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● FRONT COVER: The Golden-shouldered Parrot (*Psephotus chrysopterygius* Gould). This parrot is only found in the southern parts of Cape York Peninsula (Queensland), from Normanton north to Watson River and across to Princess Charlotte Bay. Like its close relatives, the Hooded Parrot of northeastern Northern Territory and the Paradise Parrot, it nests in a hollow made in a termite mound. Generally from four to six white eggs are laid, usually in May, with perhaps a second clutch in July or August. William McLennan discovered in 1922 that the nest hollows were kept clean by the larvae of a small moth, *Neossiosynoeca scatophaga*. Later another species of this genus, *N. agnosta*, was found doing the same in nests of the Eastern Rosella (*Platycercus eximius*). [Photo: A. D. Trounson and M. C. Clampett.] BACK COVER: This magnificent specimen of cerussite (lead carbonate), showing reticulated structure, is on display in the Australian Museum's mineral gallery. It is 13 inches high. It was mined from the upper oxidized zone of the Broken Hill (New South Wales) ore body by the Proprietary Block 14 Company, probably about the turn of the century. When the company closed down in the early 1930's it generously presented the whole of its official collection, including this and many other fine cerussite specimens, to the Museum. [Photo: C. V. Turner.]

This budgerigar has just climbed out of its nesting hollow in a tree. (Its tail is dipping into the hollow.) In male birds the cere (the patch of naked skin in front of the eyes) is dark blue. In females it is light blue when not breeding, brown when breeding. This bird is a female. [Photo: Author.]

Budgerigars

By VINCENT SERVENTY
President of the Wildlife Preservation Society of Australia

IT was probably John Gould who started the world interest in the budgerigar, which is unique to Australia. He wrote in his handbook, *The Birds of Australia:*

> As cagebirds they are as interesting as can possibly be imagined; for, independently of this highly ornamental appearance, they are constantly coquetting, squabbling, and assuming every variety of graceful position . . . indeed I am unacquainted with any Australian species that has been brought to England that has contributed so much to the pleasure of those who keep living birds. I believe I was one of the first who introduced living examples to this country having succeeded in bringing home several on my return in 1840.

A flood of budgerigars poured into England and Gould recorded seeing 2,000 in a small room of a bird dealer at Wapping. Gould called the bird the "warbling grass parakeet", though later the Aboriginal name "betcherrygah", used on the Liverpool Plains, New South Wales, became Anglicised to the present budgerigar.

In captivity a number of colour varieties have been bred from the wild green strain.

Scientifically, the most recent work on parrots by J. Forshaw regards the budgerigar as a transitional form between the *Neophema* and *Pezoporus* genera of small parrots. The *Neophema* genus includes such colourful species as the Scarlet-chested and Bourke Parrots; the *Pezoporus* genus includes the Ground Parrot and the possibly extinct Night Parrot.

Part of a flock of an estimated half a million budgerigars at a railway dam on the edge of the Nullarbor Plain. [Photo: Author.]

The budgerigar is a bird of the mainland of Australia, largely the inland, though in drier areas it may reach the coastline. Sometimes it may penetrate the wetter coastal areas, but this is unusual. K. A. Hindwood and A. R. McGill, in their *Birds of Sydney*, mention several such invasions, but stress that individual birds seen are more likely to be cage-bird escapees.

Huge flocks

However, it is in the inland that the budgerigar is seen in its full beauty and interest. To travel for mile after mile with flocks of budgerigars wheeling overhead is an unforgettable experience. At one desert waterhole I watched fascinated as the birds gathered to drink in the early morning. Flock after flock arrived until the first hundreds became thousands, then tens of thousands, and finally hundreds of thousands. I estimated half a million birds had gathered at one dam during the days that followed.

A dead tree would spring to green life as several thousand budgerigars landed, then wither once more as they took off. Hawks and crows had also gathered to the feast. For the crows the attraction was the budgerigars which had been weakened, perhaps by lack of food or water, or merely old age. They were loath to leave the waterhole and, after drinking, would creep to the bushes nearby. For the hawks it was the mass of birds which were the attraction. I watched as falcons stooped through the circling flocks but, possibly due to a "distraction" effect, the attackers were unsuccessful. The only budgerigars I saw taken were those drinking at the pool, and then the hawks usually waited until only about half a dozen birds were left. Once I saw a black falcon buffet a tree in which several hundred budgerigars were sheltering. Finally, several birds flew in panic. The falcon selected an individual and followed in horizontal flight until, with a swift grip of its talons, it secured the victim.

A flock of budgerigars come in to drink at a pool on the northern Nullarbor Plain. [Photo: Author.]

Food and water, the key to survival

Yet it is not the birds of prey and other predators which are significant to budgerigar numbers. Food and water seem the key to survival. Seed-eating birds need to drink, but water alone is not sufficient. A new waterhole, perhaps a claypan filled by a thunderstorm, or a bore sunk by a sheep station owner, both mean that the seeds within a 30-mile radius can be exploited. If the food runs out, the birds move on. If the water runs out, the birds move on.

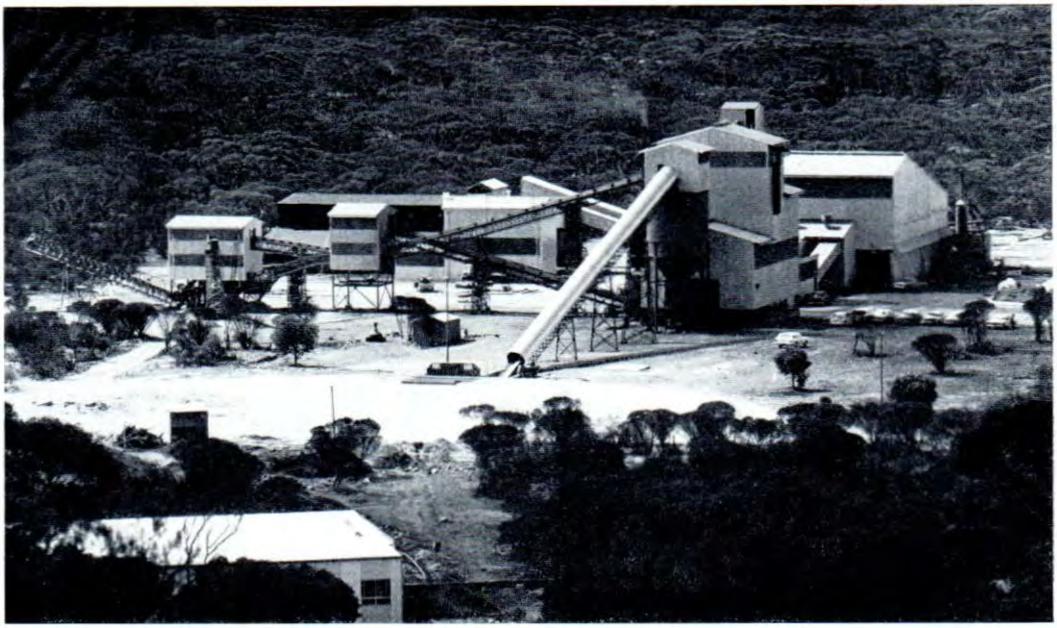
When conditions are right the budgerigars begin nesting. Knotholes in suitable trees, such as the mulga or river gum, are prospected until a suitable hole is found. In the southern parts of Australia the birds normally breed in spring and early summer. In the northern areas the dry season of winter is the favoured time. However, as with many birds of arid country, good falls of rain may be the trigger to set the budgerigars into breeding trim.

Nesting

Dozens of nests may be found in the one tree and the four to six white eggs are laid on the wood-dust in the hollow. The female sits for 18 days while her mate brings food. Thirty days later the youngsters take wing and, within 4 months, have adult plumage. It has also been found that young males may develop sperm within 2 months of leaving the nest and, if conditions are good, breeding pairs may produce a second brood in that season. It is easy to see how populations can explode.

Then the few hundred birds from each breeding area move across the plains in search of food and water. Sometimes groups may coalesce until the hundreds become thousands or more. Yet, when watching these birds drinking, it seems that the groups in these huge flocks still retain their group identity. Banding may finally reveal whether neighbours remain neighbours throughout life, as has been found with a number of other species.

Though we will discover more and more of the behaviour pattern of the birds, the magic will remain. There can be few sights the inland has to offer which can compare with thousands upon thousands of green budgerigars funnelling down to a waterhole to drink. Some drink from the edge, others lie on the surface with wings outspread as they gulp down the water with panic speed. Then the green cloud goes and another takes its place. Against the backdrop of yellow grassy plains and steel-blue sky there is an exhilaration, an excitement, a sense of wonder.



The nickel concentrating plant at Kambalda, Western Australia. [Photo by courtesy of Western Mining Corporation Ltd.]

NICKEL OCCURRENCES IN AUSTRALIA

By G. R. WALLIS
Geological Survey of New South Wales

IN February, 1966, Western Mining Corporation closed a gap in Australia's mineral resources—that of nickel—with the intersection of significant sulphide mineralization in a diamond drill hole at Kambalda, 30 miles north of Kalgoorlie, Western Australia. Today this company is a nickel concentrate producer.

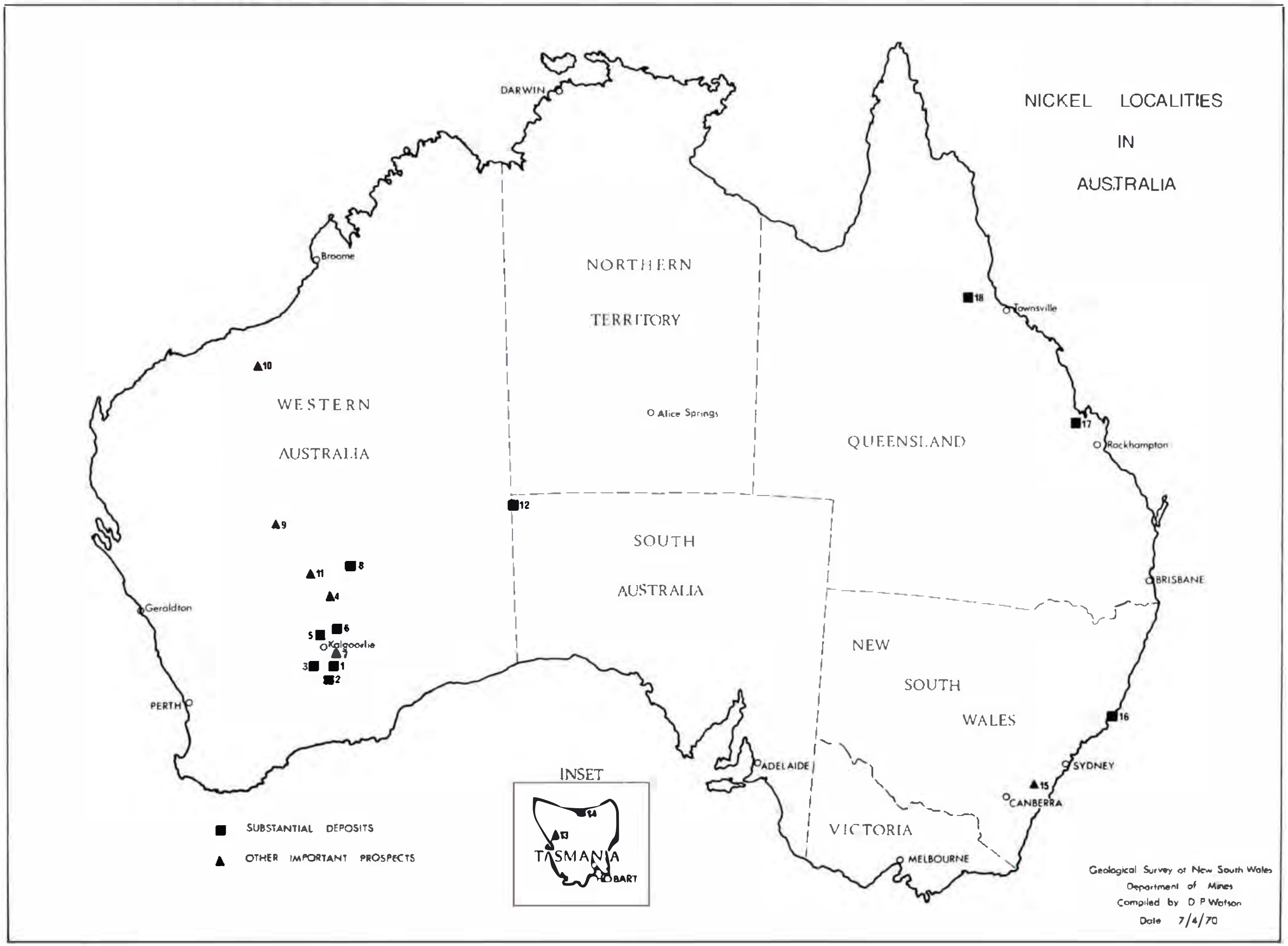
Between 1963 and 1966 nickel consumption in the free world rose by about 70 per cent. This situation, coupled with the heavy United States military requirements in Vietnam and the current labour shortage in Canada, had led to a tight nickel supply situation. As a consequence the tempo of exploration for new nickel mining prospects has substantially increased, as is evidenced by the activity in Australia.

