Breeding behaviour of the wild budgerigar *Melopsittacus undulatus* and its application to improving the breeding performance of Exhibition Budgerigars

Rob Marshall and Jean Marshall
Carlingford Animal Hospital
772 Pennant Hills Road
Carlingford NSW

Abstract

The breeding biology of the budgerigar (*Melopsittacus undulatus),* a nomadic and opportunistic breeding parrot species inhabiting a vast range across Australia was examined. The budgerigar's range across Australia is largely one of arid and semi-arid zones. Our 5 year ongoing study at five locations; Delmore Downs, Simpson Desert, Finke River, Hammersley Ranges and Lake Tandou showed that it is possible to predict the location of breeding sites and times when breeding activity of the budgerigar is most likely to occur.

High summer temperatures and an unpredictable low annual rainfall is a feature across the budgerigars' range. Budgerigars are nomadic and survive in very dry areas by following thunderstorms. In habitats where little water exists, budgerigars may arrive in explosive numbers after rain. As conditions deteriorate they then move on. Budgerigars do not breed in desert regions but rely upon desert grasses such as hard and soft Spinifex *(Triodia species)* for their survival during drought. Rainfall initiates breeding behaviour for budgerigars in Nature but a complex set of seasonal, climatic, geographical and geological circumstances is required to bring breeding activity to its successful conclusion. Budgerigars require breeding habitats that provide suitable nesting hollows, water and food supply. These sites can be predicted by geological and soil maps that are known to support nesting trees (river eucalypts) and nearby feeding areas favoured by breeding budgerigars.

Breeding behaviour is rapid in onset but remains an uncommon event because drought conditions dominate the budgerigars' range. Drought conditions may last for several years. Completion of the budgerigar's breeding cycle is determined by a rapid flush of seeding grasses and other desert and semi-desert plants that occurs after a sequential rain pattern. The best breeding outcomes in central Australia result when this pattern sequence occurs from mid-February to mid-March. The Delmore Downs study site represents an ideal breeding habitat for budgerigars across their northern range. Spring breeding is more common in the southern range of the budgerigar where a winter rainfall pattern predominates and temperatures are often too cold for breeding during autumn.

Knowledge of the breeding behaviour of wild budgerigars may be used to improve poor breeding performance of show quality exhibition budgerigars by ensuring they follow the same breeding patterns of the wild budgerigar.

Background

Geology and Soils

Geologically, Australia has been stable for at least 200 million years, with an extensive area of its inland once being occupied by tropical, shallow seas. Structures that originated as sediment in these warm inland seas have uplifted with earth movements and over a long geological time scale these outcrops of hard, mineral rich rock have weathered to release their metallic ions, especially calcium, magnesium and sodium. The resulting soil is extremely rich in nutrients. The MacDonnell and Hammersley Ranges are examples of "upland" areas of rich in nutrients.

Weathering, by wind and water, carries some of the nutrient rich sediments beyond the ranges to the low lying regions below. Sand brought with winds from the northwest of the continent into this lower region combines with the nutrients originating from the mineral rich outcrops to form a soil type that is specific to this region. This soil is fine, rich in iron and reddish brown but less fertile than the soil found in upland areas. More significantly, the soil found in some parts of these low lying areas is rich in calcium. This is a result of the limestone and clay lenses that have been exposed by weathering. Calcium supply, otherwise not available in the upland areas, is a major determining factor in the budgerigar's selection of breeding sites. The availability of calcium is necessary for egg production and thus forms an integral part of the budgerigar breeding cycle. Beyond these areas are the inhospitable sand deserts and gibber plains where budgerigars are unable to breed.

Flora

The predominant species across the lowlands are the Acacia shrubs. Underlying and surrounding the Acacias dispersed throughout these lowlands is a diverse range of perennial and annual grasses and forbs. These grasses come into flower following periods of rain and the resulting seed forms a significant part of the wild budgerigar's diet. However, during drought, when these grasses and forbs are unavailable as a food supply, budgerigars may be forced into the deserts as a means of survival. Desert vegetation is specialized for drought conditions and includes tussock grasses, Spinifex and Bandicoot Grass, Blue Bush and Salt Bush. Whilst these grasses provide enough nutrients for the survival of the wild budgerigar, the lack of rain and absence of calcium enriched soils results in an environment in which the budgerigar is unable to breed.

Climate

The climate across the arid range of the budgerigar is one of the most unpredictable in the world (*Oosterzee 1995*). Rainfall is unreliable in amount and season. Budgerigars have adapted to this unpredictable climate by being able to activate their breeding cycle very quickly after rain.

Weather patterns are believed to follow extremely long cycles (in the order of centuries rather than decades) and the breeding success and subsequent numbers of budgerigars seen in the wild will also fluctuate over an equally long period. In the wild, the breeding behaviour of budgerigars follows a distinct pattern. They respond sexually to the coming of seasonal rains that represent the imminent full growing time of plants and grasses. At

other times, when food supplies are limited by season or drought, their sex hormones lie dormant and they have no desire and are unable to breed. When food supplies run low they become nomadic, flying vast distances across their tropical range in search of new seeding grasses.

Summer rainfall patterns prevail across the northern parts of the budgerigar's range with worthwhile falls most likely to occur during the second half of the wet season (between December and March. See chart 1). The wet season determines the success of the budgerigar's breeding cycle. Its starting time and duration may vary from year to year depending upon monsoon activity further north and west of Australia. El Nino events, which occur every 4-7 years, also have a major effect on the start and length of the wet season. The consequence of El Nino events varies according to their intensity. An intense El Nino results in drought and a failure of weather conditions that allow budgerigars to breed. "Normal" years result in monsoon activity starting in November and extending through until April. Breeding success and therefore budgerigar numbers in Nature vary according to the intensity of the El Nino and La Nina, events that are thought to follow a 1500-2000 year cycle. Breeding conditions may not arise during El Nino events with a resulting decline in budgerigar numbers. Numbers should be expected again to rise when La Nina events dominate the weather pattern of the Australian continent.

