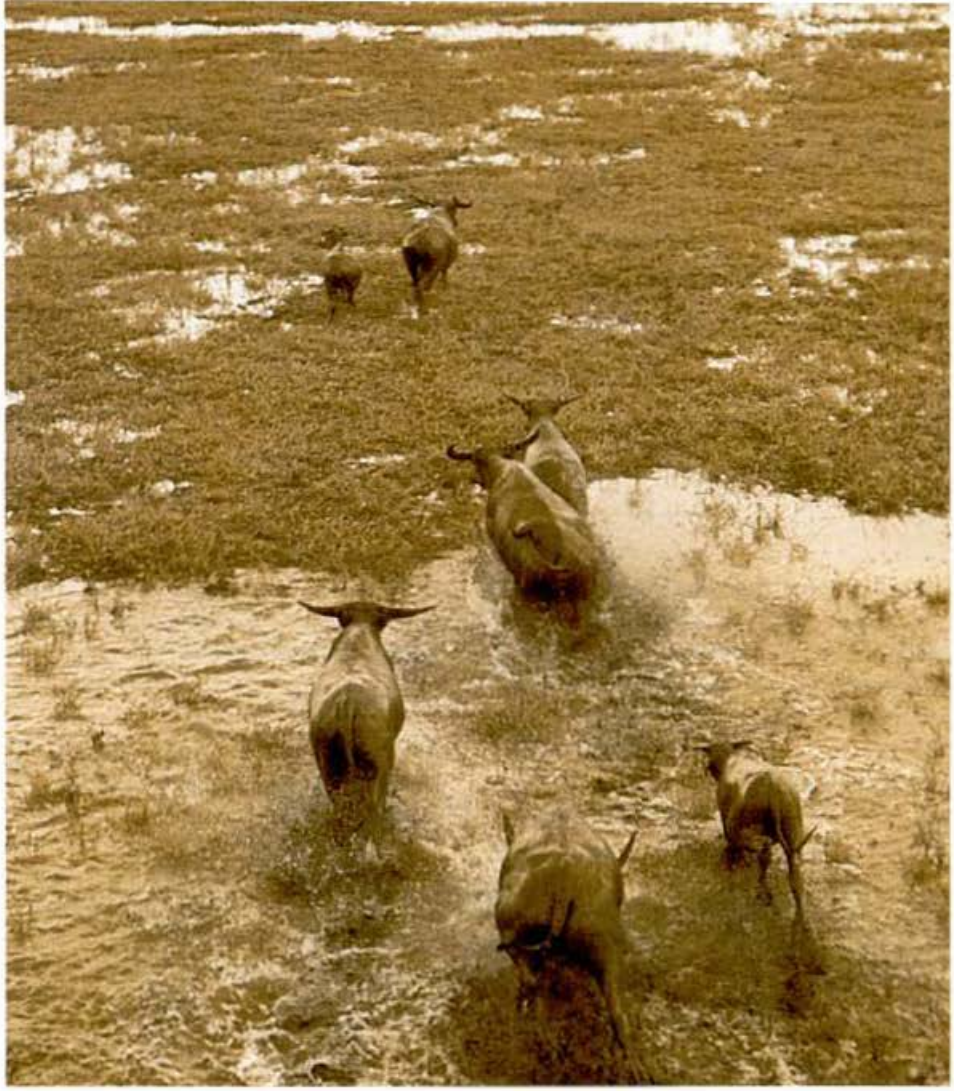


The wet season presents no problems for buffalo.

Buffalo in the Top End

Two centuries ago, Australia's first European settlers brought to this country a 'Noah's Ark' of domesticated animals. As well as rabbits, foxes, deer, and various birds, European man brought livestock — including horses, donkeys, cattle, goats, pigs, camels, and water buffalo. All of these soon established feral populations in northern Australia, and most are now acknowledged as pests. One of them at least — the water buffalo — is having a severe impact on the Top End's environment.