Ores of Nickel

E. S. Dana, in his *A Textbook of Mineralogy*, lists some thirty-five nickel-bearing minerals, but few have any commercial significance. Several, including the most important ore minerals, are listed below.

Sulphides

Pentlandite is a sulphide of iron and nickel, $(Fe, Ni)_9S_8$. The ratio of nickel to iron is approximately 1:1. Pentlandite occurs in a massive form or in granular aggregates and is light bronze-yellow in colour. The hardness is 3·5 to 4 and specific gravity 4·6 to 5·0. It occurs in highly basic rocks and is nearly always intimately associated with pyrrhotite. It is the primary source of nickel in Canadian



The principal occurrences of nickel in Australia, as listed in Table 2 at the end of this article.

ores and contains about 36 per cent of the metal.

Millerite, nickel sulphide, NiS, usually occurs as very slender to capillary crystals. It can occur as an alteration product of other nickel-bearing minerals, and is found in serpentinites, meteorites, and coal measures. The hardness is 3 to 3·5 and the specific gravity is 5·5. The colour varies from pale brass-yellow to bronze-yellow. Millerite contains 64·7 per cent nickel.

Arsenides

Niccolite, or Kupfernickel, is a nickel arsenide, NiAs. Usually massive and reniform with columnar structure, niccolite is pale copper-red in colour, with a hardness of 5 to 5·5 and a specific gravity of 7·78. It occurs together with other nickel arsenides and sulphides, and is frequently found in norites or in ore deposits derived from them. Niccolite quickly becomes coated with annabergite in a moist atmosphere.

Skutterudite is a cobalt and nickel arsenide, $(Co, Ni)As_{3-x}$. It is a tin-white and silver-grey mineral, with a hardness of 5·5 to 6 and a specific gravity of 6·5, and occurs in a crystalline or massive form. Chloanthite $(Ni, Co)As_{3-x}$, is the end member of the smaltite-chloanthite continuous series $(Co, Ni)As_{3-x}$—$(Ni, Co)As_{3-x}$.

Antimonide

Breithauptite is a nickel antimonide, NiSb. Arsenic is sometimes present but may be due to admixed niccolite. Breithauptite, a copper-red coloured mineral with a hardness of 5·5 and specific gravity of 8·23, occurs in a disseminated or massive form.

Silicate

Garnierite, hydrated nickeliferous magnesium silicate, $H_2(Ni, Mg)\ SiO_4.nH_2O$ (variable Ni:Mg ratio), is an important ore of nickel, varies in colour from bright apple-green to nearly white, is soft and friable, and has a specific gravity of 2·3–2·8.

Secondary minerals

Arsenolite, arsenic trioxide, As_2O_3, is a white-coloured mineral occurring as minute crystals, aggregates or crusts formed from the oxidation of arsenopyrite, smaltite, and other arsenic minerals.

Annabergite, "nickel bloom", is a hydrated arsenate of cobalt and nickel, $(Co, Ni)_3(AsO_4)_2.8H_2O$. It is rich in nickel, and is apple-green in colour but becomes paler green to white and passes through varying shades of pink as the cobalt content increases. It occurs as fine crystalline coatings or as an earthy mass, of hardness 1·5 to 2·5. Annabergite is formed by the oxidation of the arsenides of cobalt and nickel but is less common than erythrite ("cobalt bloom").

Origin and Mode of Occurrence

Nickel deposits usually can be classified under one of three groups, two of which are primary in origin.

Primary deposits

Segregations resulting during cooling of a magma body may produce nickel-bearing sulphides in association with basic and ultrabasic rocks. These deposits are the major source of supply, the principal minerals being pentlandite, millerite, nickeliferous pyrrhotite, and nickeliferous chalcopyrite.

If disturbance of the system occurs while the mass is still semi-mobile or mobile, the molten material may be injected into fissured or brecciated zones. Should volatiles be present, the resulting deposits may display transitions into hydrothermal deposits.

In hydrothermal and pneumatolytic deposits, the important sources of nickel are niccolite, skutterudite, and nickeliferous chalcopyrite.

Secondary deposits

Lateritic nickel deposits occur as a result of deep sub-aerial weathering of nickel-bearing ultrabasic rocks, commonly serpentine. This process, which usually is restricted to sub-tropical to tropical climates, results in the combination of nickel and magnesium with silica to form garnierite. Due to the variation in weathering profiles the distribution of the nickel concentrations may be variable.

The World Situation

As mentioned above, there has been a 70 per cent increase in the demand for nickel in the 3 years prior to 1966, leading to an over-demand situation. A number of new producers have been commencing operations

Australia's 5, 10, 20, and 50 cent coins are cupro-nickel (75 per cent copper, 25 per cent nickel). [Photo: New South Wales Department of Mines.]

during 1969 and 1970, but it is anticipated that the supply will not equal demand until 1972. This supply will still be from Canada and New Caledonia, but Australia is now in the position to be an important contributor.

One of the most widely used alloying elements in both ferrous and non-ferrous metallurgy, nickel is used to impart toughness, corrosion resistance, and low-temperature ductility to its alloys and improves their high-temperature properties. Additionally, it has certain electrical and magnetic properties. The development of new applications has, in part, been one of the factors which have contributed to the increase in nickel consumption. While the largest single use of nickel is in the manufacture of stainless steel, large increases have occurred in the copper-nickel alloys. These alloys are used in coinage and desalination plants.

World nickel prices are set by the major Canadian producers, currently being $A1.214 per pound. Although free market prices have been known to be up to 300 per cent of the producer prices, they have generally been up to 200 per cent higher than the producer prices during the current shortage. For example, during November, 1969, the London free market price was being quoted at between $A14,000 to $A15,000 per ton.

Table 1 (p. 360), part of a table published in the March, 1968, issue of the Engineering and Mining Journal, sets out the world reserve situation at the end of 1967. Now, some 2 years later, Australia has added in excess of 26·25 million tons of sulphide and 150 million tons of lateritic ore to that figure. It must be remembered that much of the Australian reserves are inferred or subject to feasibility studies in respect of milling and concentrating.

Australian Nickel Occurrences

Table 2 lists the principal occurrences of nickel in Australia, their locations being shown on the accompanying map. In addition to the eighteen listed occurrences, numerous other nickel-bearing localities of minor importance are referred to in the literature. These are commonly found in association with copper mines and prospects, often with associated cobalt minerals.

The major deposit of nickel in Australia is that of Western Mining Corporation at Kambalda, Western Australia. In January, 1968, the reserves were quoted as 9·3 million tons averaging 3·8 per cent nickel. Today there are reserves of 14·5 million tons averaging 3·7 per cent nickel at Kambalda and 1·05 million tons averaging 3·4 per cent nickel at the adjacent St Ives deposit, totalling some 570,000 tons of nickel. These reserves do not include ore in several recently discovered shoots which are currently being drilled. A nickel refinery was constructed at Kwinana, Western Australia, with a minimum annual production capacity of 15,000 tons of metal. In the 4 weeks to 11th November, 1969, the Corporation mined a record of 37,337 tons of ore, while it was estimated that nearly 10,000 tons of nickel concentrates would be produced during 1969. A smelter will be built during 1970 with a capacity greater than the present mine production to allow for expansion at Kambalda and the custom smelting of ore from other producers.

At nearby Nepean, Metals Exploration and Freeport of Australia Inc. have reserves of 0·4 million tons of ore averaging around 4 per cent nickel. The ore will be sold to Western Mining Corporation for smelting, adding some 3,000 tons of nickel concentrates to the production target of 30,000 tons per annum.

Great Boulder Gold Mines Ltd and North Kalgoorlie (1912) Ltd will be mining nickel ore from their Scotia deposit, 35 miles northwest of Kalgoorlie. In addition to the quoted figure of 1·25 million tons there are 250,000 tons of oxidized ore, averaging 1·13 per cent nickel, and 500,000 tons of disseminated sulphide ore, averaging 0·64 per cent nickel. It is anticipated that some 3,000 tons of nickel concentrate per annum can be expected from a plant owned by Great Boulder in Kalgoorlie.

The well-known prospecting company, Poseidon N.L., at Windarra, Western Australia, have recently released details of their prospecting operations. While figures of 30 million tons of sulphide ore have been quoted in the press, the only official figure released to date has been that of 4 million tons of 1·32 per cent nickel with a nickel content of 96,000 tons.

Other companies have announced nickel discoveries in diamond drilling operations in Western Australia. For example, at Widgiemooltha, International Nickel Southern Ltd, in partnership with the Broken Hill Proprietary Co. Ltd, reported that they had intersected nickel grades between 1·25 to 4 per cent in widths from 20 to 35 feet in four holes along a strike length of 400 feet. At Wingellina, International Nickel Company of Canada Ltd, in partnership with Nickel Mines of Australia N.L., have proved up 60 million tons of 1·32 per cent nickel ore. In addition there are 40 million tons of inferred ore of unstated grade. This is a lateritic nickel occurrence.

In Queensland two deposits of lateritic nickel (in weathered serpentinite) of importance have been located. Metals Exploration N.L., in a 50–50 partnership with Freeport of Australia Ltd, have announced reserves of 60 million tons of 1 per cent nickel and 0·1 per cent cobalt at Greenvale. Metallurgical and feasibility studies are continuing on this deposit. The Broken Hill Proprietary Co. Ltd, recently joined by the International Nickel Co. of Canada Ltd, are investigating considerable reserves of lateritic nickel in the Marlborough region near Rockhampton, Queensland.

Victorian Antimony Mines Ltd are investigating a large lateritic nickel occurrence at Port Macquarie, New South Wales. No reserves have been announced by the company but it is probable that some 30 million tons of ore, averaging 1·2 per cent nickel, may be ultimately proved up.

TABLE 1—WORLD NICKEL RESERVES*, 1967 FIGURES

	Million tons	Percentage grade	Mine production (millions of lb nickel)
U.S.A.	1	0·4–1·5	26·6
Canada	10	1·0–3·0	480·0
New Caledonia	17	1·0–5·0	136·0
Other free world	19	0·2–4·0	36·0
Cuba†	18	0·8–1·4	60·0
Other Communist countries, excluding Yugoslavia	10	0·4–4·0	220·0
	75	..	958·6

* Reserves includes proved, indicated, inferred. † U.S. Bureau of Mines estimate.

