PROGRESSIVE DEVELOPMENT OF WETLAND HABITATS AT THE AMC WETLANDS CENTRE, CAPEL, WESTERN AUSTRALIA[1]

by

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Abstract. A series of freshwater lakes was created during mining for heavy mineral sands at Capel, 125 miles south of Perth, in Western Australia. The lakes intercept the ground water table and have a total surface area of about 110 acres. In recognising the potential conservation value of the site, especially for waterbirds, the company established the AMC Wetlands Centre in 1987. Comprehensive research and site development programmes were implemented. Baseline studies of the hydrology, lake chemistry, algae, invertebrates, vegetation, and the waterbirds indicated the potential of the lakes for development as a wetland ecosystem whilst identifying the priorities for habitat enhancement. Significant improvements in water quality have been achieved. Extensive earthworks have involved re-shaping the banks, creating islands, channels, loafing peninsulas and shallow feeding areas. A wet woodland is being created for colonial nesting waterbirds. A variety of vegetation types is being established to provide habitat for a wide range of birds. Ongoing studies have revealed that the diversity of algae, diatoms, and invertebrates, important components of the food chain, is improving as the habitat develops. Waterbird usage of the lakes is increasing and their breeding success is improving. The site has considerable potential for public recreation and education.

Additional Key Words: mineral sands, waterbirds, aquatic invertebrates, algae, macrophytes, food chain.

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Introduction

Wetlands are a valuable and diminishing resource in the south-west of Western Australia. It has been estimated that the values of more than 2/3 the wetlands on the Swan Coastal Plain have been reduced or destroyed by various forms of land use (Anon,

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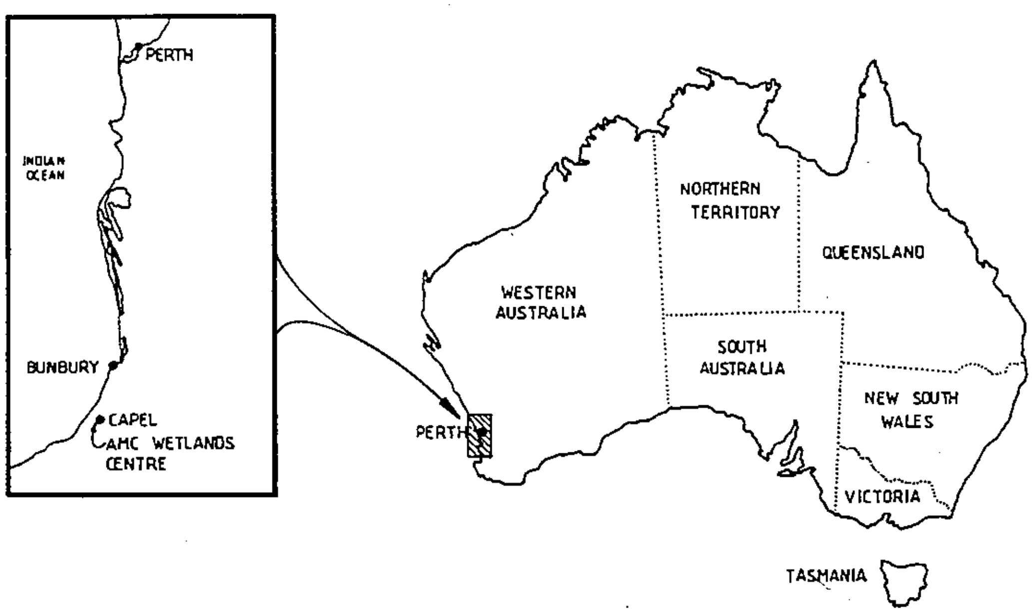


Figure 1. — LOCATION OF AMC WETLANDS CENTRE AT CAPEL WESTERN AUSTRALIA

1991). Permanent freshwater bodies, being important summer refuges for waterbirds in the south-west (Jaensch, et al., 1988), are particularly scarce as in this mediterranean climate (AAR 830mm, 32.5 in) many wetlands dry up during the summer months.

Under such circumstances, the creation of new wetlands, including permanent freshwater bodies, is a valuable contribution to the State's environmental effort, especially as the south-west is important for migrating birds (Lane, 1987). Whilst mining for mineral sands at Capel, 200km (125 mi) south of Perth (see Figure 1), AMC Mineral Sands Ltd., (AMC), created a series of permanent freshwater lakes. The establishment of a wetlands project on the site has been described previously (Brooks, 1988). This paper discusses the progressive development of the project at what is now known as the AMC Wetlands Centre.

Background

Mining for mineral sands, principally ilmenite, has continued at the site since 1956. At times, mining of very high grades resulted in significant backfill deficits, which created lakes where the pits intersected the groundwater table. The available tailings were used to restore the contours of the surrounding areas.