Since its introduction to Australia, the Asian water buffalo has built up its numbers to about 250 000 and spread over a 100 000-sq.-km margin of coastal flood-plain and adjacent woodland between the Daly River west of Darwin and Arnhem Land to the east. Paradoxically, the Top End now has more than half the world's free-ranging water buffalo.

Although, at present, water buffalo seem to be largely contained on the coastal plains of the Top End, lone bulls have been sighted as far east as Townsville, as far south as Tennant Creek, and as far west as Broome in the western Kimberleys. Breeding groups, however, have now reached Borroloola, south of Groote Eylandt to the east of Darwin, where a strip of semi-arid land presents a barrier to their spread into Cape York Peninsula.

Buffalo support a sizeable industry in the Northern Territory, providing meat for human consumption (much of it exported for smallgoods), pet meat, hides and horns, animals for live export, and the occasional big-game-hunters' trophy.

But the subcoastal plains and wooded lowlands that buffalo prefer appear to be undergoing a dramatic change. Large bulls consume up to 30 kg of dry matter each day. Trampling by the buffalo's wide, plate-like hooves — bulls can weigh up to 1200 kg — has led to accelerated soil erosion, channelling of floodwaters, salt-water intrusion into fresh-water habitats, and a loss of vegetative cover. Wallows, trails, and dung pats also scar areas that the buffalo use.

Added to this is their ability to contract and spread cattle diseases like tuberculosis. As the many free-roaming herds cannot be screened for disease and pose a threat to this country's valuable meat industry, a program of shooting feral buffalo is under way. Some herds are being redomesticated as interest in buffalo-farming grows.

The Top End now has more than half the world's free-ranging water buffalo.

From a conservation viewpoint, the buffalo's most important impact has been in the 13 000-sq.-km area east of Darwin that forms Kakadu National Park, and in the Northern Territory Conservation Commission's reserves on the Adelaide and Mary Rivers.

Remote from centres of population, Kakadu is a sanctuary for the Top End's unique flora and fauna. It is a Mecca for tourists who, each dry season, make the long pilgrimage from Sydney, Melbourne, Los Angeles, or Hamburg to witness the natural beauty of the landscape and its animal life.

In the Park, buffalo concentrate on the coastal black soil plains of the West, South, and East Alligator Rivers and their thickly forested margins. These 'wetlands', parts of which are covered by water for 6–8 months annually, turn into shimmering flat expanses of sedges, grasses, or just bare plains in the Dry. Wetlands are the richest water-bird habitats in Australia as well as supporting a diversity of plants, and the northern ones harbour the greatest diversity of waterfowl in the Territory.

In 1979, an independent Feral Animals Board of Enquiry, chaired by Dr Goff Letts, compiled evidence suggesting that substantial changes to the northern wetlands — associated with the spread of feral buffalo — have occurred since European settlement. Evidence presented to the Enquiry was based on comparisons bet-

ween early published descriptions of the vegetation and present observations, and it emphasized the severity of the problem and the need to control buffalo and rehabilitate the damaged areas.

Because the buffalo population radiated slowly from its points of origin in the Top End, it only reached areas west of Darwin relatively late. So conservationists have assumed that the plains east of Darwin, now degraded by buffalo activity, once looked like the lush plains of the Finniss and Reynolds Rivers, which are now carrying increasing numbers of buffalo.

Ad hoc exploitation

If buffalo can cause so much damage, why did we allow their numbers to build up in the first place? Their presence in large numbers, like that of most feral animals, is an accident. The Top End buffalo are a legacy of unsuccessful attempts to settle the north during the early to mid nineteenth century. Today's vast herds sprang from a few dozen animals imported during the 1820s and '30s — from what was then the Dutch-governed Timor, to Raffles Bay and Port Essington on the Cobourg Peninsula and, a little later, to Escape Cliffs at the mouth of the Adelaide River. The settlements were abandoned by 1849 and so, too, were some of the buffalo.