TABLE 2—NICKEL OCCURRENCES IN AUSTRALIA

Substantial deposits (1)	Other important prospects (2)	Remarks/reserves (3)
1. Kambalda (W.A.)	....	15·5 million tons—3·7% Ni.
2. Widgiemooltha (W.A.) ..	....	2 million tons (?) 0·5% Ni, 1 million tons 3·5% Ni.
3. Nepean (W.A.)	....	0·4 million tons, 4% Ni.
....	4. Pykes Hill (W.A.) ..	8 holes showing 1·5% Ni in oxidized zone.
5. Scotia (W.A.)	....	1·25 million tons 3·07% Ni and 0·25% Cu. 0·25 million tons oxidized ore, av. 1·13% Ni. 0·5 million tons disseminated sulphide, av. 0·64% Ni.
6. Carr Boyd Rocks (W.A.) ..	....	1 million tons 1·74% Ni, 0·53% Cu. 0·5 million tons 0·70% Ni, 0·24% Cu.
7. Mount Martin (W.A.) ..	....	4–8% Ni intersections, unproved reserves.
8. Windarra (W.A.)	....	4 million tons 2·4% Ni, 0·3% Cu (19–12–69); considerably greater reserves indicated.
....	9. Wiluna (W.A.)	Good indications of nickel ore.
....	10. Bamboo Creek (W.A.) ..	Drill intersections.
....	11. Mount Clifford (W.A.) ..	Numerous intersections reported of 2·2% Ni.
12. Wingellina (W.A.)	....	60 million tons 1·32% lateritic Ni.
....	13. Zeehan (Tas.)	Previous production in 1913–1914, 1928–1933, 1938.
	14. Beaconsfield (Tas.) ..	Extensive deposits of lateritic material and serpentinite.
....	15. Bungonia (N.S.W.) ..	0·1 to 1·4% Ni in oxidized deposits.
16. Port Macquarie (N.S.W.)	....	1·2% lateritic Ni; figures not announced but could be 30 million tons.
17. Marlborough (Qld) ..	....	Suggested tens of millions tons of lateritic Ni.
18. Greenvale (Qld)	....	60 million tons 1% lateritic Ni and 0·1% Co.

Estimated total reserves: Sulphide ore—in excess of 26·25 million tons. Lateritic ore—150 million tons.

NOTE: The reserves and remarks above are gathered from many sources of information, but, due to the rate of activity, the information cannot be guaranteed.

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Behaviour of the Humbug Fish

By PETER F. SALE
Lecturer, School of Biological Sciences, University of Sydney

THE banded humbug fish (*Dascyllus aruanus*) is a Pomacentrid fish occurring on reefs from East Africa and the Red Sea, through the Indian Ocean and southeast Asia to the islands of Polynesia. Boldly marked with three vertical black bars on a white ground, it is a common and conspicuous inhabitant of Australia's Great Barrier Reef. It reaches a maximum size of about 3 inches in length.

In late 1968 I began a study of the humbug fish at Heron Island, a small cay in the Capricorn Group at the southern end of the Great Barrier Reef. I approached the humbug fish with a particular interest in the phenomenon of habitat selection. Most animals are found in more or less specific environments, and it is useless to look for them in the wrong places. We readily recognize this fact, but for few animals do we understand the underlying reasons for their distribution. It used to be believed that animals did not occur in inappropriate habitats simply because individuals which chanced into such places were promptly eliminated. Nature, "red in tooth and claw", made certain that animals lived in the right places. This may be true for some animals, especially short-lived forms which are born and die in the same small area, but by far the majority of animals which have been examined possess behaviour patterns which help to ensure an appropriate selection of habitat. Larval barnacles, for example, are quite particular about the sort of surfaces upon which they will settle. A surface with adult barnacles already living on it is greatly preferred to others.

But why look into the habitat selection of banded humbugs? Firstly, a casual glance shows that humbugs occur in only some of the sorts of habitat offered by a reef. They don't occur everywhere. Furthermore, like most reef fishes, humbugs have a brief life as a pelagic larva drifting with the prevailing currents for a few days after hatching. Early in its life every humbug has to find a reef and choose a place upon it in which to live. Finally, such abundant, conspicuous, easily caught fish are ideal experimental animals, and coral cays are biologically fascinating—as well as idyllic habitats for man!

The humbug fish, as seen on an Australian postage stamp.

Distribution on a reef

Where do humbugs live? If we consider the Heron Island reef to consist of a shallow lagoon, a reef flat, and a reef slope, then humbugs are primarily fish of the reef flat. They are not uncommon on the patch reefs scattered thinly through the lagoon, but they are rarely seen on the reef slope. On the reef flat they average about one individual per 30 square metres, although they normally occur in groups. On the reef slope, one or two may be seen in an hour's diving. Nevertheless, they do occur at depths of at least 50 to 60 feet. The humbug's virtual absence on the reef slope may be partly the result of the presence there of two close relatives, *D. trimaculatus* and *D. reticulatus*, which do not normally occur on the reef flat.

Association with corals, and use of coral branches for shelter

Humbugs are always found associated with branching corals, and use the interstices between the branches for shelter. They occur almost exclusively in living coral colonies, but the relationship can hardly be termed symbiotic. I have found them occupying twelve species of coral from four different genera. Humbugs put into an aquarium and provided with fresh corals accept them immediately with none of the fascinating preliminaries shown by their commensal relatives, the clown fish (*Amphiprion*), when given new anemones.

This restriction to living corals is problematical. I have found that humbugs taken from the coral *Pocillopora damicornis* show no behavioural response to the odour of *Pocillopora*. A bleached specimen of this coral was not more attractive if the odour was introduced into the water around it. Humbugs do not normally eat coral tissues; they readily make do with cleaned coral skeletons in acquaria, and I have used wooden "corals" in some experiments. In the field, living corals may be recognized by their colour or texture, or it might be that some fish inhabiting dead corals successfully exclude humbugs from them.

Corals used by humbugs are all of a more or less open tree-like form. Very finely branched forms, such as *Acropora hyacinthus*, and the many forms which, though branched, are arranged into a flat plate-like structure are not occupied. *Pocillopora damicornis*, a delicately branched coral, is frequently occupied, especially by the smallest juveniles. *Acropora cuneata* is more lobate than branched, and is frequently the home of the largest fish. *Acropora pulchra* and *A. hebes* are the other two most commonly utilized species. Both are "staghorn" corals.

The predominant use of these four corals is largely due to their prevalence in areas occupied by humbugs, but the fact that humbugs of different sizes occur in different proportions among the four corals shows that the fish are selecting suitable cover from the types of coral available. This selection is probably based on the geometry of the different corals. The delicate *P. damicornis* provides ideal crevices for a fish 1–2 centimetres (from two-fifths to four-fifths of an inch) in length. *A. cuneata* provides no such shelter, but offers many spaces suitable for 5–6 centimetre fish.

Fish using one species of coral may come to prefer it over the other species available.

A humbug fish adjacent to a colony of *Acropora cuneata* coral, which it uses as a shelter. [Photo: S. Domm.]

Juvenile humbugs captured in *P. damicornis* preferred that species when offered a choice including it and *A. cuneata*, *A. hebes*, and *A. pulchra*. Juveniles of the same size from *A. pulchra* preferred *A. pulchra* under the same circumstances.

Other parameters of the habitat

Several other factors influence the distribution of humbugs. Most of my observations have been made on the reef flat, but the conclusions seem to apply in the lagoons as well. Humbugs always occur in areas of interspersed sandy and coral patches. This limits them to the inner two-thirds of most reef areas since the outer part is largely of consolidated coral or rubble. Small sand-floored pools in the outer parts of a reef flat usually will have a colony of humbugs present. In lagoons they occur around the edges of patch reefs in small corals on the sand floor.

They select coral colonies with exposed vertical faces rising from these sandy areas. The colony on the very edge of a sandy patch is likely to have a larger expanse of exposed vertical surfaces than one only a metre back into the coral growth. A solitary coral colony, surrounded by sand and with all vertical faces exposed, is greatly preferred—provided it is not too far away from coral areas.

Effect of water depth at low tide

Although unimportant in the lagoon, water depth at low tide seems to influence the distribution of reef flat populations. More humbugs occur in areas where the water is deeper at low tide. This response may be simply a result of the selection of exposed vertical faces. Areas with water 50–60 centimetres deep at low tide have corals rising 50–60 centimetres above the sandy floor. Areas with a 10–15 centimetre depth at low tide offer a much lower growth of branching corals.

Interestingly, when humbugs are seen on the outer reef slope they are found occupying branched corals growing on the edges of, or within, sandy areas. These areas only occur on the horizontal benches which occasionally interrupt the otherwise steeply inclined slope.

Other behaviour

In investigating the habitat preferences of humbugs, I have had a chance to note many other aspects of their behaviour. I found that the number of humbugs occupying a coral colony depended to a great extent on the size of the humbugs and the size of the coral colony. The density of the humbug population in the immediate area was also important. Some factor was operating to distribute the humbug population uniformly over the available cover. Like many other pomacentrid fishes, humbugs are conspicuously aggressive. Fighting with conspecifics is not uncommon. Preliminary results from experiments currently under way have shown that the amount of fighting carried on by a group of humbugs depends upon the amount of cover with which they have been provided. This intraspecific fighting seems likely to play an important role in the spacing out of a humbug population over the available habitat.

The humbugs found occupying a particular coral colony form a remarkably stable group of animals. Tagging experiments showed that individually marked humbugs were present inside, or in the near vicinity of, the coral where originally tagged whenever visited over periods of as long as 7 months. In a group of such stability, there is an opportunity for individuals to recognize each other and for stable, well established dominance hierarchies to be formed. Most intraspecific fighting seen within an established group of humbugs consists of fin erections and other threat displays. Overt fighting—chasing, nipping, or mouth-biting—usually occurs only when a stranger, a fish from a neighbour coral, wanders too close.

At low tide, humbugs on the reef flat stay close to, and frequently deep within, their corals. On one occasion during an extreme low tide a tagged fish 5·5 centimetres in length was observed lying on its side in a small depression in the sand at the base of its almost completely exposed colony of *A. hebes*.

At high tide, humbugs maintain position in the water column above or in front of their coral shelters. Here, when not fighting with neighbours, they feed upon the planktonic crustaceans and other animals being swept past. They also feed to some extent

Inter-specific aggression. A damsel fish (*Pomacentrus* species) attempts to avoid the threat approach of a humbug fish. [Photo: S. Domm.]

on the fine filamentous algae growing on rocks and dead basal portions of coral colonies.

Lagoonal populations of humbugs are able to remain active throughout the tidal cycle. They seem to spend all day in mid-water feeding on plankton. It would be interesting to determine if the diet of lagoonal humbugs contains a higher percentage of plankton food than does that of the reef-flat populations. Alternatively, a poorer supply of plankton in lagoon water may necessitate this continuous feeding by lagoonal fish.

At night, humbugs retire to crevices deep within their coral colonies. They rest lightly against the coral surface, adopt a darkened coloration, and sleep until daylight.

Reproduction

Spawning occurs during the late spring and summer months. As with the other pomacentrid fish, spawning and care of eggs are quite elaborate. Male fish select an area at the base of the coral colony for use as a nest. Nest preparation is haphazard. It consists cf the nipping away of some of the fine filamentous algae always growing on dead coral, and numerous passes over the area with fins practically in contact with the surface. Throughout this period (which lasts most of a day) the male spends much time chasing other fish away from the nest-site. Both conspecifics and other species are chased, and there is a lot of threatening fin-spreading. Only the immediate nest-site is defended, and humbugs inhabiting the coral colony where it is situated are not forced to leave.

With the nest-site prepared, the male begins to court females, using a special "jerk dance". The male swims up into the water above his nest, and, when 3 or 4 feet above the substratum, commences a series of rapid, short swims directed downward at about 45°. During each of these he spreads all his fins widely as he moves downward. The fin spreading halts his downward movement. He rises again to about the height he started from and lowers his fins partially before commencing the next downward motion. The powerful downward swims, suddenly halted by the erection of all fins, occur in series of from 6 to 30 or 40, at a frequency of about 1·2 per second, giving a conspicuous jerking appearance to his behaviour.

Gravid females, occupying neighbouring corals, may now be attracted by the display, and swim towards the courting male. Alternatively, the courting male may swim over to neighbouring corals and perform his jerk dance in the vicinity of other fish. Humbugs move further from home while courting than at any other time. I saw one male swim 8 metres to a neighbouring female. Once a female moves towards him (whether at his nest or near her coral colony) the male turns towards his nest, and while still jerk dancing, swims towards it. The female follows, her fins erect.