Temperature & Rainfall

The budgerigar has adapted to the climate of arid and semi-arid Australia. Temperature and rainfall govern their breeding seasons. The ability to breed spontaneously after rain is inherent to the budgerigar, although breeding is not made possible only by the presence of rain. It is a combination of rainfall associated with moderate temperatures that brings the budgerigar into breeding condition. Although there is adequate rain, breeding in summer across the northern range is not possible because of extreme temperatures. Similarly, in the southern range, temperatures are too cold in winter to allow breeding even when rainfall is adequate. During the winter months budgerigars may migrate north east into the semi-arid zone of North Queensland where warmer temperatures may allow breeding after rain. The remaining seasons, spring and autumn, are the most suitable times for budgerigar breeding because adequate rainfall and moderate temperatures allow for the successful completion of the breeding cycle. The opportunistic nature of the budgerigar allows breeding to occur at any time when there is adequate rainfall and moderate temperatures. Breeding is not restricted by particular seasons because of the variable nature of rainfall and temperature throughout their vast range.

Water Supply

Water is a scarce resource in the arid centre of Australia and one which budgerigars must seek in order to ensure their survival. It has been estimated that an average of 80% of the desert waters come from thunderstorms. These thunderstorms have a flash flood affect, causing water to flow down the slopes of the ranges and into the dry river beds that cut through the lowland areas. When fed by rain these desert rivers and the waterholes along their length provide an ideal breeding habitat for budgerigars. The filling of the water table after heavy rain enables the growth of Red River Gum (*Eucalyptus camalduslensis*) and other nesting trees along the banks of the dry riverbed.

A vast area of the inland zone is underlain by a huge artesian basin. Under pressure this water can be lifted to the surface by bores, thus providing a mineral rich, but often hot, water supply for these semi-desert and desert areas. Farmers of this region have implemented such bores in order to provide water for their cattle. This man made effect offers an alternative water supply for breeding budgerigars.

INTRODUCTION

The wild budgerigar has adapted to tropical and temperate semi-arid and arid areas of Australia by becoming a nomad, breeding "on the run" and reducing its size. It has adapted to drought conditions that may persist for up to ten years. During prolonged droughts many budgerigars perish and only the fittest survive. On average drought conditions prevail for five out of every ten years across the range.

Seasonal weather patterns determine the breeding activity of budgerigars. Their gonads remain dormant until stimulated by rain. A sequential pattern of rain falling in a breeding environment is required for completion of the breeding cycle. Budgerigars require suitable nesting holes, calcium and mineral rich soils and a sustained supply of food in order to breed.

It is possible to predict where budgerigars breed from knowledge of the geology, soil types, vegetation and water source across their range. Budgerigars may breed on the fringes of but not within desert regions. They may however inhabit deserts to take advantage of desert resistant grasses such as Spinifex and other desert plants that suddenly come to life after rain. Knowledge of climate, seasonal and local weather patterns makes it possible to predict when a breeding outcome is possible. Autumn breeding is more likely in the north and spring breeding in the south of their range.

This study was initiated to learn more about the breeding behaviour of the wild budgerigar in order to improve the breeding performance of the exhibition budgerigar.

Over the past 20 years the standards for exhibition budgerigars have promoted a large bird with "buff-type" feather. Nowadays infertility and breeding difficulties are linked with the best quality exhibition budgerigars. Knowledge of the breeding behaviour of wild budgerigars may be used to improve breeding outcomes for show quality exhibition budgerigar. Improvements can be achieved by ensuring the budgerigars to be paired are first exhibiting signs of breeding condition and that breeding activity is not initiated when it is too cold, too hot, a month prior to the shortest day of the year or during the natural moult period.

Methods

Study Species

The budgerigar (*Melopsittacus undulatus*) is a small compact bird 18cm in length. The sexes are alike in colour and size. Cocks have blue and hens a brownish cere colour. Budgerigars are highly nomadic and follow flushes of seeding grasses after thunderstorms. They are most active during early morning and late afternoon when visiting waterholes to drink, marching through grass searching for seeds or flying from one tree to the next *(Forshaw, Parrots of the World 1973).* They feed on seeds procured on or near the ground. Important food items are spinifex *(Triodoa)* and Mitchell grass *(Strebla) (Forshaw 1973).* Pigface seeds *(Portulaca oleracea)* have also been found

in the crop of budgerigars *(Lea & Gray 1935).* During the heat of day they spend their time well camouflaged in trees or tall bushes.

Study Sites

The study sites selected for this research encompass the major habitats of Central Australia. A temperate location in the budgerigars southern range was also included. The major habitats used by budgerigars include riverine woodlands, desert ranges, mulga woodlands, sand-dunes and sand-plains. These habitats are not defined by strict borders and often a number of these environments were contained within the one study site. The Finke River study site was selected as an area of **riverine woodland** that provided a habitat suitable for budgerigar breeding where food and water were made available following rain. Mulga woodlands were nearby. The vast **sand plains** of the Simpson Desert study site play a significant role in the survival of the budgerigar species. In periods of drought the desert hardy grasses found here are the only food sources available to budgerigars. Spinifex, one such desert hardy grass found widely across Australia, is favoured by budgerigars but alone does not facilitate breeding. The Delmore Downs study site, similar to the riverine woodlands of the Finke River proved the most suitable environment for breeding budgerigars. This site is set apart from the Finke River study area by the existence of calcium deposits and clay lenses within a richer soil. At this site the **semi-desert iron rich red soils**, in combination with calcium from limestone deposits provided an area in which, following rain, budgerigars could find enough nutrients, water and nesting sites to complete their breeding cycle. The nearby **mulga woodlands** and Mitchell grass plains, rich in grasses for feeding, supplement this zone and further its idyllic breeding nature. The Hammersley Ranges provides an example of a **desert range**, where rock outcrops have uplifted with earth movements, creating extensive gorges and steep hillsides. During thunderstorms these gullies act as a water catchment zone, which in turn feeds the otherwise dry riverbeds of the surrounding lower lying areas. Riverbeds on the outskirts of Newman provided the study site. Mulga woodland and spinifex heathlands were part of the variable environment near the study site. The Lake Tandou study site, a semi-arid, man made **inland waterway** in the southern part of the budgerigars range provided a site in which budgerigars were known to breed.