The lake system comprising the AMC Wetlands Centre was formed between 1975 and 1979. There are 12 lakes in the system, mostly interconnected, with a total water surface of about 44 ha (110 acres). Prior to mining, most of the area supported a pine plantation of low productivity (State Forest), with the balance being private grazing land. Following mining, the newly formed lakes served as the mine water supply until 1988, and they have continued to receive treated effluent from the mineral processing plants enroute to the discharge point.

Initially, reclamation of the area mined concentrated on re-establishing pastures on the surrounding land and on planting trees and shrubs around the banks of the lakes for aesthetics and to attract birdlife. Most of this work took place between 1977 and 1983. Meanwhile, the lakes became partially colonised with wetland flora, and waterbirds were frequently observed to visit them.

In 1984, the company commissioned the Royal Australasian Ornithologists Union (RAOU) to advise on the potential of the lakes for development of self-sustaining wetland ecosystems for the benefit of waterbird conservation.

Jaensch (1985) reported that with a number of development techniques the lakes had potential to achieve the stated objective, as well as providing considerable opportunities for research, education and passive public recreation. On this basis, the company initiated a wetlands project in 1986, over and above the regulatory requirements of its mining lease.

The AMC Wetlands Centre was established with the following objectives:

1. To develop self-sustaining wetland ecosystems for the conservation of waterbirds in lakes created by mining at Capel.

2. To facilitate research into wetland ecosystems including their development and management.

3. To develop the potential and facilities for public education and recreation at the Capel wetlands.

4. To develop and demonstrate rehabilitation technology for wetlands created by human activities.

A management committee for the Centre was established to advise the company on future directions of research and management, including budgets, and to review progress. Membership of the committee represents the main expertise in and responsibilities for wetlands and waterbird conservation in the State, thereby forging links between appropriate government authorities, industry, research, and conservation institutions. There is representation from the company, RAOU, Department of Conservation and Land Management, The University of Western Australia, Curtin University of Technology, and Murdoch University. The interaction within this group is proving to be one of the valuable and exciting benefits flowing from the project.

Baseline Studies

One of the first steps was to initiate a series of multi-disciplinary baseline studies to determine the ecological status of the lakes and to indicate priorities for future research and development. Nearby natural wetlands were used as control sites. These studies were completed in 1987.

Hydrology studies of the lake system and surrounding areas revealed that water levels in the lakes were being maintained artificially high by 0.5-1.0m because of an effluent stream and management of the lakes for mine water supply (Nield and Townley, 1987). In addition, the levels did not reflect the seasonal fluctuation of the groundwater table, thereby inhibiting development of the ecosystem, particularly the fringing vegetation and associated invertebrate populations. Subsequently, a water bore was installed in the deep aquifer to supply the mine with make-up water. The discharge point at the end of the lake system was then set at the estimated winter high water mark to enable a normal seasonal fluctuation to become established.

A preliminary survey of waterbird usage of the lakes, with monthly recordings by volunteer observers, was conducted from November 1984 to November 1986. A total of 24 species of waterbirds was recorded on the lakes system during the survey period (Jaensch, 1986; Bamford and Jaensch, 1987). Whilst the lake system supports an appreciable number of species and individuals, it was not as valuable as natural wetlands in the district. Limitations of the habitat in supplying food and shelter were reported as being the main probable factors. This conclusion was supported by the observation that the older lakes, which had achieved more advanced habitat development, were more heavily utilised by waterbirds. Seasonal patterns of usage revealed that the system was of greatest value as a refuge in the dry season (late spring to late autumn) when seasonal waterbodies in the district dried up. Two species, Pacific Black Duck (*Anas superciliosa)* and Black-fronted Plover (*Charadrius melanops*), were observed breeding on the lakes during the survey.

The breeding success of waterbirds on the lakes was studied during the 1986/87 breeding season (Bamford, 1987). Although 12 species bred on a nearby natural swamp, only 5 bred on the lake system, and with a poor success rate. Most losses occurred within the first 2 weeks from hatching; the major causes apparently being poor nutrition and predation. The Pacific Black Duck, which relies heavily on invertebrates as a protein source, fledged only 2 ducklings from a minimum of 22. On the other hand, the Purple Swamphen (*Porphyrio porphyrio*), which has a more varied diet, fledged 7 chicks out of a minimum of 10. Breeding success was highest on the oldest lakes with better developed emergent vegetation providing more breeding sites and improved nutrition. The species list was increased to 27 during this study, 25 of which could have bred on the lakes given suitable conditions. Thus, these results reflected the early development of habitats on the lake system.