From Cobourg Peninsula and further west, feral buffalo spread steadily, well-adapted to their new environment. So few European settlers lived in the area that occasional shooting of animals made little impact on early population growth.

In 1845, the explorer Ludwig Leichhardt reported, in his diary, the presence of buffalo at Red Lily Lagoon, on the eastern bank of the East Alligator River, 250 km from Port Essington. By the 1880s, when some 20 000 animals ranged over the Cobourg Peninsula alone, buffalo were becoming the main grazing animals on the subcoastal plains and river basins between Darwin and Arnhem Land.

Buffalo wallows seen from the air.

At this time, the hide-hunting era, which lasted for the next 80 years, began. The early hunters shot on foot, but later turned to hunting buffalo from horseback. Shooting was unregulated and continued apace. Hide production reached an annual average of more than 6000 by the mid 1920s, and climbed to a record 16 549 hides during the 1937/38 season. The market eventually collapsed in the late 1950s, partly because the international price for hides dropped and partly because the hides were poorly prepared.

Trampling and grazing around water sources during the Dry subjects plants to intensive selection.

The buffalo meat industry took over from the hide trade in the late 1950s. It began by supplying pet meat, but soon became a source of meat for human consumption, sold under either export or certified standards. Abattoirs were set up and continue to operate, processing export meat mainly intended for use in smallgoods or sausages. Some pet-meat suppliers still shoot buffalo from four-wheel-drive vehicles and butcher the carcasses on the spot.

During the nine decades of exploitation, an estimated 700 000 or so buffalo have been killed for hides, meat, and even, in one instance, for fertilizer.

The research era begins

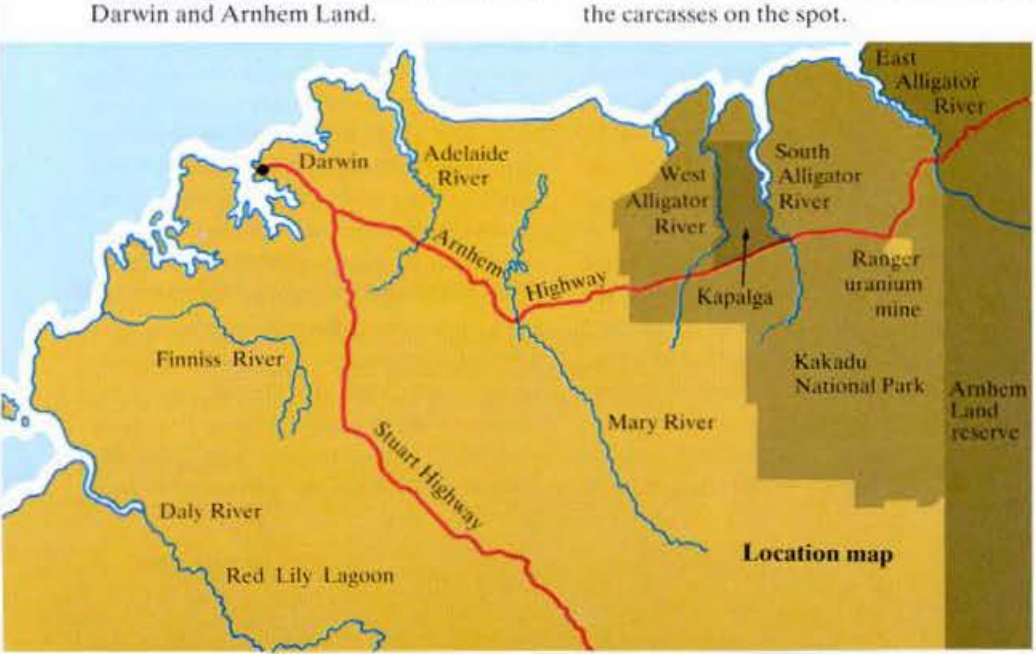
Although buffalo have been blamed for serious environmental damage to the wetlands between the Daly River and Cobourg Peninsula, empirical research on the problem only began in the 1970s and scientists are still measuring the full extent of the impact.