The **chenopod shrublands and gibber plains** are a major habitat within Central Australia but one in which budgerigar breeding does not take place. Whilst this environment is rich in nutrients, its absence of surface water results in an environment not suitable for budgerigar breeding. For this reason no site within this region was selected for study.

The study covered a vast area and range of environments across Australia. These included Finke River, Northern Territory; Simpson Desert, Northern Territory ; Delmore Downs, Northern Territory;
Hammersley Ranges, Western Australia and Lake Tandou, New South Wales.

Finke River, Northern Territory

The study site is located in an area west south west of Alice Springs and extends from Latitude 23.5-26˚S. The Finke River originates in the MacDonnell Ranges west of Alice Springs and flows south east towards the Simpson Desert. It forms part of the ephemeral river system of Central Australia and remains dry, except after heavy rains. Flash floods may occur in summer after violent thunderstorms and winds of high velocity carry the sediment over a broad stream area creating the dry and sandy riverbeds of the Finke River and its tributaries. Mulga *(Acacia aneura)* and Red River Gums *(Eucalyptus camaldulensis)* fringe these wide river beds and their deep root systems

reach down to the water table. Coolibahs *(Eucalyptus coolibah)* grow in the alluvial basins and distributary channels. Beyond this, vegetation becomes sparse. The riverbed and its surrounds is an excellent breeding ground where at the time of study (August/September 1998)) there were nests everywhere, ranging from ground level to the near tops of the trees. One nest was observed under a pile of stones.

Budgerigars were observed flying in small groups of 20-30 birds to the south east. Together with many other budgerigar groups they were seen feeding in an area of diverse plant life, ranging from forbs and flowering plants including Billy Buttons (*Craspedia charyantha*), Daisies (*Minuria sps.*) and Parakeela (Calandrinia sps.) to a variety of grasses including annuals; Button Grass (*Dactyloctenium radulans*) and perennials: Native Millet (*Panicum decompositum*).

Early each morning, with the desert in full bloom, budgerigars were observed flying in small groups from the breeding area in the direction where plant life was prolific. During the study, midday temperatures were recorded at 38-40˚C, at which time budgerigars camouflaged themselves amongst the leaves and remained silent. However, later in the week and during the midday heat two budgerigars were observed flying back and forth from the feeding to the breeding area. At the feeding areas there was a continuous but quiet communication as they grazed. Late in the morning small groups of budgerigars were observed drinking at a permanent water sink. They circled, quickly drank, flew off and circled again, then repeated the process before flying off in the direction of the breeding grounds. In captivity similar feeding activity, whereby budgerigars continuously seek food for their rapidly growing feathered nestlings has also been observed. This observation supports the idea that budgerigars in captivity emulate the breeding activities of their wild counterparts.

Further south east, both the vegetation and waterholes became smaller and increasingly sparse. In this area budgerigar populations diminished and breeding activity was not observed.

The Finke River (Maloney Creek tributary) study site provided an ideal breeding environment for the wild budgerigars. The water sink found at the Maloney Creek site together with a nearby feeding area, some 20 kilometres away from the nesting hollows, provided the water and nutrients required for the completion of their breeding cycle.

Simpson Desert, Northern Territory

The study site is a typical sand dune environment, where high winds, moving sands, low rainfall and high evaporation produce sparse and stunted vegetation. The desert extends southwards from about Latitude 21-26˚S and is characterized by broad and shallow dry creek beds similar to the Finke River study site. With sparse vegetation to hold the moving sands and no obvious water sinks, breeding budgerigars were not observed. Our study site was in the surrounds of the Andado Homestead. Midday temperatures were above 40 degrees each day. Here budgerigars were located but not observed to be breeding. They were seen flying westward early mornings. On inspection it was noted that they were utilizing the same feeding grounds and sinks used by the breeding population of our Finke River study site more than 100 Kilometres away.

During drought conditions budgerigars were observed climbing up the stems and eating the tops of the Spinifex (*Triodia sps.*) on the sand hills, where Kerosene Grass (*Aristida contorta*) and Bandicoot Grass (*Monachather paradoxa*) also provided a food supply. Spinifex species are widespread covering 60% of the Australian continent. Hard Spinifex (*Triodia basedowii*) is the most common species with a geographic distribution of almost half the area of central Australia.

Soft Spinifex (*Triodia pungens*) and Feathertop Spinifex (*Plectrachne schinzii*) are also widespread throughout the Simpson Desert. The environmental value of Spinifex lies not only in its ability to hold moving sands but also as a food supply for budgerigars and aborigines. After rain or fire aborigines rely upon the presence of budgerigars feeding on Spinifex as an indication that the spiky plant is producing seed.

The Simpson Desert study site did not provide a breeding environment for wild budgerigars because temperatures were too high, there were no suitable nesting trees, no water and food supply was sparse.

Delmore Downs, Northern Territory

Delmore Downs is a cattle station situated on the Bundey River 250 kilometres north east of Alice Springs on the Tropic of Capricorn (Latitude 23.5˚S). The Sandover River and its tributary, the Bundey River, have cut down into rock layers and exposed limestone (calcium) residues. These originate from coral reef formations of ancient times when a broad area of Central Australia was a shallow, warm inland sea.