Lack of aquatic invertebrates as a protein source was confirmed as one of the major factors in the poor breeding success of the birds (Cale and Edward, 1987). Whilst a high invertebrate species richness was recorded in the lakes, abundance was low compared with natural wetlands. Eighty-three invertebrate taxa were recorded in the lakes, the most abundant being Coleoptera (18%), Chironomidae (17%) and Crustacea (10%). The oldest lake supported 57% of all identified taxa, and was best in all habitat components (i.e., benthic, macrophyte and plankton). This result correlated strongly with the level of macrophyte cover. The faunal studies confirmed that the lakes had the potential for development as self-sustaining wetlands, although the need to increase their productivity through habitat development was highlighted.

Factors limiting the productivity of the lakes were found by Gordon and Chambers (1987) to include steep slopes, hard substrates, and poor water quality. These factors limited the development of fringing emergent and submerged vegetation and the invertebrate populations they support. The ponds were well oxygenated, lacked temperature and oxygen stratification, and showed small diurnal changes. Water quality limitations included low pH (3-4), extremely high ammonia levels (22,300-82,700 μg/L), low phosphorus concentrations (4-120 μg total P/L), and high iron and manganese levels that could give rise to phosphorus complexing. Sediments were also low in inorganic and organic phosphorus. This study demonstrated the need for extensive landscaping of the existing system to provide shallow areas with wide, flat banks of soft sandy substrate to encourage the development of vegetation and the need to improve water quality.

The poor water quality was reflected in the algal populations of the lakes, which were diatom-dominated with a well established benthic diatom community of low diversity (John, 1988). The assemblage of diatoms in the lakes was indicative of low pH with little biological symptom of eutrophication. Conversely, the assemblage of algae in a nearby natural wetland sampled at the same time indicate it is an eutrophic system. Of the 67 taxa recorded, 55 were diatoms. A nearby natural wetland displayed the maximum species richness with 62 taxa. The maximum species richness in the Centre's lakes occurred in the oldest, best developed lake, with 40% (25 species) of the species present in the natural wetland. These results confirmed that the lake system was in a relatively undeveloped state.

Habitat Development

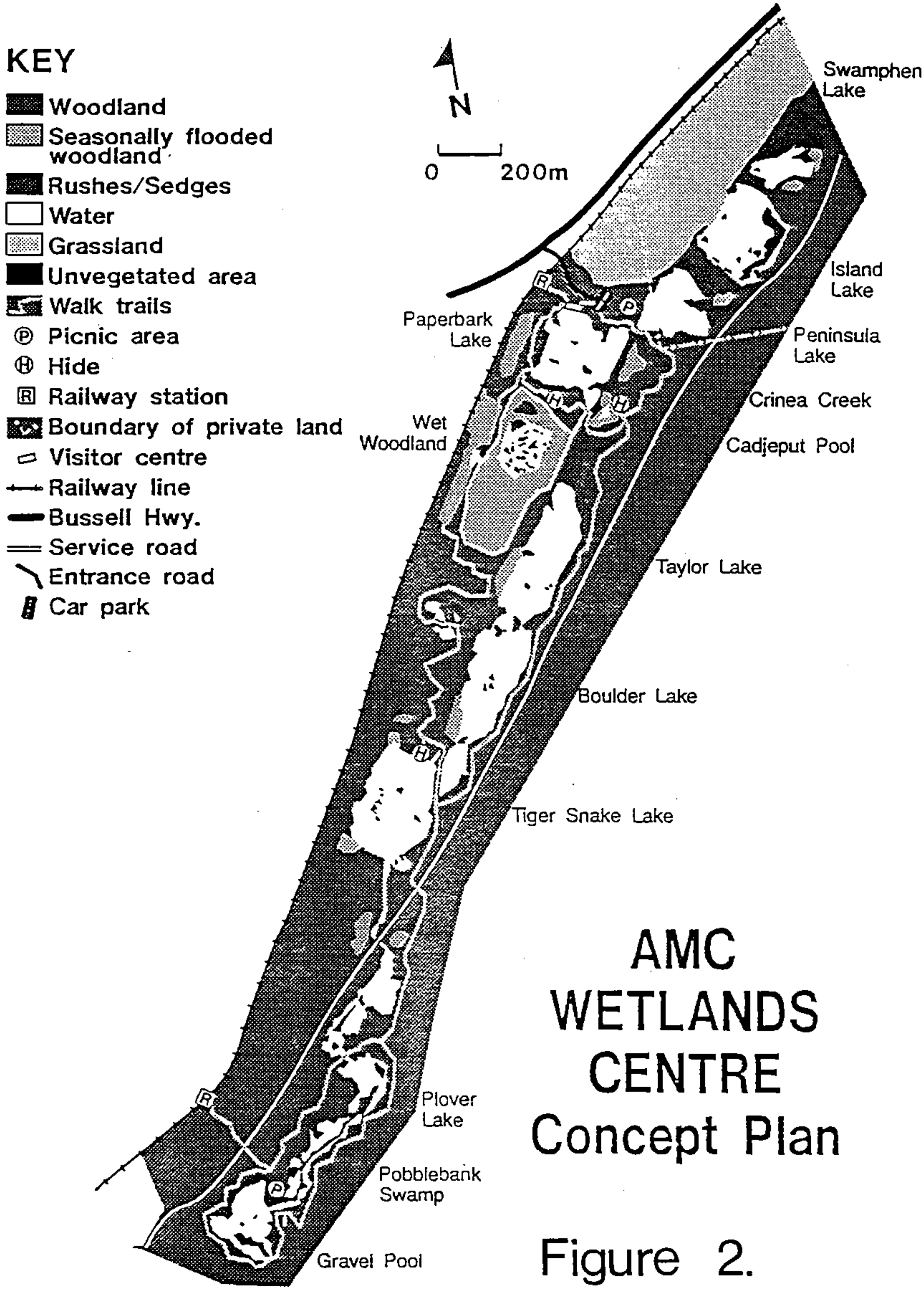
Whilst the baseline studies indicated that the lakes had potential for development as a wetland ecosystem, productivity needed to be improved substantially at all levels of the food chain. Priority attention was to be given to water and sediment chemistry, re-shaping of shorelines, vegetation establishment, and development of the specific habitat needs of fauna, including invertebrates, birds, and other vertebrates.