At the nest-site, the male skims the surface first, and then he and the female alternately skim over it five to ten times. If spawning is to occur, eggs are released onto the nest-site, where they adhere, and the male fertilizes them. The female is usually chased away by the male. A male will use the same nest to spawn with several females, but I have not seen spawnings occur on the same nest on more than one day.

Once the male has a nest of eggs he becomes very aggressive for about 2 days, keeping all fish away from the eggs. He also makes very frequent swims over the nest—in much the same manner as when preparing it, or when spawning. Such swims might serve to aerate the developing eggs. Pomacentrid eggs hatch into minute fish which drift off to sea with the changing tide. Once his eggs have presumably hatched, the male begins to prepare another nest. The total process from nest preparation to egg hatching takes about 4 or 5 days.

The newly hatched fish is planktonic for an unknown length of time. If the humbug is like other pomacentrids, larval life lasts for 5 or 6 days. At the end of this time, the juvenile humbug, about 0·8 centimetres in length, selects a coral colony to occupy. Somehow it selects the right sort of habitat, and the cycle is complete.

BOOK REVIEW

AN ILLUSTRATED ENCYCLOPEDIA OF ABORIGINAL LIFE, by A. W. Reed, 1969. A. H. and A. W. Reed, Sydney. Introduction, appendices, illustrations in line, and 16 colour prints. 175 pages. $4.95.

The best way to review an encyclopedia is to choose a few entries at random. I shall describe three examples, as follows:

Archaeology: A general tendency to triteness is found here, when the author refers to middens as the happy hunting grounds of archaeologists. The diggers themselves are said to define cultural stages by examining spearheads. In addition to these general comments, the data cited are roughly 4 years out-of-date, such as the "earliest" carbon date for the presence of man in Australia, which is one published by Mulvaney in 1965.

Axes: Stone axes are described here, with no reference to their peculiar position in Australian prehistoric studies. Ground axes occur here in a hunter-gatherer context, which was recognized as a curious phenomenon years ago since most prehistorians considered that they were the markers of a farming or Neolithic society. Furthermore, they are found in very old contexts in Australia, about 15,000 years earlier than any other part of the world, a fact that was established and published some 2 years before this encyclopedia appeared.

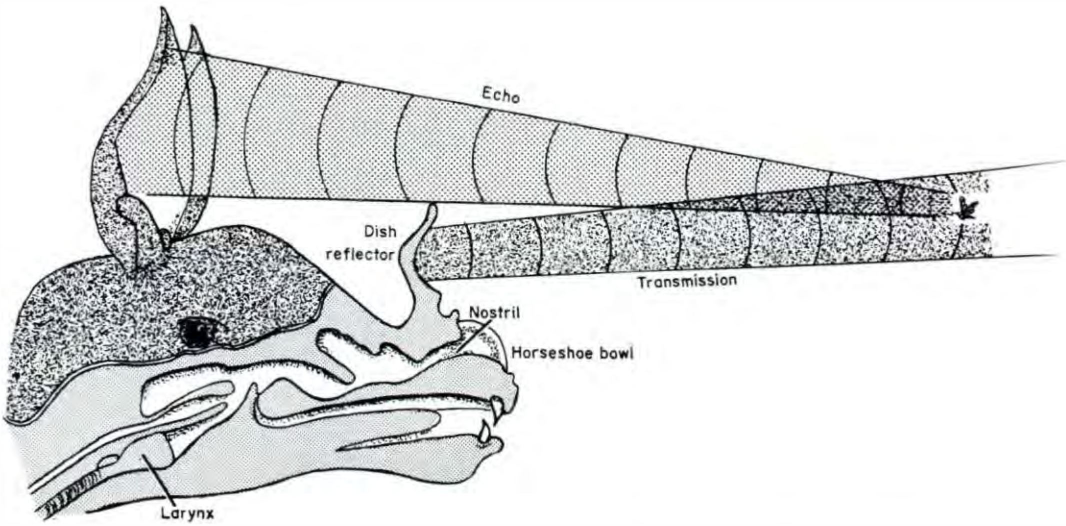
Sex: An astonishing piece of ethnographic erotica occurs here, as follows: "When tribal dignity was offended the erring woman might be forced into intercourse with many males to cure her of her promiscuity . . ." At the risk of punning on a Berndt title, I suggest that excess seldom breeds restraint. Furthermore, a glance at the work of those sturdy pioneers of the American sexual scene, Masters and Johnson, will support this contention.

Although it is no easy matter to compile an encyclopedia about Aborigines, this one is not a good start, being somewhat out-of-date in a field that has expanded greatly in the past 5 years. Also, it contains some inaccuracies which might stem from the need to condense information but which make Aboriginal behaviour appear very strange indeed. In short, I would not recommend this volume to serious students, nor to the layman.—*Carmel White, University of Sydney.*

THE ABORIGINAL PEOPLE, by Aldo Massola. Historical Backgrounds No. 2. Cypress Books, Melbourne, 1969. 69 pages, 14 black and white plates. $1.35.

The first 27 pages of this book give a brief overview of traditional life, covering everything from prehistory to social and religious organization. Generally accurate but oversimplified, this could serve as a secondary school introduction. The rest of the book deals in detail with the first contacts between Victorian Aborigines and the colonists, with later developments, especially after 1850, being only sketchily covered. There are neither gross errors nor fresh interpretations in this mostly well-known material.

The title of the book is misleading in view of most of the contents, but the illustrations are interesting and the book is a well-written general account of the disappearance of one State's Aborigines under European pressure.—*J. Peter White, Australian Museum.*



This diagram shows how the horseshoe bat uses its dishlike nasal structure to project sound ahead of it for detecting prey and obstacles. Horseshoe bats transmit the sound from their nostrils. Chambers in the air passages amplify the sound by resonance. [Diagram by the author.]

THE USE OF ECHO-LOCATION BY BATS

By J. H. PRINCE
Former Associate Research Professor at the Ohio State University Medical College and Research Centre

ALL animals which fly, swim, or move around in any other way in total darkness must obviously have some highly developed sense that will enable them to avoid collision with unseen objects or other animals, and to enable them to capture prey. The sense of hearing is the most logical one for nature to have adapted, and in the majority of such animals this is what we find. Hearing requires neither light nor the close proximity that touch would demand. The direction of smell would be difficult to identify quickly enough, and only sound will establish all the qualities necessary to glean a completely informative mental picture of an unseen object.

Few objects in this world produce continuous unvarying sounds that can be used for this purpose, so another faculty has been perfected by many animals living in the dark and relying on sound to relate themselves to other animals and objects. This is the transmission of their own sounds that will echo back from anything they strike. This has variously been called radar and sonar, but both are wrong. Radar is electrical and sonar is used in water only. The correct term is "echo-location".

Not only do these sounds have frequencies that may be special to a species, but they have been developed to a range that serves each species best in its own particular environment, whether they are marine mammals, oil birds, moths, or bats. The 800 species of bats have intrigued man for generations, but only in this century has the

The head of a horseshoe bat, *Rhinolophus megaphyllus*, showing how the nostrils are situated in the dishlike horseshoe which aids in directing the sound straight forward or at slight angles. [Photo: Author.]

mystery of their power to avoid obstacles in the dark been solved. Only since it has been possible to record and demonstrate sounds beyond the range of human hearing have proof and analysis of this ability been possible.

When sound reflects from an object it gives information of the object's size, shape, and texture or hardness. When an object is hard it reflects sound accurately and with little change in quality, but when sound strikes softer objects the echo is muffled because of absorption by unresisting material. We hear the kind of echo from hard objects or materials in bare corridors, or in valleys. We do not get the same kind of echo from soft bodies, such as fabric curtains.

Bats' finely tuned ears

The finely tuned ears of the bats and some other animals, however, can pick up reflections of sound from every kind of object, and, with experience, can differentiate to a fine degree the hardness or softness of the body, and so identify it. Because of the speed at which sound travels, and the high frequencies used, the bat can decide the position of the object, its direction, and its speed if it is moving. This same principle is now being used for blind people. They use a hearing device which also transmits sounds and records their echoes.

This technique demands remarkable discrimination by a bat, because it moves at high speed itself, and at the same time many species must identify tiny flying insects for food. Insect-eating bats all use echo-location, and some are so sensitive that they can "home-in" on insects as small as fruit flies, catching them so fast that high-speed cinematography has shown one catching two flies in half a second and another catching 220 flies in 15 minutes.

When cruising, a bat sends out pulses about ten times a second, but, as soon as it receives back an echo suggesting food, the pulses are increased as the object is approached until there are maybe 200 a second. As the pulses of sound are changed, so also is the frequency or pitch. For instance, while the pulses are ten a second, the sound may be pitched at 100,000 cycles per second; but when an insect is detected this drops as the latter is approached, until it may be only 20,000 c.p.s. This scaling-down of frequency as an object is approached is evidently a device used by the bat to be certain it is listening to its own echoes, and not those of another bat.

Pulse rate and sound frequency do not depend on each other. Frequency can remain constant no matter what the pulse rate. For instance, if a note of 10,000 c.p.s. is transmitted in 100 pulses each second with equal spaces between the pulses, each pulse will be one two-hundredth of a second long (100 pulses and 100 spaces). So, as $\frac{10,000}{200} = 50$, each pulse will contain 50 of the 10,000 cycles. If 10,000 c.p.s. are emitted in 500 pulses each second, however, the pulses and the spaces will be a thousandth of a second long, and, as $\frac{10,000}{1,000} = 10$, each pulse will contain only 10 of the vibrations. But the note will still be 10,000 c.p.s. in pitch.

Precise judgment

The preciseness of a bat's judgment of direction is remarkable. The sounds entering the two ears are compared, and their amplifications analysed in the brain in thousandths of a second. If one ear is plugged the animal can avoid only large obstacles, and if the plug were permanent, or there were irreparable injury, the bat would starve to death, unable to locate insects. The echo-location system breaks down again if the mouth is forcibly closed. Any bat with a damaged larynx would not only starve, but also kill itself by crashing into obstacles.

The moth's hearing seems to be as efficient as that of the bat, and there is no doubt that many insects can take evasive action from bats by using a similar system. This perhaps is why the bat seldom takes prey straight into its mouth, but instead scoops it up with its wing or tail membrane and takes it into the mouth from there just as quickly as if it actually captured with the mouth.

Great volumes of noise do not interfere with the bat's echo-location, and efforts to catch them in nets by confusing them with man-made noise are seldom successful. Most of the sounds made by bats are far above our own level of hearing, but if we could hear them they would be astonishingly loud for so small a creature. Obviously, this is necessary to get echoes from such small insects as mosquitoes and fruit flies. Some bats even have a tiny muscle in the middle ear which increases the pulse pressure when this is below 50 c.p.s., giving greater amplification to echoes from distant targets.

Although some bats' brains weigh no more than three or four tenths of an ounce, they contain relatively large and highly evolved hearing centres—far more advanced than our own. However, there are species differences, just as there are species differences in their voices, which vary in different localities. Bats are not always quiet when they are not flying. Many of them keep on transmitting ultra-sounds as long as they are alert. They are looking around them, so to speak, just as we do with our eyes.

Sound transmitted from nostrils

Because of strangely shaped membranes on their noses, horseshoe bats and false vampire bats are able to use entirely different forms of echo-location from those bats emitting the sounds from their mouths. The horseshoe bats transmit the sound from their nostrils, which are surrounded by bowl-like membranes having strangely shaped upright extensions behind them. These, with the shoe, project sounds forward in a narrow beam, giving them extreme accuracy and loudness.

The contours of these membranes can be altered by the movements of a complex system of muscles, while chambers in the air passages amplify the sound by resonance. The upright extensions mentioned may also be important in directing the transmitted sounds away from the bat's own ears, so that they will not confuse the returning echoes,

The leaf-nosed bat *Hipposideros diadema* has nasal structures which function similarly to those of the horseshoe bat. The folds in the ears may be for directing sound into the ear channels more intensively. [Photo: Author.]

but at present this is merely speculation. It is easy to see that this method of transmission, and a pair of highly movable ears, constitute a most sophisticated location mechanism.