Over millions of years, storm waters from the southern reaches of summer monsoons and local thunderstorms have created a river system that has cut down through the rock layers, forming a narrow and deep river. The surrounds of the Sandover River support tall trees that provide an abundance of nesting hollows. The river beds of Delmore Downs are narrow, deeper and less meandering than the "flash flood" broad, shallow channel country further south and east at the Finke River and Simpson Desert study sites. The resulting effect of this narrow river system is less evaporation than that seen at the southern study areas. Accompanying the natural water holes of the Delmore Downs, there are 18 sinks, originating from the underlying Great Artesian Basin, providing additional and permanent water.

Plant types found in this area are similar to those found in other study sites. However, with two possible wet seasons (spring and autumn) and its geographic situation relative to the tropics the vegetation here is more abundant and larger than further south. Whitewood (*Atalaya hemiglauca*) and Ghost gums (*Eucalyptus papuana)* provide excellent nesting hollows along the riverbank. These eucalypts are additional to the Blood eucalypts (*Eucalyptus opaca)* and other gums found in other study areas. Buffel Grass (*Chenchrus ciliares*), an introduced species, is widespread across Delmore Downs with thick growth lining the riverbank during summer. Following heavy rain, alluvial flats are predominated by seeding succulents of the Portulaca "Pig Weed" family (*Calandrinia remota*), an ideal food source when parents are feeding their feathered young. Extending from the limits of the riverbed are the Acacia scrublands. These are predominated by the Gidgee (*Acacaia georginae*) and Mulga (*Acacia aneura*) interspersed with Witchetty bush (*Acacia kempeana*). Further afield there are natural perennial grass plains containing Mitchell grass (*Astrelba pectinata*) and Wooly Butt (*Eragrostis eriopoda)* grasses. Mulga and other acacias are found intermittently throughout these vast plains. Highly nutritious annuals such as Wooly Oat (*Eneapogon avenaceus*), and Button (*Dactyloctenium radulans*) were found beneath and near these acacias.

We consider this subtropical calcium rich land with clay lenses to be an ideal breeding and feeding ground for budgerigars. The abundance of plant and grass species available to budgerigars following rain in this area provides budgerigars with a plentiful supply of food for successful breeding.

The region is characterized by good soil, low evaporation, abundant nesting hollows, more moderate temperature diurnal ranges, two distinct breeding seasons and following sequential rains, an abundant food supply. Nesting hollows are high up on the branches, overhanging small but permanent water holes and the feeding grounds are nearby. The calcium rich soils and moderate temperatures (with less diurnal temperature variation) during autumn and spring are capable of providing a great variety of nutritious plants and seeds.

Newman, Western Australia

This is a subtropical desert containing clay and limestone lenses located to the north of the Hammersley Ranges. This study site contains a more varied environment compared to the Delmore Downs study site. The environment is variable, supporting Mulga scrubland, Spinifex heath and riverine woodland habitats. The area offers a perfect environment for breeding opportunity. Nest holes are present in a variety of eucalypt species (*Eucalyptus camaldulensis, Eucalyptus vitrix, Eucalyptus leucophloia* and *Eucalyptus aspera)* that line the dry riverbeds. Compared to central Australia rainfall is more predictable and droughts are an uncommon occurrence in this region. Annual mean rainfall is 348millimetres of which 275millimetres falls during the wet season (December to March). About 80% of the rains come from afternoon thunderstorms and 20% from cyclones.
There are many suitable breeding habitats for budgerigars but breeding activity is an uncommon occurrence because most rain comes at the height of summer when temperatures are too hot. Average maximum summer temperatures fall between 33-39 degrees Celsius. Humidity is also generally very low (17%-48%) with highest recordings seen in June and July when the likelihood of breeding is low. Over the past 15 years budgerigars have bred only once in the local area. Autumn 1995 was the last occasion that budgerigars were seen to breed here in high numbers (*pers. communication David Kaljuste 2003*).

Lake Tandou, New South Wales

This temperate semi arid area of New South Wales is situated in the Broken Hill area very close to the Darling River (Latitude 33˚S, Longitude 142˚E). The Tandou Creek and Lake are man made and part of the Menindee Lakes Scheme. The Tandou waterway joins with the Darling River and passes through flat semi-desert in the form of a chain of lagoons and shallow lakes. It is part of a gravity fed irrigation system on self mulching, grey clays and is protected from flooding from the Darling River system by an intensive levee system made up of two high red soil dunes. The Darling River receives the bulk of its water from the Macintyre River area of Queensland. The remainder comes from monsoonal rains (35%) and from the channel country of Queensland (20%). These waters take about two months to reach the Menindee Lakes Scheme.

The climate of the southern parts of Australia follows a winter rainfall pattern. Most of the annual rain in this district falls in winter. Lake Tandou has an average winter rainfall of 225mm (8”). Winter rain is brought across by westerly winds. During spring and summer desert storms are prevalent. It is an extremely dry area with poor sandy soil that supports specialized plant growth.

The vegetation supported by this flat, poor quality, semi-desert soil completes its life cycle in about four weeks. These dunes are vegetated with Coolibah (*Eucalyptus coolibah*) trees, Ironwood (*Acacia estrophiolate*) and other acacia species interspersed with Blue Bush (*Chenopodium auricomum*), unidentified native grasses and Saltbush species. High temperatures and evaporation during summer prevents the growth of other than semi-arid flowering plants, forbs and trees.

In the past budgerigars have bred in this region during late winter and spring (August to October). This study site was chosen when large flocks numbering thousands were observed moving into the shallow creek and lakes system during October after a heavy storm dropped 50mm (2 inches) of rain. By the time of our arrival in mid-November most birds had left the area. Several nests containing recently hatched chicks were found abandoned. Temperatures at this time were between 40-43 degrees Celsius.