A concept plan was prepared for the Centre to set the direction of its long term development (see Figure 2). In addition to planning the habitat development of the lakes and surrounding uplands, the concept plan also set out potential development of facilities for public usage of the Centre, including visitor's centre and carpark, picnic areas, walk trails, viewing hides, and tower.

Site development works commenced during the 1987/88 summer and have since concentrated on enhancement of the habitat. Development of the public facilities is envisaged at a later stage when the ecosystem has developed to a satisfactory level of productivity. Project funding was established on a 5 year basis to cover project management, research, and development, with a review at the end of that period.

The baseline studies had indicated that poor water quality was one of the main constraints on development of the ecosystem. These problems had arisen because the mineral processing plant's effluent treatment facilities were not performing adequately. These facilities were progressively upgraded between 1987 and 1989 for operational reasons and the wetlands subsequently benefited. Water quality at the end of the lake system has improved markedly (see Table 1). Iron, manganese and pH levels are now all within acceptable limits, and sulphate levels continue to improve. Nitrogen and phosphorus levels remain out of balance, because of release of ammonium in the effluent stream.

In planning the habitat development programme, it was recognised that each species of waterbird has particular habitat requirements for breeding, feeding and loafing (Nicholls and Davies, 1990). For example, ibis and other colonial nesting birds need wet woodlands. Dabbling ducks usually nest in hollow trees, while shovellers and black



AMC WETLANDS CENTRE Concept Plan

Figure 2.

Table 1 - Quality of water discharging from the lake system averaged over the October - December quarter for 1987/90 (Galloway, pers. comm.).

Parameter	1987	1988	1989	1990
pH	3.64	6.82	7.53	7.42
Fe (ppm)	1.4	0.4	0.3	0.5
Mn (ppm)	22	9.4	0.3	0.1
SO_4 (ppm)	1,033	866	1,360	856

ducks will nest on the ground under shelter. Swans, diving ducks and marsh harriers breed in reed beds. Grebes and rails require emergent vegetation and waders prefer bare shores.

Swans and coots feed on benthic macrophytes and graze on grassland. Diving ducks, cormorants, grebes and most ducklings feed on aquatic invertebrates. Herons and waders feed in shallow water on invertebrates and small vertebrates. Dabbling ducks feed on seeds in shallow water, often in seasonally inundated areas. Swamphens feed on macrophyte rhizomes. Reed warblers feed on upland invertebrates, while marsh harriers feed on small vertebrates around the lakes.

All waterbirds need to be able to loaf and roost in safety. Islands are ideal for this activity. Ducks need sands spits, bare rocks and islands. Cormorants need exposed sites to dry their wings and use dead trees and poles for this purpose.

To ensure adequate resources for waterbird feeding, other links in the foodchain are essential. The specific habitat needs for algae and diatoms, invertebrates, small vertebrates and vegetation have to be provided. Thus, in order to develop a self-sustaining ecosystem, the project team aimed to develop all stages of the foodchain.

Extensive earthworks have been carried out on the site to improve the topography of the lakes. Shorelines have been modified to create gentle, sloping banks and shallow water, as well as to make them more irregular to increase the length of shoreline. Islands have been created by excavating channels across peninsulas. Bare sand spits have been created to provide loafing areas for a range of bird species and nesting grounds for waders. A number of small ponds have also been excavated as breeding sites for frogs.

