and suitable for burrowing by platypuses, from the water's edge could also be measured at the various flows. In the case of projected increased flows, the percentage area and/or height of earth banks at various flows could be measured (Grant and McDonald, this volume). Similar methodology has been carried out to successfully assess instream requirements of fish populations. This methodology must be assessed under field conditions.

Appendix 2

"Instream flow requirements for the platypus (*Ornithorhynchus anatinus*): High flows. Studies of water transfers from the Shoalhaven River system to the Hawkesbury-Nepean River system." by Tom Grant and Geoff McDonald, presented at "Platypus Biology", a National Symposium held at Charles Sturt University, Bathurst, November 1996. (To be published in *Australian Mammalogy*)

Abstract: During periods of lows into the storages of the Hawkesbury-Nepean system, Sydney Water Corporation (Sydney Water) pumps water from the Shoalhaven River system, releasing it into the upper Nepean River storages and/or via the Wingecarribee River to the Wollondilly River which flows into Warragamba Dam. Prior to the formulation of an operational release strategy for this system, controlled releases of water were made and the effects of a range of flows on bank stability, water birds, benthic organisms and platypus populations and their habitat were assessed. A regime of maximal operational releases was formulated after the various investigations indicated that flows of 400 ML/day during September to March (water bird and platypus breeding and nesting season) and 600 ML/day at other times would have minimal impact on the ecology of the two river systems. Monitoring studies involving netting and observations of platypuses in the upper Nepean River system indicated that operational releases within the suggested regime between July 1994 and May 1995 may have led to slightly reduced body condition in some animals during the higher flows in the winter of 1994. However the smaller discharges during the latter period of releases did not appear to result in platypuses entering the winter of 1995 in poor condition. Capture and observational monitoring studies indicated that releases of up to 500 ML/day in the Wingecarribee River between February and June 1995 had no noticeable effect on platypus activity or populations. Further monitoring needs to be done prior to, during and after high flows and/or for longer periods in the Wingecarribee River and Glenquarry Creek-Nepean River system to assess long term impacts on platypus populations as a result of controlled releases of water.