Here, surrounded by water, they were protected from most predators except the Azure Kingfisher. Several nests had been abandoned. Budgerigars were observed nesting within small, deep hollows of dead Black Box trees within the lake. Remaining parents birds were seen searching for food beneath native grasses and amongst dying succulents.

Lake Tandou study site was not considered to be a good breeding habitat for budgerigars. Although the lake system provided a permanent water supply and a plethora of nesting hollows food supply was severely compromised by the semi-desert sandy soil vegetation, high summer temperatures and low rainfall.

DISCUSSION

From an evolutionary viewpoint, the budgerigar (*Melopsittacus undulatus*) moved into an environment that satisfied its dietary, water, breeding, and hence survival needs. Few environments can satisfy all the needs of fauna. However, in the harsh desert and semi-desert environment of Australia budgerigars have managed to adapt and flourish across a broad range of soil types, temperatures, rainfall and latitudes.

There is a strong correlation between flora and soil types, however, rainfall, temperature, wind velocity and the movement of sediment determine which flora will predominate. An enormous variety of annual and perennial grasses, forbs (flowering plants), shrubs and trees exist across the many different environments inhabited by budgerigars. Budgerigars occur across a number of varying topographical habitats. Some may be used for breeding and others for survival. We have used the following land types (Perry 1962) as an ecological guide to the soil types and flora available to the budgerigar for survival and breeding.

Porous, infertile sandy deserts and gibber deserts cover at half of the vast range of the Budgerigar. These deserts are unlike the mobile sand dunes of the Sahara desert as they are capable of supporting specialised vegetation such as Spinifex and small forbs. Budgerigars are unable to breed in deserts because temperatures are too high in summer and too cold in winter to support an adequate food supply. Additionally suitable nesting trees and water sources are lacking. Budgerigars were seen to move into the Simpson Desert in search of food. Spinifex may be the only food available to budgerigars in a drought year. Drought years are experienced approximately every five to seven years in the desert area (*Isaacs 1987*) and may last for up to ten years. Spinifex grasses and other tussock grasses become green and lush after fire or rain and provide a survival food for budgerigars.

Like the Australian aborigines, budgerigars move large distances in their seasonal movements. Falling rain can be seen in the desert for up to 80 kilometres at ground level. The Budgerigar Dreaming paintings (aboriginal ontological stories) by Pintupi artist, Malcolm Jagamarra, depict budgerigars spiralling skyward then leaving en masses in a north west direction on their migratory journey in search of food and water. In flight budgerigars are able to see vast distances and are

capable of flying 500 kilometres in a single day. Seasonal migratory pathways of budgerigars may be predicted to avoid deserts and also follow seasonal wind patterns.

The breeding grounds of budgerigars may be predicted from the soil types and associated flora. Riverine woodlands provide the best breeding habitat for budgerigars. These breeding grounds occupy narrow strips fringing rivers or depressions and support trees of the Eucalypt family. The trees provide perfect nesting hollows and protection from heat and predators. The completion of the breeding cycle of budgerigars is dependent upon a special set of climatic and seasonal circumstances. Rain and temperature combined with suitable nesting trees, topography, soil types and associated flora dictates the success or failure of breeding outcomes. Often many different soil types and their associated flora are found within distances that are of no burden to the athletic budgerigar who is capable of flying considerable distances in a short time.

Flood plains associated with the Finke River and Sandover River study sites are mainly red, sandy earth soils. Such soil types provide budgerigars with potentially good feeding grounds during a breeding season. These areas support short lived and spectacular forbs of many types especially after flooding rains.

Brown, grey or red poorly drained cracking clay soils on gently sloping plains outside Newman are mostly treeless and support medium height perennial tussock (Spinifex) grasslands of variable density. At Delmore Downs the most dominant of these grasses was Barley Mitchell Grass (*Astrelba pectinata*). Spinifex and Mitchell Grass are both drought tolerant grasses that respond after rain. Fire stimulates regeneration of both these grasses. They are considered to be survival rather than breeding grasses for budgerigars because of they have a moderately high food value and only when green.

Sand dunes composed of coarse infertile soils extending north east of the Delmore study site supported Mulga (*Acacia aneura*) under which grow short lived grasses and forbs. These plains were not far from the breeding grounds and would have been used during breeding.

Fairly shallow limestone country found especially north east of Alice Springs and at the Delmore Downs study site supports Witchetty Bush (*Acacia kempeana*) with an understory of short grasses and forbs. Witchetty Bush also grows in fairly shallow acid stoney skeletal soils and red earths associated with Spinifex. Budgerigars require an immediate source of calcium when laying eggs and calcium rich soils or lenses of calcium must lie close to nesting trees in a breeding environment.

The dry riverbeds of the Finke River breeding grounds study site are rich in calcium (limestone and other mineral salts washed down over time). Here there is no shortage of calcium for budgerigar hens to lay eggs. At the Delmore Downs breeding grounds study site calcareous red earths overlying limestone provide the necessary calcium rich soils required by breeding budgerigars. This soil type supports low open woodland or a low forest of Gidgee (*Acacia georginae*) above low short-lived grasses and forbs. The Gidgee is taller and denser than the Witchetty Bush (*Acacia kempeana*). In more open land red earth supports short lived grasses that may be used by budgerigars as feeding grounds during breeding.

Shallow and gritty soils overlying a granite base support low open woodlands of Iron Wood (*Acacia estrophiolata*), mulga (*Acacia aneura*), White Wood (*Atalaya hemiglauca*) and Cork Wood (*Hakea suberea*). Grasses and forbs are present in this region after rain. This habitat also provides protection for budgerigars during the heat of the day.