A low-lying area occupying 8 hectares (20 acres) adjacent to the lakes has been excavated to below winter water level. The objective was to establish a series of islands and channels of varied dimensions on one end, and a shallow area for winter flooding on the other. A wet woodland for colonial nesting birds is being established on the islands and channels, and the shallow winter flooded part will provide feeding sites. The area is surrounded by a bank and moat for protection against predators, and to minimise disturbance by visitors.

The specific habitats being developed at the Centre can be grouped structurally into woodlands, fringing vegetation, and water (Nicholls and

Davies, 1990).

In the wet woodland, a number of *Melaleuca* spp. are being established in zones relative to their individual water level preferences. Sedges and rushes are being similarly planted in some of the channels.

A larger range of species is being used to establish fringing woodland communities on the original lakes. In addition to the *Melaleuca* spp., Flooded Gum (*Eucalyptus rudis*), She-oak (*Allocasuarina obesa*), Swamp Banksia (*Banksia littoralis*), and wattles (*Acacia* spp.) are being planted because their individual attributes have specific value to the ecosystem.

A mosaic of plant communities is being established on the surrounding uplands to enhance the habitat for vertebrates such as reptiles and small mammals, and to provide further breeding and feeding sites for birds. The communities are grouped into four structural types (forest, woodland, heath, and grassland) representative of vegetation in the region. It is also expected that this mosaic will become a valuable educational resource.

Fringing vegetation provides important breeding and shelter habitat for waterbirds as well as habitat for the aquatic invertebrates which constitute a valuable component of waterbird diets (Nicholls and Davies, 1990). Sedgelands are being established in shallow waters and reed beds of *Typha* and *Baumea* spp. are developing in slightly deeper water. Seasonally-flooded areas are being sown as water meadows to provide grazing and seeds for some of the birds.

While the fringing vegetation is developing, straw is being added to shallow water to provide a carbon source and habitat for invertebrates. Street and Titmus (1982) found that the addition of straw to lakes at Great Linford in the United Kingdom improved the invertebrate populations substantially, and the breeding success of birds using invertebrates as a protein source improved as a result. Observations at Capel support these findings and quantitative data are being collected.

Areas of deep water are important for diving birds such as cormorants, grebes, and diving ducks, as well as providing loafing areas for ducks and swans. These areas are not being planted, although some natural colonisation is occurring.

Open shallow-water areas are being retained as important feeding sites. Such areas, if sheltered, are usually highly productive for algae and invertebrates because of the high light and oxygen levels, and are valued by the wading birds.

Areas of bare shoreline are also being retained as loafing and nesting sites for a number of species.

Additional roosting sites are being provided for cormorants, herons, and ducks by the placement in the lakes of whole, dead trees cleared from the mine path. Aquatic invertebrates also benefit from this technique.

As the habitat enhancement programme is now well advanced, attention is being turned to developing landscaping plans for the public facilities to be established in the longer term. Carparks, picnic areas, walking trails, and viewing sites are being planned so that screening vegetation can be established early, principally on the uplands. This will minimise disturbance of the waterbirds by visitors. Whilst planting of the screening vegetation has commenced, it is likely the infrastructure will be phased in over a number of years.

Research Programme

A multi-disciplinary research programme, co-ordinated by the Management Committee, is an integral part of the project, and focuses on the development of the foodchain. The programme is measuring changes in the biota of the lakes over time, investigating methods of nutrient enhancement, and studying inter-relationships between various components of the ecosystem. Studies are being conducted into water ecology, algae, invertebrates, vertebrates, macrophytes, and birds.

Water Ecology

In the early stages of the project, the following four factors in the water chemistry were limiting the productivity of the system (Gordon and Chambers, 1987):

1. Low pH (≈ 4)
2. High ammonium concentrations (≈ 50,000 µg/L)
3. Low phosphorus concentrations (0-15 µg/L)
4. High concentrations of iron, manganese, and sulphate.

As the productivity of the lakes was low, the amount of utilisable carbon to establish a foodchain was presumed to be low.

Initially, benchtop studies of intact water/sediment columns were conducted to examine the effect of improving water quality on the plant and invertebrate productivity (Chambers, 1991). It was found that the buffering capacity of the microsystem was very high, although the mechanism is unknown; daily additions of alkali were necessary to maintain the pH near neutral. When phosphate was added to the microsystem, a large proportion was immediately removed from solution, most likely through bonding to particulate material and complexes in the water column. Additional experiments showed that the sediment has a large capacity for uptake of phosphorus, probably due to its high iron and manganese content. However, the phosphorus bonded to the sediment is still available to algae for growth, provided the phytoplankton is in close proximity to the sediment. Results from phytoplankton cultures showed that pH was not a barrier to algal productivity, but did affect species assemblage.