The pulses emitted by these bats are longer than those described earlier, being about a tenth of a second each, and each species of horseshoe bat emits pure frequency sounds characteristic to the species, the difference between the lowest and the highest being as much as 25,000 c.p.s. This longer pulsation means that an echo has returned before the completion of a pulse transmission, but this is unimportant because horseshoe bats do not orient themselves by timing the echoes, but by the change in intensity of the echo as the object is approached. They move their heads from side to side and carry out complicated ear movements, whereas the insect-eating bats keep their ears motionless. Because its ears are so movable, plugging one of them does not handicap the horseshoe bat, but plugging both ears or the nostrils does.

Three sound-transmission systems

The sounds that bats use to communicate with each other are quite different from those they use for echo-location, and each species appears to have its own language, just like the different human tribes. It is a little unexpected to find a bat that uses more than one sense for its nocturnal activity. One genus, *Rousettus*, which lives in caves, has developed an echo-location system like that of the insect-eating bats in which judgment of distance is by the time taken for an echo to return to the animal's ears. Nevertheless, this is a fruit-eating bat with active vision and a good sense of smell. What is stranger about this animal, however, is that the sounds it makes are not made by the larynx but by the tongue. So there are at least three systems of sound transmission among bats, and it is perhaps not impossible that yet another may be found eventually.

FURTHER READING

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Allen, Glover Morrill: *Bats*, Dover Publications Inc., New York, 1962.

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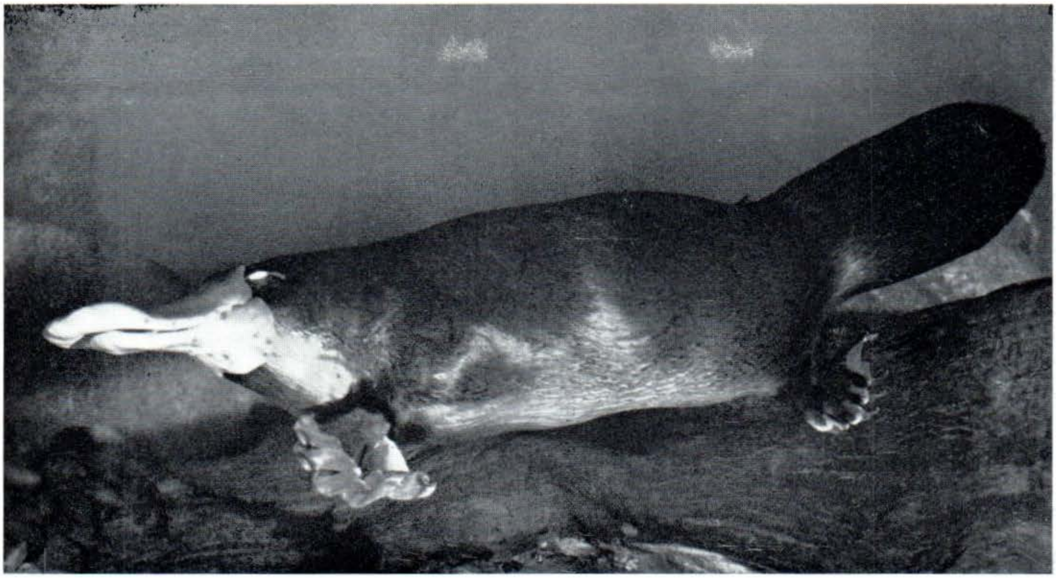
BOOK REVIEW

THE LIVES OF WASPS AND BEES, by Sir Christopher Andrewes. Chatto and Windus, London, 1969; 204 pages, 16 plates. $4.90.

Sir Christopher Andrewes has had a distinguished career in medicine and is the author of *The Natural History of Viruses* and similar books. His lifelong interest in bees and wasps has now been consummated in this concise and attractive book. By and large, it is a synthesis of current knowledge of the behaviour of those perennially fascinating insects, illustrated with excellent photographs selected from a variety of sources. The book is evidently not intended for the layman, who may find it rather dry and fact-laden; nor is it for the specialist, who will have learned all this from the original sources. Rather, it is directed toward amateur entomologists, few of whom, the author believes, "pay any attention to the many species of wasps and bees". Unfortunately, amateur entomologists are a fairly rare breed.

The author has organized his material well and has come to grips with many of the important problems in the field. But to be truthful, I must report that there are errors of many kinds: incorrect spellings, faulty nomenclature, misinterpretations of published findings, and bothersome omissions (imagine writing on this subject and not mentioning Martin Lindauer's book *Communication in the Social Bees*!). Fortunately, few of the errors of fact are serious, but if the book had been more carefully edited, indexed, and proof-read, and particularly if it had been read in manuscript by persons actively involved in the study of wasp and bee behaviour, it might have turned out to be a very fine book indeed.

Australians will be struck by the fact that no mention is made of the bees and wasps of their country. For this they have only themselves to blame. Except for Tarlton Rayment's rather curious contributions, they have grossly neglected these insects. As Sir Christopher points out, wasps and bees may not be of great immediate importance to man, but they provide invaluable material for the study of the evolution of patterns of behaviour. Actually, many important genera occur both in the Northern Hemisphere and in Australia (for example, *Bembix*, *Cerceris*, *Megachile*), so much of the research reviewed here applies reasonably well to Australia. It is to be hoped that a fuller knowledge of some of this research will stimulate further studies of the rich and exciting Australian fauna in the future.—*Howard E. Evans, Museum of Comparative Zoology, Harvard University, U.S.A.*



A platypus swimming. Note the backward sweep of the "hand" and "foot". Charles Darwin saw a platypus near what is now the town of Wallerawang, near Lithgow, during his journey from Sydney to Bathurst in 1836. [Photo: Author.]

DARWIN'S JOURNEY IN N.S.W.

By P. J. STANBURY

Curator of the Macleay Museum and Senior Lecturer in Zoology, University of Sydney

CHARLES DARWIN spent 18 days in New South Wales in January, 1836, towards the end of the voyage of the *Beagle*. From his account in his *Journal of Researches*, Darwin, like many an English traveller after him, felt uncomfortable in the vast new colony. He did not stay long enough to appreciate the unfamiliar land, and, in exception to his normally straightforward writing, summed up his stay in Australia with this horrid piece of Victorian sentiment:

> Farewell, Australia! you are a rising child, and doubtless some day will reign a great princess in the South; but you are too great and ambitious for affection, yet not great enough for respect. I leave your shores without sorrow or regret.

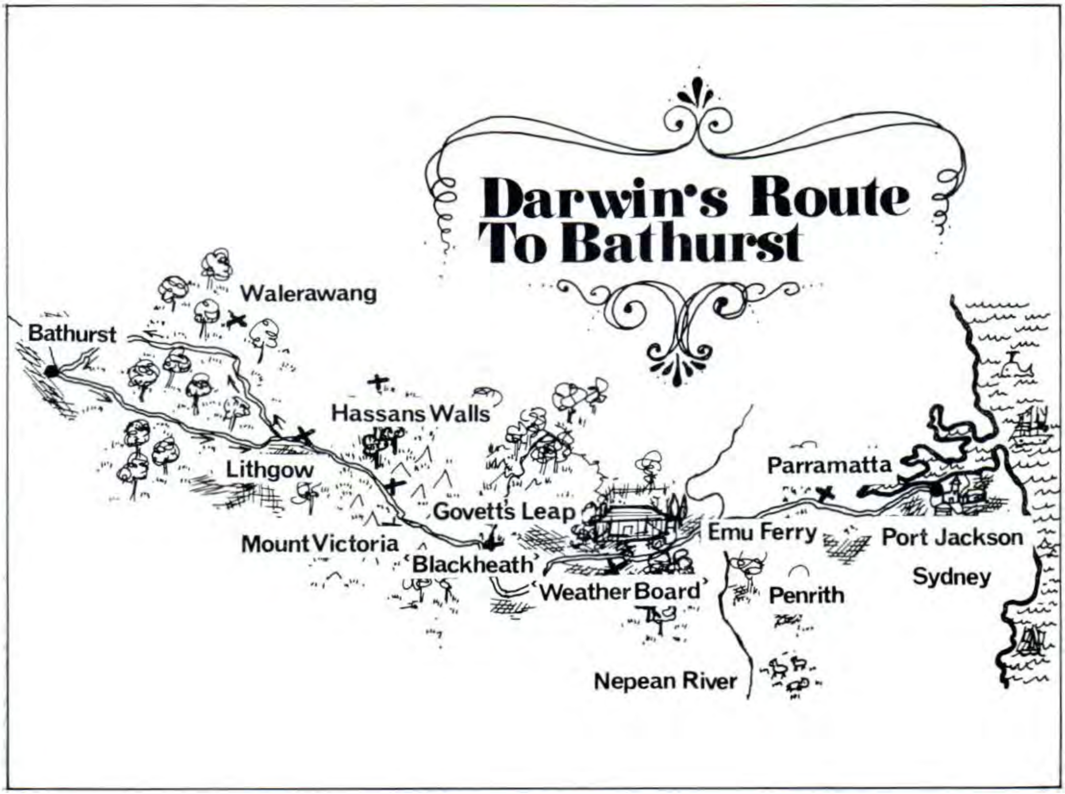
What did Darwin see in New South Wales?

He spent most of his time here on a horse trip to Bathurst. With the exception of convict gangs, and the lack of traffic and buildings, Darwin saw much the same as anyone who cares to make the same trip today.

Bushy road to Parramatta

He went first to Parramatta along the fenced MacAdam Road. The greater part of the land on either side of the road was bush: Darwin noticed how eucalypt leaves hang vertically rather than horizontally, thus presenting a smaller area to the sun. To his English eyes, the "woods" appeared light and shadowless, although he noted that this arrangement allowed grass to grow close to the tree-trunks, unlike the situation under deciduous, horizontally-leaved trees.

Just before reaching Emu Ferry—a ferry over the Nepean River just by what is now Penrith—the party came across a party of Aborigines, which even by 1836 was beginning



Map by Marenelle Record

to be an uncommon sight around Sydney, for their number had been decreasing due to their slaughter and poor resistance to European diseases.

Darwin spent the night at Emu Ferry; on the next day he crossed the Nepean and started up the slopes of the Blue Mountains. Here the sparsely inhabited nature of Australia began to strike him; although the road was an important one he met only a few bullock waggons loaded with wool. Darwin had lunch at the "Weatherboard", at what is now Wentworth Falls, and had an evening meal at the "Blackheath". Both these houses were early inns, although that name is perhaps too grand for what were really only places for travellers to eat and shelter from the weather. The "Blackheath" was named after the district and had been built only a few years before in 1831–32 by one Andrew Gardener, who had applied for the land in 1829.

"Geologising" at Govett's Leap

The next morning Darwin got up early and walked 2 miles to the waterfalls known as Govett's Leap ("leap" means cataract in Scotland), where he did some "geologising" and speculated about the origin of the Grose Valley. He attributed the high perpendicular cliffs of the valley to marine action, which was a reasonable hypothesis for a young geologist to make and which neatly bridged the gap between the old catastrophic explanation and the modern fluvial one.

Darwin then continued along the road to Bathurst, through a pass cut in the sandstone of Mount Victoria, until he came to Hassan's Walls, which still look the same now as when Darwin saw them.

Here he turned off to spend a day at a farm called Walerawang (this is Darwin's spelling; other sources give it as Wallerowang and the military map of the area, and maps generally, now spell it Wallerawang).

The view from the top of Hassan's Walls, a group of striking sandstone cliffs near Lithgow. [Photo: Author.]

Darwin spent a day on this property, and was taken on a kangaroo hunt on horseback. However, he was out of luck as they saw not one kangaroo, and Darwin consequently bemoaned the lack of conservation in Australia:

> A few years since this country abounded with wild animals but now the emu is banished to a long distance, and the kangaroo is become scarce . . . It may be long before the animals are altogether exterminated, but their doom is fixed.

The greyhounds of the party, however, did run down a kangaroo rat and Darwin saw some birds—flocks of white cockatoos, parrots, crows, and magpies.