The number of possible breeding grounds available to budgerigars is restricted by the availability of nesting trees. Eucalypts provide budgerigars with suitable nesting hollows. Eucalypts and therefore potential breeding rounds are rare across the range of the budgerigar.

The flora across the range of the budgerigar occurs in various forms, as trees, shrubs, grasses, herbs, forbs and flowering plants, each with its own soil and water needs. The distributions of Mulga woodlands and budgerigars across Australia are closely aligned. Mulga woodlands grow mainly on red earths. By extracting nutrients deep in the soil and recycling them in leaf fall individual plants act as nutrient pumps.

A characteristic feature of mulga and budgerigar lands is the unreliability in amount and season of rainfall.

Mulga is extremely resistant to moisture stress. They use their shape to channel water down to their trunks and into the ground creating a mini-refuge for grasses such as Mulga Grass (*Aritida contorta*) and Window Mulga Grass (*Thyridolepis mitchellana*) that have a very high food value and are favoured by budgerigars.

Grasses occur as annuals or perennials and both produce an abundance of small seeds. Annuals otherwise known as ephemerals have adapted to resist heat and drying out and may survive for long periods of drought. After rain germination is rapid and a lifecycle that may be as short as a month. Perennials range from grasses to shrubs to tall trees whose deep roots are paramount to their surviving in the arid environment and during flash flooding. Budgerigars take full advantage of the rapid germination, short life cycle of highly nutritious annuals such as Native Wooly Oat following rain. Perennials are more numerous and provide the breeding budgerigar with a sustained supply of food.

The nutrient content of grasses is higher in the early vegetative state of growth (*Fisher 1973*) but many grasses dry out before the budgerigars are attracted to them. There are many grasses available to the budgerigar after rain. Of the 132 arid and semi arid area grasses classified by Lazarides, 114 were found north east of Alice Springs and extending past Quilpie in Queensland. The variety decreased southward with 98 varieties in the Northern Territory-Finke River-South Australia region but decreasing towards each of the deserts and especially in Western Australia as well as the Darling River system in New South Wales. The diversity of summer annual and perennial grasses present at Delmore Downs has already been noted in the 1930's by a South Australian scientific expedition.

Native grass seeds are much higher in protein and fat levels than commonly cultivated cereal plants such as wheat (*Isaacs 1987*). Nutritionally they provide enormous amounts of energy and a high quality protein for breeding budgerigars. Although most seeds are small each grass bush bears heavily. Herbs and succulents also provide breeding budgerigars with many nutritious seeds. Grasses *of Panicum, Brachiaria* and *Eragrostis* genera seem to predominate and are common throughout central Australia, particularly near and along watercourses, in floodplains and mulga areas favoured breeding sites. Particularly nutritious grasses include Woolybutt Grass (*Eragrostis* sp.), Summer Grass and Native Millets (*Panicum decompsitum*). Barley Mitchell Grass (*Astrelba pectinata*) and succulent *Portulaca* species also found at the Delmore Down study site are particularly nutritious and staple for the Pintupi aborigine people.

Grasses of the deserts are mainly tussock spinifex of a number of varieties. Aborigines do not use spinifex as a staple. Budgerigars use it as a survival food in times of drought. Budgerigars may

also use bandicoot Grass (Monachather paradoxa) together with Cane Grass and Long Tails (grasses specific to the Simpson Desert) during drought.

Buffel Grass (*Chenchrus ciliares*) is an exotic drought resistant grass introduced from the Northern Hemisphere. It is now widespread, has a relatively high food value and is favoured by budgerigars. Although it is overtaking the native forbs and grasses in some regions it appears to have little detrimental effect on the breeding outcome of wild budgerigars. Buffel Grass was widespread at the Delmore Downs site.

Summer grasses are utilised by breeding budgerigars. A large variety of summer grasses were available to breeding budgerigars at Delmore Downs. Donald Holt classifies summer grasses as those that grow from between September and May. They included the highly nutritious Golden Beard Grass (*Chrysopogon fallax)*, Native Millet (*Panicum decompositum*), Summer Grass (*Brachiaria miliiformis*), Button Grass (*Dactyloctenium radulans*), Native Oat Grass (*Enneapogon avenaceus*), Wooly Oat Grass (*Enneapogon polyphyllus*) and Threeawn Grass (*Eriachne aristidea*) to provide quality food in summer.

Donald Holt classifies winter grasses as those that complete their life cycles in the months of June to September. Winter grasses including Pussy Cat Tail, Golden Beard Grass and Poached Egg. They may provide budgerigars with quality winter nourishment as a survival rather than breeding food, as there is a strong bias for budgerigars to leave Delmore Downs in winter and migrate northward where it is warmer. Winter grasses are of little significance to budgerigars across central Australia because they appear when it is too cold to breed.

Budgerigars were observed eating forbs and flowering plants at the Delmore Downs and Finke River study sites. These short lived heavy seeding smaller plant contribute a dietary supplement and variation to the budgerigar diet especially during breeding and particularly in a good season when the desert "blooms" in a carpet of colour. Bright purple Parakeelya (*Calandrinia parakeela*) is widespread after heavy rains and grows on sandy loam, sand plains and dunes. They flower in summer followed by capsules containing large numbers of minute kidney shaped black seeds, which when piled in a heap, look like black sand. Each plant bears a large quantity of seeds that are highly nutritious and an ideal food for breeding budgerigars. These succulents are water, vitamin and mineral rich being most valued during hot weather and drought.