In 1976, the CSIRO Division of Wildlife and Rangelands Research secured a 700-sq.-km study site at Kapalga, 160 km east of Darwin. Studies there on the workings of tropical ecosystems include work on the environmental repercussions of feral buffalo activity and have encompassed surveys of vegetation, mammals, birds, reptiles, and amphibians, buffalo population counts, and buffalo feeding and water-intake experiments.

About two-thirds of Kapalga comprises tall open forest, mixed with a little woodland, and a moist thickly forested margin. The rest is mainly low-lying black soil sedgelands between two northward-flowing rivers, the West Alligator and the South Alligator. These are normally flooded between December and April, becoming vast fresh-water wetland areas. Plants here range from sedges and grasses to forests of paperbarks, white gums, and pandanus on their margins The flood-plains provide breeding areas for many ducks and geese, and a refuge for other waterfowl during the dry season.

The margins contain occasional pockets of monsoon forest, consisting of a variety of tree species, vines, mosses, lichens, ferns, and orchids. One ecologist has described monsoon forest as 'a depauperate rainforest'. Further from the wetlands, stringybark and woolly-butt eucalypts make up a large part of the tall open forest.

A consultant to the Conservation Commission of the Northern Territory, Mr Peter



Fogarty, carried out a wider-ranging survey of buffalo damage to the Top End wetlands in 1981. Using aerial photographs taken in 1950, 1963, and 1978, he found that one of the more serious effects was extensive intrusion of salt water into billabongs and onto plains. This rapidly led to the death of vegetation, and the disappearance of freshwater habitats, as saline mud was deposited and mangroves became established. He concluded that, while salt-water intrusion may be a natural process, the presence of buffalo has exacerbated it.

Buffalo behaviour

One of the Territory's pioneers of buffalo research, Dr Don Tulloch, began recording the behaviour of these animals many years ago, before the Kapalga site was established. Perched for hours at a stretch in the lower branches of trees on the margin of their feeding grounds, he observed their interactions and their seasonal and daily activities, accumulating a store of valuable information on their habits.

In the wet season, from October to about April (the main mating season), calves are born and adult bulls court cows 'in heat'.

The scientists have marked this buffalo for a food-intake experiment.

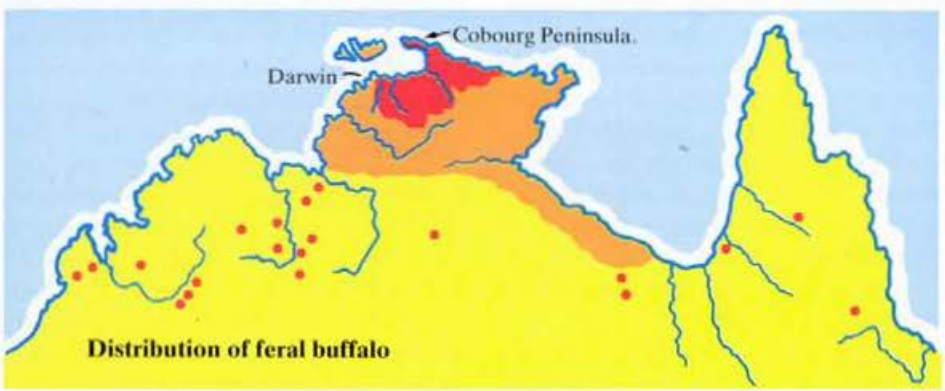
During the dry season (from May to about September) bulls and cows live apart. Cows and their calves mainly inhabit the heavily forested fringe of the black soil plains, next to higher ground, where water, shade, and green feed are plentiful. Adult males live more on the open plains, where they have little or no shade, and also further upslope in the open forests, where they have only dry feed outside the wet season.