Darwin and the platypus

In the evening he took a stroll along a creek and saw a platypus, an animal which can still be seen today by the patient, for luckily platypus fur is difficult to work with, and in any event the animal has been totally protected for many years now. I must record, unfortunately, that Darwin's host, the manager of Walerawang (Mr Andrew Browne), shot one. It did give Darwin, however, the opportunity of realizing that the "beak" is quite soft in the living animal' unlike the hard structure in stuffed and mounted specimens one sees in museums. Darwin later wrote to Lyell (just after "The Origin" was published) about how little is known of why some animals are common and some rare, and some, like the platypus, have been in existence for millions of years without significant evolutionary change.

Along the bank of the creek Darwin saw several pits of the lion-ant, which we now call the ant-lion for some reason. These conical pits are made by an insect (actually the larva of a winged Neuropteran and thus no more an ant than a lion) which has a hole or lair at the bottom of its pit. If an insect happens to walk near the sides of the conical pit it often tumbles down the loose shifting sandy sides towards the waiting ant-lion, which sucks the body fluids from the victim. Often sand is flicked at the intruder to help it lose its footing on the shifting surface.

Hot weather at Bathurst

The next day Darwin rode the 25 or so miles to Bathurst. It was a tiring day—

An ant-lion's pit, similar to those seen by Darwin during his journey. The needles are those of a *Casuarina;* ant-lion's pits are often found beneath these trees. [Photo: Author.]

the temperature in the sun was 119° F. Bathurst was dry and parched and the Macquarie River was a "mere chain of ponds." (In Machattie Park, Bathurst, is a plaque commemorating Darwin's visit).

Darwin's account of his return is even less informative than the trip out, although he mentioned that he was upset by the idea of being waited on by convicts who could be flogged for trifling misdemeanours such as a single complaint from him.

Darwin noted that the main exports of Australia were wool and whale-oil. The latter is an often forgotten industry of our early days. Yet the Sydney Customs' returns of the 1830's show that the value of whale-oil exported to England reached £175,000 and more; such over-exploitation of any natural resource could only last a few years, and by the 1850's whaling from Sydney was barely profitable and the gold rushes of the fifties finished most large-scale operations.

Darwin's return was via a new road called Lockyer's Line (after the surveyor of roads and bridges in New South Wales in 1828), Mount Victoria, and the "Weatherboard". On the way, the party passed through "large tracks of country in flames" with "volumes of smoke sweeping across the road"—another sight that you may well see if you decide one summer weekend to retrace Darwin's footsteps.

BOOK REVIEW

AUSTRALIAN BUTTERFLIES IN COLOUR, Text by Alexander Burns, photographs by E. R. Rotherham. A. H. and A. W. Reed, Sydney. Price, $3.95.

This book is one of a fine series and gives an excellent introduction to the butterflies of Australia. However, it is disappointing, after seeing other books in this series, to find that the illustrations do not show the insects alive and in their natural environment.

The eighty-five species selected by the author show the great diversity in the Australian butterfly fauna. The selection covers many of the common species, but also includes some which are considered rarities.

The plates give false impressions of size. Many of the butterflies are shown considerably larger than in nature while a few are shown in natural size. There is also a lack of consistency in the quality of the plates; some are excellent and show the specimens in their true colours, some tend to be glaring (figs 32, 54, and 55), and others are rather wan, especially figs 75 and 76.

The distribution maps form a valuable part of the book, as they show at a glance the recorded range of the species concerned. It must be noted, however, that the Wanderer (fig. 32) is occasionally seen in Tasmania. The map for the Alpine Skipper shows it as occurring on Flinders Island instead of Tasmania.

Scientifically the book is not up-to-date, as a number of generic and specific names have been altered during the past 5 years and these have been neglected by the author.

The text must surely interest readers in our butterflies and their habits and life-histories, as many of the notes have been written by the author from his own observations during many years of fieldwork all over Australia. It is a pity that examples of eggs, larvae, and pupae are not included in the illustrations.

Despite its shortcomings, this book will find a place on the shelves of all those interested in the study of Australian butterflies: it should prove to be a most stimulating and useful book for those whose interest in butterflies is only just beginning.—*John V. Peters, Australian Museum.*

A small flock of Black Swans and, second from the right, one Mountain Duck (*Tadorna tadornoides*), over Lake George, New South Wales. Note that three swans are carrying plastic identification neck bands and that the last is a juvenile with a black tip to all its primary and secondary flight feathers. A number of males—notably the first, fifth, and probably the three last swans—can be recognized by their relatively long necks. [Photo: Ederic Slater.]

The Black Swan

By L. W. BRAITHWAITE
Biologist, CSIRO Division of Wildlife Research, Canberra, A.C.T.

FEW birds are as conspicuous or as well known as the Black Swan. In its native Australia, and in New Zealand where it has been introduced, it occurs in enormous numbers. On Moulting Lagoon in Tasmania, the Coorong in South Australia, and Lake Ellesmere in New Zealand, Black Swans may often be seen in tens of thousands. Throughout the world they are immensely popular in zoological gardens and parks.

The Black Swan was discovered by the Dutch navigator Vlaming on the Swan River estuary, Western Australia, in January, 1697. It was given the name *Anas atrata*. Now, on the basis of its close relationship with other swans, it is named *Cygnus atratus*, and is one of five closely related species in its genus.

Despite the Black Swan's popularity, and large wild populations, very little was known of its biology until the last decade. Since 1962, it has been a subject of intensive study by the CSIRO Division of Wildlife Research.

The Black Swan is among the smallest of swans, the males averaging in weight about

6 kilogrammes (about $13\frac{1}{4}$ pounds) and females about 5 kilogrammes (about 11 pounds). With an abundance of the favoured foods—succulent pondweeds—these weights may, however, increase considerably, with both males and females occasionally exceeding 9 kilogrammes (about $19\frac{3}{4}$ pounds).

The black plumage is relieved by a variable amount of white on the major flight feathers and their coverts. In birds more than 2 years of age all the primaries (except the vestigial eleventh) and the first three to six secondaries are usually entirely white. In birds in their second year the first three to six secondary feathers are frequently tipped with black. In birds in their first year all flight feathers, if not entirely black, have a black tip.

Newly hatched cygnets are a soft grey. This gradually changes to a mottled grey-brown and black plumage at the time of fledging some 4 to 6 months later. The duration of the period to fledging appears dependent on the abundance and quality of food. Within 6 months of fledging the young swans are, with the exception of their major flight feathers, almost indistinguishable from their parents.

Distribution and movements

Black Swans are obviously capable of powerful and sustained flight. They have been recorded striking aircraft at heights of about 1,000 feet, and have appeared on desert waterholes more than 400 miles from the nearest known water. Unless disturbed, they make their flights in the late evening and during the hours of darkness.

Although the swans have been recorded throughout Australia, with the exception of Cape York Peninsula, the main population is concentrated in the better-watered coastal and southern regions. In New South Wales they have a complex movement pattern. Initially they concentrate on coastal lakes and estuaries and lakes on the southern tablelands during dry or drought periods farther inland, and then disperse from these lakes to the inland regions when rains or floods create large areas of temporary habitat.

In addition, they have a more regular pattern of dispersal within the coastal and southern regions. They move from the permanent lakes and estuaries, which provide summer moulting refuges, to less permanent swamps and lakes that provide breeding grounds in winter and early spring.

Food and feeding

Black Swans are entirely grazing birds. Aquatic insects and snails are consumed only accidentally. On the freshwater lakes their food is usually Ribbon Weed (*Vallisneria*) and on the more saline lakes and estuaries Widgeon Grass (*Ruppia*), Prickly Pondweed (*Najas*), or Musk Grass (*Chara*). If they are living on lakes with large stands of Cumbungi (*Typha*) or on permanent Cumbungi swamps, then the tender young leaves and new shoots of this bullrush form a major part of the diet. However, for the majority of the population inhabiting the southern coastal permanent lakes and estuaries Widgeon Grass is by far the most important food.

When temporary swamps are filled in the better watered regions of the continent, or with floods inland, the swans quickly desert their permanent refuges and seek the new green food provided by various herbs, grasses, and succulent sedges and rushes. For this reason they are attracted to flooded pastures and have gained some notoriety as a pest species in Tasmania and Victoria.

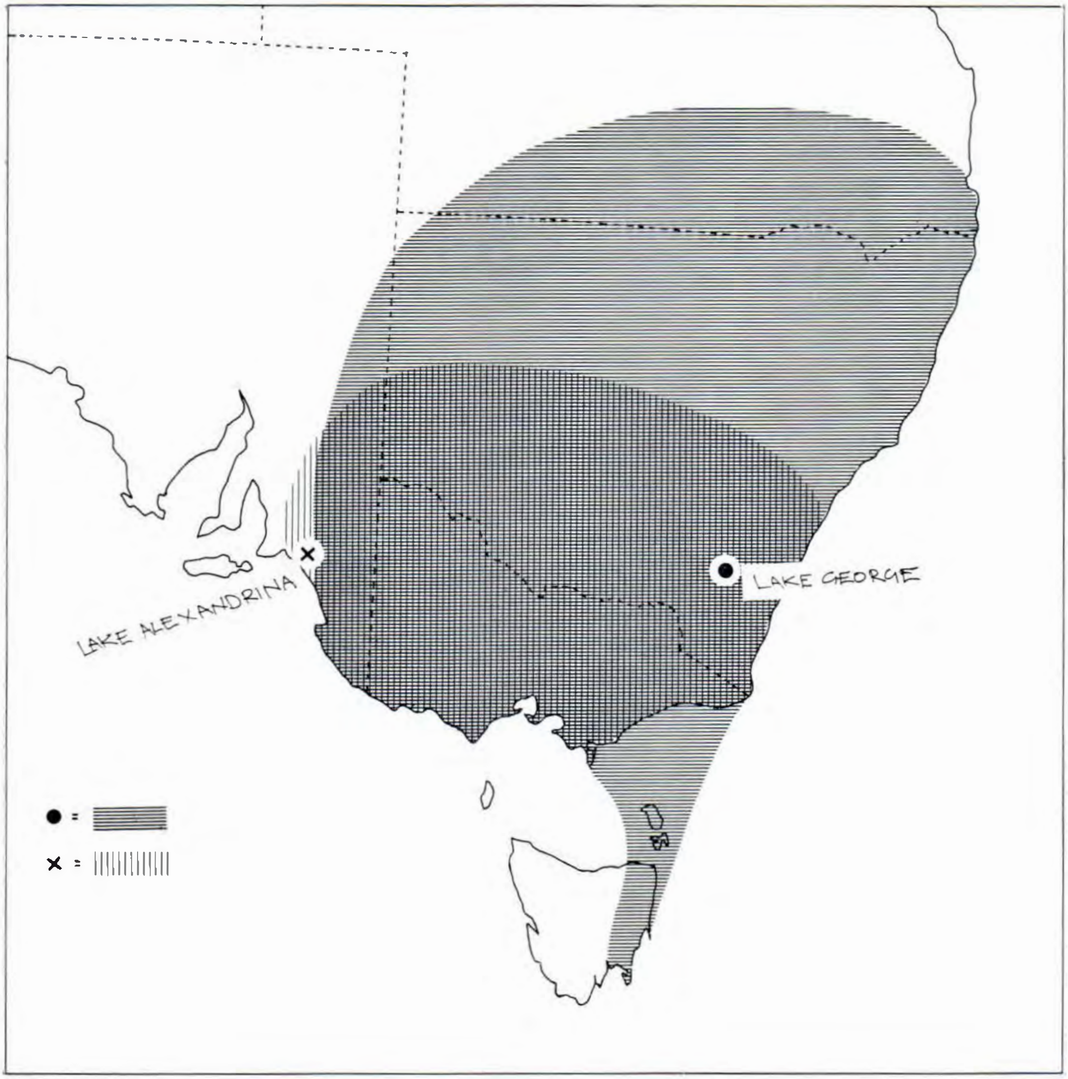
Breeding and social organization

As indicated above, swans tend to breed regularly in winter and early spring throughout the southern parts of their range. Farther north—for example in north Queensland and in the arid regions—their breeding is more closely dependent on the availability of suitable habitat, so that its occurrence is directly related to the incidence of the rains required to fill their favoured habitats. In north Queensland they tend to breed regularly in the February-May period each year, following the monsoons. Within the arid zone they may appear and breed at any time of the year, provided suitable habitat has become available; breeding may continue for as long as the habitat exists, so that records of continuous breeding for 18 months or more are not unusual. The reason for this extended breeding in many of the lakes in arid and semi-arid regions appears to lie in the abundance and high quality of the foods.