Addition of phosphorus and carbon together rapidly produced a bacterial bloom which gave rise to a reducing environment in the sediments. However, the anaerobic conditions did not bring about a marked increase in free phosphate in the water. Algal blooms followed the collapse of the bacterial bloom.

While these experiments were being conducted, water quality in the lakes had improved substantially, with pH increasing to near neutral, and iron and manganese being reduced to low levels. Accordingly, field studies that followed the initial benchtop experiments concentrated on effects of added phosphorus.

Initial field experiments examined the effect of added phosphorus on algae and macroinvertebrates in experimental enclosures within a lake (Chambers and Cale, 1991). Phosphorus concentrations up to the maximum rate of 10 mgP/L produced marked increases in chlorophyll concentration within 1 week. Inorganic phosphorus concentrations in the water column dropped to negligible levels within the same time period. Invertebrates (principally micro-crustacea) also responded to phosphorus addition. The density of micro-crustacea in the benthos, copepods in the plankton, and total zooplankton also increased with increasing levels of phosphate addition. Whilst the experimental techniques had limitations for examining long term effects, the results clearly showed the potential for increased productivity of the lake system with the addition of phosphorus.

Initial results from current research on a whole lake appear to confirm these findings. Phosphorus was added to one of the smaller lakes in the system at a rate comparable to 7 mg/L. A green algal scum on the lake surface formed within 1 to 2 weeks (Chambers and Cale, pers. comm.). Benthic algae increased productivity, and there are indications of species richness also increasing. Approximately 1 month after the phosphorus addition, a bloom of the water flea *Daphnia* sp. was observed, and a second species of *Daphnia* appeared in the second month. *Daphnia* is still present in the lake 8 months later.

Algae

Initial algal studies by John (1988) provided baseline data from only one sampling date (May 1987). Current work involves monitoring the algal populations on a seasonal basis, and quantitative sampling for statistical analysis of similarity and diversity of ponds, as well as quantitative abundance of individual species. Also, further work is in progress on the taxonomy of microalgae in the region, as this information will be an invaluable tool for monitoring water quality.

Since the pH of the water in the lake system increased in 1988, there has been a transition from acidophilus species to a dominance of circumneutral species (John, pers. comm.). Concomitantly, there has been a substantial increase in species diversity, indicating the potential of the system to sustain diverse consumer communities. This increasing species diversity was further illustrated by the observation of a planktonic diatom bloom within the last year.

Invertebrates

Following the initial baseline studies (Cale and Edward, 1987), a detailed monitoring programme was set up in one of the lakes (Boulder Lake) to determine the spatial and temporal distribution of abundance and diversity of the invertebrates.

Major changes in the composition of the benthic and planktonic communities were observed as the pH of the lake water increased in 1988 (Cale and Edward, 1990a). Seasonal diversity and species richness increased, with additional species of Chironomidae, Ostracoda, Cladocera, and Cyclopoida appearing in both the benthos and plankton. Both total abundance and standing biomass in the benthos decreased as the pH increased. As the invertebrate communities are in transition, these effects are not expected to continue long term. The zooplankton of the lake was also affected by rising pH, as micro-crustacea increased and coleopteran plankters decreased. This was seen to be beneficial to the productivity of the habitat, with benefits flowing to waterfowl, as the micro-crustacea have shorter generation times than the coleopteran taxa. The seasonal distribution of abundance and diversity was masked by the rise in pH.

The number of species comprising the benthic fauna at the end of the first study period (December 1988) was comparable with values obtained in studies of other wetlands on the Swan Coastal Plain (Davies et al., 1987). Similarly, the standing biomass observed in the benthos in this study was comparable to values reported from other Australian studies (Maher and Carpenter, 1984). The functional nature of benthic communities also changed in response to pH. Filter feeders became more abundant, joining the predators and collectors previously recorded. It was concluded that the increased complexity afforded by the addition of functional feeding groups will enhance the stability and productivity of the lakes (Cale and Edward, 1990a). This monitoring is continuing.

In a further study, Cale and Edward (1990b) investigated the benthic macroinvertebrate faunas of 3 different habitats: viz *Typha orientalis*, *Isolepis prolifera*, and open water. The 2 vegetation habitats had significantly higher species richness, abundance, and standing biomass of invertebrates than the open habitat, but were not different from each other. Standing biomass was nearly an order of magnitude greater in vegetated habitats than in the open habitat. A standing biomass of 8 g/m^2 was measured for the *I. prolifera* habitat, a value comparable to that from studies of other Australian wetlands (Maher and Carpenter, 1984).