The wild budgerigar uses nesting hollows found in Eucalypts. Eucalypts are considered rare compared to Mulga across the enormous range of the budgerigar. The opportunity for breeding habitats is limited by the availability of these nesting hollows. Suitable breeding grounds for budgerigars may be predicted by the presence of Eucalypts or soils that support Eucalypts. Eucalypts belong to the *Myrtaceae family*. They prefer deep river bed soil where their roots extend down to the underground water reserves and are found along more defined river courses. Ghost gums (*Eucalyptus papuana*) and (*Eucalyptus microtheca*) provide nesting holes for breeding budgerigars in Queensland's Channel Country. Budgerigars were seen nesting in Red River Gums (*Eucalyptus camaldulensis)*, Coolibahs *(Eucalyptus coolibah)* and Ghost gums (*Eucalyptus papuana*) at the Finke River and Delmore Downs study sites. Budgerigars may nest almost anywhere within an established breeding ground when breeding conditions are ideal and nesting hollows become unavailable. Budgerigars were seen nesting in Whitewood (*Atalaya hemiglauca*) at Delmore Downs and under rocks at Finke River.

Breeding grounds must provide Eucalypts for nesting protection, calcareous red earth soils or limestone country to provide an immediate source of calcium for laying eggs, a water supply and a

nearby environment that supports seeding grasses, herbs, forbs and other potentially nutritious plants after rain.

Temperature and rainfall then determine when breeding should occur within these breeding habitats.

Successful breeding outcomes remain a seasonal activity for budgerigars in the wild although rain dictates their breeding behaviour. Breeding opportunities are erratic and rely upon the availability of food. Food supply must be sustained in order for budgerigars to complete their breeding cycle. The plants that budgerigars use in order to reproduce have adapted to the same inhospitable environment and unpredictable rainfall. Grasses make up the bulk of the wild budgerigars' diet, especially after rain, followed by forbs.

Except during drought it is not excessively dry across the northern range of the budgerigar (at the Finke River and Delmore Downs study sites) where breeding grounds are found. However, a summer rainfall pattern works against plant growth and budgerigar breeding across this region. Summer rains are often in the form of heavy thunderstorms but their effect is short lived because extreme temperatures and high evaporation rates prevent sustained plant growth. The likelihood of a breeding outcome increases as temperatures moderate towards the end of summer when there remains a possibility that downpours may create conditions that favour sustained plant growth.

Delmore Downs represents an ideal breeding environment for the wild budgerigar but it remains an uncommon event for very large numbers to breed. Donald Holt runs the Delmore Downs cattle station. As a third generation occupier of Delmore Downs he has an intimate knowledge of the conditions required for sustained plant growth. From talking with Mr Holt and his mother, Jesse Holt, it was concluded that budgerigar breeding is determined by a rapid flush of seeding grasses and other desert plants after a sequential rain pattern with the best breeding seen when this sequence occurs in March.

The rain sequence starts with a substantial fall of around 25mm (personal communication with Donald Holt). The initial downpour germinating the seeds. A follow-up rain of at least 5mm two weeks after the first guarantees the plants and grasses complete their cycle and continue to do so irrespective of follow up rains. After such a sequence of rain there is a bountiful supple of feed as long as the temperatures are not too high. Breeding success is assured when the above sequence occurs when moderate temperatures arrive at the beginning of autumn (March). Even though the average rainfall during December, January and February may be higher than for March native plants and grasses on Delmore Downs rarely complete their life cycle because very high temperatures burn off the shooting grasses. Similarly breeding was abandoned at Lake Tandou when high temperatures "burnt" off food supply.

Budgerigars are stimulated into breeding condition by the first rains but require the second rain two weeks later to complete their breeding cycle. The entire life cycle of the grasses is utilised by breeding budgerigars. Germination of desert grasses and plants is usually rapid producing tasty sweet high-energy shoots within a few days after rain. Names such as Eight-Day Grass (*Fimbristylis dictoma*) and Five-Minute Grass (*Tripogon lolliforms*) reflect their very short life cycle. Eight-Day Grass germinates in two days after rain or storms and completes its life cycle within a very short time. This valuable grass is widespread across Delmore Downs and is favoured by budgerigars when green. Umbrella Grass (*Digitaria brownii*) and Barley Mitchell Grass (*Astrelba pectinata*) are also most nutritious when "green". Wooly Oat Grass *(Enneapogon polyphyllus*), Native Millets (*Panicum decompsitum*) and Parakeela (*Calandrinia remota*) provide

their highest food value when dry. The oil and protein rich Parakeela seeds are a favorite of budgerigars. The energy rich shoots stimulate the birds into breeding condition.

Breeding continues whilst the grasses continue to germinate and provide a rich source of energy. After an initial heavy downpour and follow-up rain there is a plentiful supply of food for budgerigars to continue breeding until summer grasses start to die off under the effect of shortening day length and decreasing nighttime temperatures.

By June, after completing their autumn breeding cycle, budgerigars leave Delmore Downs because there is not enough high-energy foods to support breeding. They fly off in a north-easterly direction to avoid the Simpson desert and head towards the warmer temperatures of Queensland.

The modern day exhibition budgerigar has lost none of the instincts that have made its wild budgerigar cousin such a successful breeder. The nomadic budgerigar has adapted to the harsh conditions of Central Australia superbly by surviving during the dry times on very limited nutritional resources and then very quickly breeding after seasonal rainstorms turn the desert into an oasis of seedling grasses and nutritious plants of enormous diversity. In the desert, the life of plants is very short lived and the budgerigar breeding cycle has evolved around the nutrients provided by these seeding native grasses and desert plants. After rain there is a great variety of seeding grasses and plants available for the breeding budgerigars to feed their young, but without further follow up rain or permanent water holes this food supply dries up very quickly.

The wild budgerigar will only start breeding when the natural conditions indicate that there is a very good chance of breeding success. The aviary budgerigar must follow nature's same rules. Rainstorms play a most important part in the life of desert plants and consequently for the breeding success of the wild budgerigar. It is a unique stimulus for desert breeding but the wild budgerigar is also influenced by the ancient seasonal breeding instincts common to all birds with temperature and day length playing important roles in breeding success. Instincts still present in the aviary budgerigar can be used to improve their breeding success.