Although Black Swans show the first inclination to breed by making rudimentary attempts at nest building during their first year, none actually mate or produce eggs while retaining their juvenile plumage. Given suitable food many attempt, and are quite successful at, breeding during their second year; others, however, may fail to breed in 5 years.

Swans produce from four to eight eggs, with five and six being the most common clutch sizes. Clutches of less than four have probably suffered some loss, frequently due to ravens. Clutches of more than eight are probably produced by two or even three birds.

In clutches of four and five, incubation usually begins after the third egg is laid, but



The range of movements of Black Swans from Lake Alexandrina in South Australia and Lake George in New South Wales. The vertical hatching shows their range of movements from Lake Alexandrina and the horizontal hatching their range of movements from Lake George. [Map by F. Knight.]

Part of a colony of about 120 nests on an island in Lake George. Note that there is only one bird in attendance at each nest. This is characteristic of birds that do not maintain a strong pair-bond. Those that maintain a strong bond are rarely far apart, so that a second bird is always in close attendance to the nest if one bird is brooding. This photo was taken during the 1962–63 summer, when there was an exceptional and unseasonal breeding of Black Swans at Lake George. This breeding coincided with a massive bloom of alga, which formed the bulk of the swan's food at the time. [Photo: Ederic Slater.]

after the fourth egg in clutches of six, and usually after the fifth egg in clutches of seven or more. The eggs are laid at the rate of one every 2 days to two every 3 days. If the initial clutches are lost before incubation is well established, as many as five clutches may be laid in as many months. Hatching of the brood occurs from 35 to 45 (average 40) days after the beginning of incubation, and takes from 24 to 48 hours. In large clutches the last egg is often deserted before it hatches.

From hatching, the survival of the cygnets depends primarily on the availability of suitable food—an abundance of succulent aquatic plants usually found in the shallow water around the edge of the habitat, and fresh green herbs, grasses, sedges, and rushes. Under good conditions an average of approximately four cygnets hatch from each clutch, and of these approximately three survive to fledging. Under obviously adverse conditions on one lake, as few as eight cygnets were known to fledge from a total of 189 clutches.

Little is known of the social relationships of wild Black Swans, due to the difficulty of marking individually and observing sufficient numbers of birds. The alternative is to study captive colonies and to interpret information from these studies in terms of what can be observed of large but unmarked populations in the field.

Like the Mute Swan (*Cygnus olor*), some Black Swans have a strong pair-bond and they maintain a strict territory around their nest or loafing site. It seems that even in a drought year those birds that maintain a strong pair-bond annex for themselves a sufficient area of suitable habitat for them to at least attempt breeding. Should this territory comprise a small swamp or pond, then all other swans are driven from such a habitat. This situation is typical of much of the habitat in areas of relatively close human settlement and has led to the general but quite erroneous belief of an almost universal maintenance of a strong pair-bond and territoriality among breeding Black Swans. In fact birds with a strong pair-bond probably comprise only a very small percentage of the birds breeding in an "average" or "good" year, or non-drought year.

Most swans—and if plumage characteristics are any guide, particularly the younger birds—appear to have a far more casual attitude to life. They may or may not maintain some semblance of a pair-bond, they tend to mate indiscriminately, and some even form homosexual associations.

In most breeding associations the female is usually left to bear the brunt of incubation duties with, if she is lucky, some help from a friendly male or another female that may also lay in the same nest. Those birds lacking a strong pair-bond also show little, if any, evidence of territoriality and the territory may be limited only to a peck distance from the nest. The same birds frequently nest in colonies in reed beds or on small islands, and sometimes there may be more than 100 nests on an island of less than 1 acre in size. Here nest materials are often in short supply, with the result that the material is constantly pilfered and the eggs become dislodged from nests. Such dislodged eggs are then rapidly incorporated into other nearby clutches. It seems that a stray egg or even an unattended clutch is just impossible to resist for a swan that has some intention of setting up house. These habits cause chaos in colonies where there is a shortage of nest materials so that there is often a great wastage of eggs. Nevertheless, large numbers of cygnets hatch under these circumstances, and there can be no doubt that significant numbers manage to survive of those hatched on highly fertile and productive lakes.

In a captive colony kept under observation cygnets that hatched to parents which maintained a relatively weak pair-bond usually remained with their mother while they required brooding for the first 2 or 3 weeks. This was particularly so in cool weather. Thereafter, if the mother laid another clutch the cygnets attached themselves to other nearby friendly swans, usually either the breeding males or their mother's earlier brood, or both. These cygnets, when roosting, kept their mother company but did not participate in any incubation duties. In this way a female swan could raise as many as three broods in one year compared with the usual single brood of a pair maintaining a strong pair-bond and a rigidly defended territory. In pairs maintaining a strong bond the male actively assists in incubation duties, and once the brood hatches both birds carefully ferry the cygnets around until some months after they fledge. Thus, under these circumstances the brood, once hatched, has a good chance of survival, but only one brood is produced each year.

The family group breaks up when the adults enter their annual moult and lose much of their aggressiveness and their interest in the young birds. If the young are still in the vicinity when the old birds complete their moult and become more aggressive, then they are driven off as are any unrelated swans.

The existence of such varied forms of social organization seems an adaptation to the kaleidoscopic variation in environmental conditions in Australia, ranging from those recurring regularly on an annual basis in the better-watered southern and coastal regions to those fluctuating erratically in the inland. In the inland there may be prolonged and extreme droughts, and then floods may form new and vast areas of highly productive habitat. Those birds maintaining a rigid territory can annex for themselves optimum habitat in which they can not only maintain themselves in good health but also often breed during even the severest drought. The multitude of birds that are not so lucky form a reserve that can re-invade and breed in the interior with the coming of floods. There seems little doubt that the success of the Black Swan as a species lies in this remarkable adaptation to the Australian environment.

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CIRCADIAN RHYTHMS

By **BRIAN S. FLETCHER**
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MAN is far from being the only organism that has become a slave to time. Indeed, it would seem that the temporal orderliness of our day-to-day activities is an important consequence of our physiological make-up, because it is now known that daily rhythmicities at behavioural, physiological, and cellular levels are a basic property of almost all living systems. Locomotory activity and emergence from the pupa in insects, the running activity of mice and other small mammals, blood sugar levels, body temperature, the excretion of sodium and potassium salts in man, the time of opening of flowers, leaf movement, cell division, and D.N.A. synthesis, along with many other biological events, have all been shown to occur with a daily rhythm.

Almost 250 years ago, De Mairan, an astronomer, found that the daily leaf movement of plants persisted even when the plants were placed in constant darkness. At that time the importance of this observation was not recognized and it is only in the past 30 years that investigators have fully realized the significance of daily rhythms which persist under constant conditions. It is now known that, under these constant conditions, the rhythm does not occur precisely every 24 hours but begins slightly earlier or later each day (fig. 1). The rhythm has a period (i.e., the time interval between the expression of the rhythm on two successive days) that is only approximately a day in length. Because of this, rhythms which persist in constant conditions are commonly referred to as circadian rhythms (from the two Latin words "circa" meaning around and "dies" a day).

Evidence for "biological clocks"

Some investigators have claimed that organisms with rhythms that persist under constant experimental conditions, where light intensity, temperature, and humidity are rigorously controlled, might be sensitive to less obvious daily cycles associated with the earth's rotation, as, for instance, cosmic ray showers and air ionization. However, the observation that under constant conditions the period of the rhythm is not exactly 24 hours, is a strong argument against this possibility and favours the now widely accepted hypothesis that circadian rhythms are controlled by endogenous time-measuring processes. These are frequently referred to as "biological clocks", although this does not imply that their mechanism is in any way comparable to man-made clocks.

Studies on a wide variety of organisms, ranging from Protozoa to man, have revealed that many of the main properties of circadian rhythms are similar in all of them, and this suggests that the basic time-measuring process may be essentially the same in all living systems.

The free-running rhythm

The rhythm of an organism in constant conditions is commonly referred to as a free-running rhythm (fig. 1). The period of the free-running rhythm, although not exactly 24 hours, may be extremely accurate from day to day. The period of the flying squirrel's free-running activity rhythm, for example, may show a deviation of as little as $\pm$ 2 minutes per day. The period of the free-running rhythm has different values in different individuals and may change spontaneously even in the same individual. The period of the free-running rhythm is also affected by the parameters of the constant environment. When a rhythm is measured under constant condition at a series of increasing light intensities, the period length of a diurnal animal's rhythm decreases, whereas that of a nocturnal animal increases. This is known as Aschoff's rule and is generally applicable to all rhythms, although a few exceptions have been reported.

Entrainment and phase-shifting

In nature, of course, most organisms experience a 24-hour cycle of alternating light and darkness, accompanied by changes

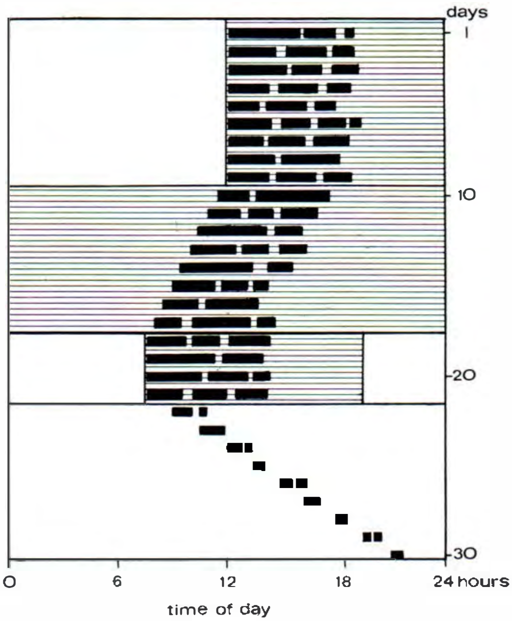

Figure 1. The activity rhythm of a nocturnal animal in an aktograph. On days 1–9 the rhythm was entrained by a 24-hour light-dark cycle. On day 10 the animal was kept in constant darkness, whereupon the rhythm became free-running with a period of approximately 23 hours 30 minutes. On day 18 the rhythm was again entrained by a 24-hour light-dark cycle, and then on day 22 the animal was placed in constant light. The rhythm became free-running again, but with a period of approximately 25 hours 30 minutes. Constant light also caused a significant reduction in the total amount of activity. The black bars indicate the times when the animal was active and the shaded areas the intervals of darkness. The records for successive 24-hour periods are placed one below the other in chronological order. [Diagram by the author.]

in temperature and humidity. Under these cyclical conditions the rhythm becomes entrained, or synchronized with the 24-hour cycle, and reaches a steady state with a period of exactly 24 hours. Moreover, the rhythm is phase-set so that the event it controls always occurs at a particular time each day, which is characteristic for that organism—e.g., the Queensland Fruit Fly (*Dacus tryoni*) mates at dusk, while a closely related species, *Dacus neohumeralis*, mates around mid-day. This phase-setting is brought about by reference to some recurring component of the day-night cycle, which is called the synchronizer or zeitgeber.

It seems that in nocturnal animals the onset of darkness acts as the main zeitgeber, whereas in day-active animals dawn has the main effect. However, laboratory experiments have shown that the true situation may be more complicated than this and that the ratio of the light to the dark part of the cycle, as well as other factors, may be important in determining the phase-setting of the rhythm.