An additional habitat study is now in progress. Other species of macrophytes are being examined, as well as a mat of straw of comparable surface area (Cale, pers. comm.). This will enable the effects of "shape" of each habitat to be compared to gain a better understanding of the habitat requirements of aquatic macroinvertebrates.

Vertebrates

A monitoring programme studying the status of frogs and reptiles was initiated in September 1988 and is continuing. Trapping revealed that probably all frog species common in the region were present on the wetlands site (Bamford, 1990). Not all species were observed breeding, however, recently metamorphosed frogs of several species, notably *Crinia glauertii* and *C. insignifera*, were found to be widespread in 1988/89. Breeding was restricted to seasonal pools adjacent to the wetlands and to Swamphen Lake and Litoria Swamp. At least 1 species, *C. insignifera*, bred in the wet woodland less than 1 year after construction, indicating the potential for the wetlands as they develop. The presence of the mosquito fish (*Gambusia affinis*) in most of these lakes may well be restricting frog breeding, as this species preys on young tadpoles. However, increased development of fringing vegetation may mitigate this predation.

In 1990, it was found that the continuing colonisation of the site by frogs was being aided by the creation of "frog hollows", which separated them from the mosquito fish-infested lakes. Several species of frogs were found to be breeding in the wet woodland, which is also free of mosquito fish.

Species of reptiles were poorly represented in the initial trapping results, as many species probably present in the region were not recorded (Bamford, 1990). The distribution of reptiles was irregular, with most species recorded close to remnant native vegetation. In 1990, additional species were recorded for the first time, and some of these were associated with the introduction of logs, rocks, and gravel to some upland areas. It is expected that the development of upland vegetation will benefit the reptile species significantly.

Macrophytes

A 3 year research project commenced in 1989 to investigate practical means to propagate and establish a select number of sedges, rushes, and bulrushes, and to determine their preferred habitat. As there is a paucity of information in the scientific literature on these aspects, this research should provide important information for wetland management and restoration elsewhere.

Transplantation trials have been set up for 12 species where the effect of planting rhizomes at 5 water depths on establishment and tolerance to seasonal flooding will be studied (Chambers, pers. comm.). Some of the species suffered setbacks in the early stages by either wave action or grazing from waterbirds. However, after 15 months, definite trends are beginning to emerge. The trials will continue for another 12 months to consolidate these trends.

To supplement the field trials, a controlled experiment has been set up at Murdoch University to examine the effect of water depth above and below ground surface on 9 species (Chambers, pers. comm.). The species chosen represent 3 size classes: small (<0.5m in height), medium (≈1m), and tall (2-3m). Water depths range from 1m below ground to 0.75m above ground. The plants are being monitored fortnightly for their condition, productivity, flowering, and seed set. Measurements on their physical environment are also being made including redox of the sediment, pH, and temperature of the water, and light intensity both in the air above the plants and at various water depths. After 8 months, definite trends in species survival with water depth are beginning to show. Surprisingly, all species are performing well where water level is up to 1 metre below ground surface, although this may change as the dry summer progresses.

Additional information is being gathered on the phenology and habitat preferences of 13 species. Transects have been set up across the water gradient in natural stands of these species (Chambers, pers. comm.), and monitoring of a range of parameters is conducted monthly. Early data already show differences between species in plant condition and flowering at different parts of the water gradient.

Trials are also being conducted to determine the viability, germinability, and germination requirements of seed of 13 wetland species (Chambers, pers. comm.).

All of these investigations have been designed to obtain a better understanding of the biology of the wetland macrophytes common to the region.

<u>Birds</u>

The research described above is all designed to benefit the waterbirds. Therefore, the monitoring programme initiated during the baseline studies continues to record how the birds respond to changes in their habitat.

The number of bird species recorded at the Centre is steadily increasing (see Table 2). The increase of 14 species from 1987 to 1988 is partly attributable to the presence of a resident observer since December 1987. It may also reflect improving water quality in 1988/89, because the number of bushbird species recorded did not increase to the same extent as the waterbird species.

The pattern of usage of the lakes by the waterbirds varies considerably. The numbers of some species of waterbirds seen on each survey has increased significantly, notably for the Australasian Grebe (*Trachybaptus novaehollandiae*), Black Swan (*Cygnus atratus)*, Australian Shelduck (*Tadorna tadornoides*), Pacific Black Duck and Musk Duck (*Biziura lobata*) (Davies, Bamford and Doyle, pers. comm.). Other species have declined in numbers, whereas still others showed

Table 2 - Number of bird species recorded at the AMC Wetlands Centre from 1985 to 1990 (Davies, Bamford and Doyle, unpublished data).

	1985	1986	1987	1988	1989	1990
Waterbirds	23	24	30	42	45	48
Bushbirds	*	*	39	41	42	43
Total			69	83	87	91

* Not recorded

an initial decline followed by a rise.