The wild budgerigar starts to breed when it is in breeding condition. Aviary budgerigars must also be in breeding condition to successfully complete their breeding cycle. Desert life completely determines the breeding cycle of the wild budgerigar. In summer wild budgerigars do not breed in Central Australia because even after rain the plants do not survive for long in the intense heat. Summer therefore is an ideal time for the nomadic budgerigar to replace its feathers in what is referred to as its "annual moult". Normally, the wild budgerigar replaces its body feathers, wing and tail feathers during December, January and early February. During cold winter desert nights, when the temperature drops to below freezing, the budgerigar is insulated and waterproofed by a thick cover of down feathers. These are produced continuously throughout the year. For wild and aviary budgerigars summer is a time for the natural annual moult. Breeding of exhibition budgerigars should also not occur during the heat of summer.

In budgerigars, there is an intimate link between the moult and breeding. The end of the moult is heralded by the appearance of pin-feathers on the head and at this time the budgerigar shows a heightened level of activity and vitality. This heralds the onset of "breeding condition" in budgerigars and the best time to start breeding aviary budgerigars.

The moult primes the budgerigar into breeding condition**.** The monsoon rains and seasonal rainstorms of late summer in northern Australia coincide with the completion of the "annual

moult", a perfect time for the budgerigar to start breeding as it is in perfect physical condition and primed physiologically to come into breeding condition.

A sudden change in weather can stimulate a short body moult in aviary budgerigars. A sudden hot or wet spell often stimulates a moult in the aviary and this appears to be a remnant of the link between the moult and breeding condition in the wild budgerigar. In summer, a hot spell triggers the aviary into the "annual moult" with tail and wing feathers being dropped and replaced sequentially. At other times and especially in late winter and spring wet spells accompanied by warmer temperatures induce a partial body moult that often sends healthy budgerigars into breeding condition.

After rain, a short body moult primes the wild budgerigar into breeding condition. The wild budgerigar has adapted to the severe conditions of the desert outback because it conserves water and energy so well. It is extremely energy-efficient flying vast distances in search of food and water even after food supplies have dried up. Under these conditions it is in "survival mode" and in no physical condition to breed. Breeding starts only after the grasses and plants come to life turning the red desert into a green carpet of seedlings. The energy efficient budgerigar quickly converts the energy and nutrient rich sprouts into a short body moult.

Autumn is the best time for the wild budgerigar to breed. For over a million years the weather patterns and climatic conditions have brought rain to Central Australia during autumn. Summer grasses and plants have relied upon moderate temperatures and rains for their continuing existence and the budgerigar has adapted perfectly around Autumn breeding. Similarly, across Australia except for the cold southern and inland regions such as Canberra, Melbourne and Tasmania, autumn is the best time for aviary budgerigars to start breeding. Spring is the best time for southern states to start their breeding season.

In winter, the conditions in the desert are not favourable for breeding. The wild budgerigar, as do all birds, retains the breeding patterns of its ancient forebears. In winter, the desert nights are often below freezing. Winter rains do produce native grasses and many are frost resistant but as winter moves towards shorter days the grasses die off and breeding activity declines because of food shortage and the ancient effect that a shortening day length depresses breeding activity.

Winter breeding for aviary budgerigars is hazardous in cold climates. Aviary budgerigars already on eggs or with youngsters may breed successfully in winter in some warmer areas but breeding failure is inevitable when breeding is commenced within a month of the shortest day of the year. June 23rd in the Southern Hemisphere and December 12th in the Northern Hemisphere are critical times for the budgerigar breeder because budgerigars do not naturally come into breeding condition when it is too cold or the day length is too short. Artificial lighting and heating may be used to increase the day length and improve breeding results.

Spring is naturally a very good time for wild budgerigars to breed. The wild budgerigar responds favourably to the increasing temperatures and day length of spring when seasonal native grasses and desert plants provide the wild budgerigar with the energy stimulus to breed. In many areas of Central Australia a spring flush occurs after an especially wet autumn has filled the water table. After such seasons wild budgerigars will breed prolifically around permanent water holes in the absence of rain. Aviary budgerigars breed well towards the end of winter and early spring when the days are lengthening and becoming warmer. Good breeding results for aviary budgerigars are enjoyed when breeding starts a week or more after the shortest day of the year as long as it is not too cold.

Summer is the most dangerous time to breed aviary budgerigars. Summer is the natural time for the moult and in aviary birds establishes the breeding and health pattern for the entire year. When breeding starts or continues into summer, budgerigars are placed under considerable stress because they postpone their annual moult until the end of breeding when they often fall ill because they have not replenished their depleted nutrition and energy levels. The heat of summer places breeding budgerigars and their young under further stress often precipitating Polyomavirus (French Moult) outbreaks in otherwise healthy flocks. Breeding should be stopped in the first month of summer and resumed only after the new tail feathers are fully-grown and pin-feathers appear on the head.

The incorrect breeding season starting time is the most common cause of diseases of captive-bred budgerigars. Excessively high infertility, dead in shell, sick and dying hens and poor development of the nestling are common when the birds paired are not in breeding condition. In Australia this occurs most often when breeding starts during the natural moulting season of December, January, February, when it is too cold or the birds are paired too close to the shortest day of the year.

The budgerigar fancier can use the natural cycles of the wild budgerigar still present in the aviary budgerigar to improve the breeding results. The exhibition budgerigar is more susceptible to breeding failure and illness than the wild budgerigar, but still retains many of the strong survival characteristics of its ancestors. The most important part of breeding success is to start breeding at the best possible time and not to breed during the budgerigar's natural moulting season, when it is too cold, too hot and just prior to the shortest day of the year.

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