When an animal which has been kept under constant conditions is placed in a 24-hour light-dark cycle which is out of phase with the animal's free-running rhythm, it normally requires several transient cycles, during which the period length changes, before the rhythm becomes entrained and adopts a constant phase-setting in relation to the new 24-hour light-dark cycle. If a nocturnal animal is placed in a light-dark regime in which the onset of darkness occurs during the animal's prior subjective day (i.e., several hours before the normal onset of activity), the activity rhythm is gradually advanced by phase-shifts over a number of transient cycles until it takes up its original phase-setting in relation to the new time of dusk (fig. 2). Similarly, if the new dusk occurs during the animal's subjective night (i.e., a few hours after the normal onset of activity) the rhythm undergoes a series of delay phase-shifts until it regains its original phase-setting (fig. 2).

It is also interesting to find that when an organism is moved from one light-dark regime to another, different rhythms regain their original phase-setting at different rates. This means that the different rhythms become dissociated or out of phase with each other. This occurs in man during jet travel between different time zones, or as a result of shift work. Then the rhythms of body temperatures, water and sodium and potassium excretion, etc., may become dissociated for a few days, resulting in the well-known feelings of tiredness and fatigue.

Different organisms will become entrained by a wide range of light: dark ratios in a 24-hour cycle, although at the two extremes approaching total light or total darkness entrainment may be lost and the rhythm remain free-running. In the mosquito *Aedes aegypti* 15 minutes of light every 24 hours is sufficient to entrain the oviposition cycle, although 5 minutes is not long enough. In hamsters 50 minutes of light are required, whereas in *Drosophila* a light flash of one-thousandth of a second is effective.

Although relatively large changes can be made in the ratio of light to darkness within a 24-hour cycle without interfering with its entraining properties, the rhythms of most organisms will only become entrained or synchronized by light-dark cycles in which the light plus dark fraction is close to 24 hours. Approximately 20–28 hours seem to be the limits for entrainment in most organisms. A cycle with 10 hours of light alternating with 10 hours of darkness, for example, would not entrain most circadian rhythms (fig. 3).

The effects of temperature

Although light appears to be the most important factor, some rhythms can be entrained by a 24-hour cycle of alternating high and low temperature. Often the variation in temperature need only be a few degrees.

Even though 24-hour temperature cycles may cause entrainment, one of the most remarkable properties of circadian rhythms is their nearly total temperature-independence over a wide range of temperatures, although temperatures below freezing point have been shown to have a more marked effect upon the rhythm, often delaying it for as long as, or even longer than, the period of chilling.

Most biochemical reactions have a co-efficient, or Q10, of 2, indicating that the rate of the reaction is doubled by every 10° C rise in temperature, but because the period length of circadian rhythms is little affected by temperature the Q10 is normally only slightly greater than 1. Indeed, in some organisms, including Protozoa and Algae, a Q10 of less than 1 has been recorded, indicating that the period length has actually been increased by decreasing the temperature. The functional significance of this near temperature-independence is apparent when it is considered that under natural conditions organisms frequently experience large temperature changes during a 24-hour period. A time-measuring system which was any-where near as sensitive to temperature changes as most biochemical systems would be of very limited value, particularly in situations where the "clock" is continuously consulted, as in sun-compass orientation.

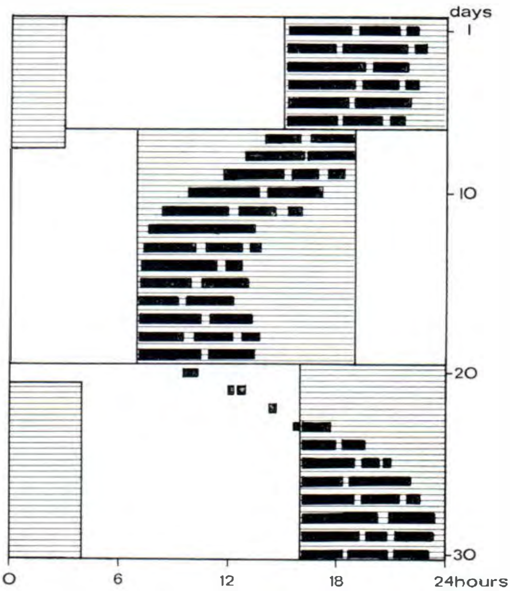

Figure 2. The activity rhythm of a nocturnal animal which had been entrained by a 24-hour light-dark cycle on days 1–6. On day 7 the dark fraction was advanced by 8 hours. The rhythm underwent a series of advanced phase-shifts or transients (days 7–14) until it regained its original phase-setting. On day 20 the dark fraction was delayed by 9 hours and the rhythm then underwent a series of delay phase-shifts before it regained its original phase-setting. [Diagram by the author.]

Sun-compass orientation and time sense

Animals, including insects, fish, and birds, which navigate by sun-compass orientation can correlate the direction of their goal with the sun-azimuth (i.e., the direction of the sun in the horizontal plane.) The angle between the sun and the direction in which they need to travel is referred to as the solar angle. Due to the earth's rotation, however, this angle is constantly changing throughout the day as the sun-azimuth travels from east to west with an angular velocity of approximately 15° per hour. To enable it to compensate for this the animal requires an accurate time sense. There is, however, no fundamental difference between this phenomenon and the time-measuring process involved in circadian rhythms.

Many of the most interesting experiments on time sense have been carried out with honey bees. Bees can be trained to feed at different feeding stations at different times

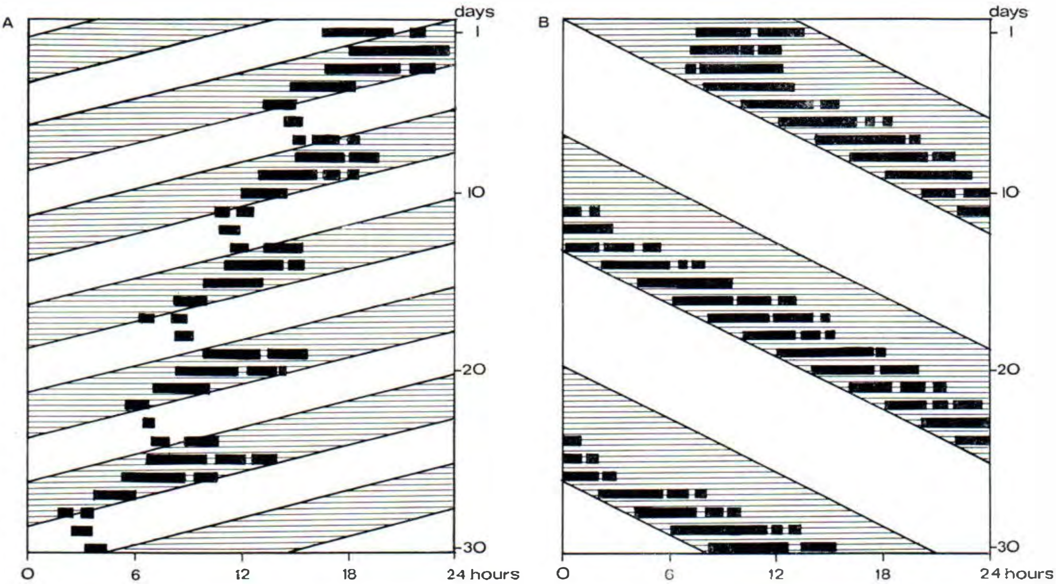

Figure 3A (diagram at left): The activity rhythm of a nocturnal animal in a 20-hour cycle of 10 hours light and 10 hours darkness. The rhythm did not become entrained by this cycle, and remained essentially free-running. The period of the rhythm changed, however, depending on whether activity occurred in the light or the dark part of the cycle. Figure 3B (diagram at right): The activity rhythm of a nocturnal animal in a 26-hour cycle of 13 hours of light alternating with 13 hours of darkness. In this case the rhythm became entrained to the cycle even though it differed in length from a 24-hour cycle. [Diagrams by the author.]

of day. They can remember not only the different directions but also the times at which feeding occurs. They are also able to indicate these correctly back in the hive by the celebrated bee dance. Normally, the bee performs a dance to indicate the direction of the feeding place straight after it returns to the hive from foraging. If the dance is delayed for some reason, however, the direction of the tail-wagging dance is moved slowly counter-clockwise at approximately 15° per hour to allow for the change in the sun-azimuth. Also, if the bee has been trained to visit several feeding stations, when it does a delayed dance it indicates the direction of the feeding place where food is available closest to the time at which the dance is being performed.

The nature of the "clock"

Despite the data that have been accumulated on circadian rhythms, very little is known about the physiological and biochemical mechanisms involved in the time-measuring process. Pittendrigh and co-workers at Princeton University, U.S.A., have emphasized the remarkable similarities between the observed properties of circadian rhythms and the behaviour of physical oscillator systems. They have suggested that the time-measuring process is best considered as two or more coupled oscillators, although there is no clear idea of how these oscillators are manifested at a biochemical or biophysical level. Even efforts to determine where the oscillator or "clock" that controls the activity rhythms of insects is located has produced a lot of seemingly conflicting results. This is partly because the rhythm can be disrupted by several procedures which do not necessarily involve destruction of the "clock", and also because there is a lot of evidence that organisms may contain a hierarchy of "clocks", each of which is partly, at least, autonomous.

The most recent experiments on cockroaches suggest that the "clock" which controls the activity rhythm may be located in the optic lobes of the brain. Attempts to locate specific "clocks" in mammals has met with a similar lack of success, although here again the brain seems the most likely location. The localization and elucidation of the timing processes which control circadian rhythms, therefore, still remain one of the most stimulating and challenging areas of biological research.

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BRIAN S. FLETCHER was born in England. He obtained a B.Sc. in Zoology and Comparative Physiology from the University of Birmingham in 1963 and a Ph.D. at the same university in 1966. He then joined the CSIRO Division of Entomology to work on various aspects of the ecology and physiology of the Queensland Fruit Fly in the Joint Unit of Animal Ecology at the University of Sydney. His main interests are dispersal and sexual physiology, and at the moment he is working on the mating rhythm of this insect.

J. H. PRINCE was born and educated in England, and has lectured in comparative anatomy there and in Canada, Australia, New Zealand, and U.S.A. From 1952 until his retirement in 1966 he was Associate Research Professor at the Ohio State University Medical College and the Ohio State University Research Centre. Professor Prince is the author of sixteen books, six of which deal with animals, and about 200 articles. In 1958 he was awarded the British Optical Association Research Medal for work on the eye. He is a Fellow of the Zoological Society of London. His biography is in the fifth edition of *Leaders in American Science*.

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VINCENT SERVENTY is a Science and Education graduate of the University of Western Australia. After a number of years in the professional field of science education, which included a period organizing museum classes at the Western Australian Museum, he became a freelance writer, lecturer, broadcaster, film-maker, and telecaster in the field of natural history. He has taken part in numerous expeditions to various parts of Australia, including the central desert region and the Archipelago of the Recherche. At present he is president of the Wildlife Preservation Society of Australia and editor of *Wildlife in Australia*, and is on the Council of the N.S.W. Gould League.

PETER STANBURY is Curator of the Macleay Museum and Senior Lecturer in Zoology at the University of Sydney. Since working on the biochemistry of the intestine for his Ph.D. at the University of Adelaide his interests have changed and he is now learning about the way in which animals move and adapt to their environment. Although a collector of books and, as he puts it, cheap antiques, Dr Stanbury believes that collecting live animals is usually wrong and avoidable. He says that dead animals, together with facts and photos, often suffice, and leave the living animals in the best care—their own.

GRAHAM WALLIS was a trainee geologist with the New South Wales Department of Mines from 1955 to 1958, during which time he attended the University of New South Wales. He graduated from that university in 1958 as a Bachelor of Engineering in Applied Geology, and he is an Associate Member of the Australasian Institute of Mining and Metallurgy. His experience as a geologist in the Department has been varied and extensive, but his prime interest in recent years has been in the field of hydro-geology, with a particular interest in the Great Artesian Basin. He was a member of the 1964–65 Enderby Land Expedition to Antarctica with A.N.A.R.E. He was Assistant Director (Regional and Special Services Division), Geological Survey of New South Wales, when he wrote the article in this issue, but he is now Commercial Manager for Mincoa Australia Limited and Clifford McElroy and Associates Pty Ltd, mining and geological consultants.

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