A number of factors may be affecting the waterbirds including seasonal differences, improvements in water quality, site disturbance during the development programme, and changes in habitat relative to the specific needs of individual species. Seasonal influences can be quite marked. For example, the 1987/88 summer was very dry and many waterbirds used the lakes as a summer refuge. The numbers of Pacific Black Duck increased about threefold in this period.

Further promising trends are being observed in waterbird breeding at the Centre. The number of species breeding and the number of nests recorded at the site rose substantially in the 1990/91 summer (see Table 3). Nest totals may be higher than those shown, as it has been difficult to assign some juveniles to broods. Siteworks may have disturbed some of the birds from 1987 to 1989.

Species observed breeding at the site include Pacific Black Duck, Purple Swamphen, Australian Shelduck, Black Swan, Musk Duck, Grey Teal (*Anas gibberifrons*), Australasian Grebe, and Black-fronted Plover. Of these, the Black Swan was the only species that did not breed on the lakes in 1990/91. It had bred successfully on the lakes in the previous 3 years, but had suffered fox predation in the 1989/90 summer.

Breeding success, as measured by the percentage of fledglings to hatchlings, is difficult to determine at this time. Some broods migrate to neighbouring wetlands before fledging. However, observations indicate that more juveniles are being raised to an older age than previously, presumably because food supplies are improving. Predation remains a limitation to breeding success and it is hoped that this factor may diminish in time as the habitat develops. The wet woodland will certainly be helpful in this respect, as the surrounding moat protects the area from ground predators.

The lakes are in a transitional phase, recovering after extensive siteworks and improvements in water quality. As research on the other components of the ecosystem shows the habitats are developing, and the waterbirds are showing the benefits.

Public Use and Education

Whilst the development of public facilities is still in the planning phase, public interest in the project is increasing. This interest is coming from a wide spectrum of the community, ranging from politicians to school children. Although it is not proposed to open the site to the

Table 3 - Waterbird breeding trends at the AMC Wetlands Centre from 1986 to 1991 (Davies, Bamford and Doyle, unpublished data).

	1986/87	1987/88	1988/89	1989/90	1990/91
No of species breeding	3	3	4	5	7
No of nests	6	4	6	10	22

Table 4 - Visitation to the AMC Wetlands Centre on guided tours during 1990.

Month	Tours	Visitors	Month	Tours	Visitors
January	3	29	July	8	21
February	4	9	August	8	38
March	7	52	September	11	179
April	7	157	October	16	241
May	4	117	November	22	753
June	5	200	December	11	205

general public for some years, pre-arranged tour groups are given guided inspections. During 1990, a total of 106 groups containing a total of 2,001 visitors toured the Centre (see Table 4). Of these, 51% of the tours were by local community groups, and 18% were from local schools, the latter contributing 45% of the total visitation.

The visitors' experience from the guided tour is being supplemented by educational folders. The folders contain information on the project, as well as on the ecological aspects of wetlands and waterbirds. These fact sheets are being added to progressively, and are being designed for various target audiences. This activity will grow in significance as the Centre develops.

<u>Technology</u>

From the outset, it was recognised that this project provided an excellent opportunity to further community understanding of wetlands and their reconstruction. Such information is of value to the community only when it is communicated to a wide audience.

This is being achieved in a number of ways. First, findings from the research and monitoring programme are being reported in a Technical Report Series that is lodged in relevant libraries and referenced in this paper. Initial reports in this series are relatively site specific; however, as the research programme focuses increasingly on functional relationships, the reports will have wider application.

Second, the guided tours are educating a wide range of people including politicians, government officials, industry personnel, education specialists, school children, and the general public. We believe it is important that the community at large understand how our environment can be managed successfully.

Third, the Western Australian Environmental Protection Authority has approached the company with a request to prepare a manual on wetland restoration. The EPA receives numerous requests for such information, and it was considered that the AMC Wetlands Centre provided an excellent base for the preparation of such a manual. The concept is being developed.

Conclusion

When the AMC Wetlands Centre was established in 1987, it was recognised that the lake system had potential for development as a conservation area for waterbirds. At the same time, it was understood that the lakes were in the very early stages of successional development, and a number of limitations had to be overcome.

Over the past 4 years, considerable effort has been put into developing the various habitats needed by a range of bird species. This work has been supplemented by a multi-disciplinary research programme. As a result, the lakes are in a transition phase; various facets of the food chain are increasing in productivity. The waterbirds are responding with increased usage of and breeding on the lake system. It is anticipated that the productivity of the system will increase rapidly over the next few years.

Meanwhile, the emphasis of siteworks will gradually change to development of public facilities, subject to availability of funds. The research programme will continue to be an important part of the project, and will focus increasingly on functional relationships of the wetland ecosystem.

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