Buffalo, especially cows, are restricted in their movement and establish a very strong 'site attachment'; that is, they have a well-defined home range. Dr Mike Ridpath, of the same Division, concluded from his work on buffalo that most animals have a home range with a radius of about 6 km. Inside this home range are a number of fixed points, like camps, rubbing trees, and so on, linked by trails. So strong is their site attachment that buffalo often die rather than move into another area when feed and water are scarce; many animals die bogged in the viscous mud of shrunken waterholes in the Dry.

A home range can contain cow herds varying in size from 30 to 500 animals, which are joined by males in the breeding season. Female calves remain with their mothers, possibly for life. Maturing bulls have to quit the herd; if they remain, these young males can be seriously injured by the dominant bull.

Young cows have their first calves between 2 and 3 years of age. Buffalo enjoy a high calving rate, with 75–90% of cows producing calves. (Some re-domesticated herds have had 100% success.) The birth of a calf is a major event for a home-range clan, with most of the animals approaching the new-born calf and nuzzling it. If a calf is orphaned, cows will readily adopt it — Mr Tulloch has even recorded a case of a weaned calf being adopted by a bull!

Adoption is not the only apparently altruistic behaviour buffalo exhibit — they



Distribution of feral buffalo

The red area contains the main concentration of buffalo, and the orange area small scattered groupings. The points indicate spots where isolated animals have been reported.

Trampled mats

Throughout the flood-plains of the Top End, the strange botanical phenomenon called 'floating mats' occurs in billabongs. These structures, made up of consolidated plant matter, grow progressively on a base of the floating leaves of water lettuce. Floating mats are used as a nesting habitat by estuarine crocodiles and as shelter by barramundi and other native fish. They also seem to be able to trap nutrients washed through billabongs during flooding.

From their studies on floating grass mats, Mr Richard Hill and Dr Grahame Webb, of the University of New South Wales in Sydney, gathered evidence that buffalo are the main cause of damage to these living pontoons and of their widespread disappearance from Northern Territory wetlands. The animals trample the edge of the mats and graze plant colonizers. Eventually, the connection between bark and floating mat breaks, and in the Wet the mats break up, or are washed down rivers, or get stranded on the frying plains, where they die.

Floating grass mats of the Northern Territory. R. Hill and G. Webb. *Wetlands*, 1982, **2**, 45–50.

Floating mats carpet the Finniss River.

also set up 'creches' on the edge of feeding areas. While most of the nursing cows graze, their calves are left under the care of an adult (usually a young cow, but very occasionally a young bull) in a calf 'pool'. The caretaking animal is relieved of its duty after an hour, usually by another cow with a calf in the pool. Such nursemaid behaviour ensures that mothers can graze far out on the plain without being hampered by calves.

Mr Tulloch's patient observation also revealed the reasons behind buffalo wallowing. During the hottest part of the day, between 10 a.m. and 3 p.m., animals lie in any available water — often shallow, muddy holes — mainly to keep cool. While shade seems to lower deep-body temperature just as effectively, as shown by rectal temperature measurements, buffalo seem to prefer wallows to shade. The explanation may be that animals can spend more time grazing out on the plains with a wallow nearby than they can in the margins under shade. Wallowing can also be a form of protection against insect attack at night by providing a thick coating of mud that adheres to the body, keeping buffalo flies and mosquitoes at bay.

Empirical studies

Buffalo can cause a number of immediate changes to their watering and feeding areas. Dr Kent Williams of the Division and Dr Ridpath studied a herd of buffalo inhabiting a seasonally flooded swamp on the South Alligator River at Kapalga, to determine what they ate and how much water they took in daily. The scientists found that buffalo have a high rate of water turnover, each animal drinking about 20 litres per day. Their food requirements are equivalent to 6 kg, dry weight, of sedge per day.

Using vegetation production data, Dr Williams and Dr Ridpath estimated that the swamp could support about 41 buffalo continuously. But counts of buffalo that used the swamp varied from 20 in the late wet season to about 200 in the Dry. The feed in the swamp was completely grazed out by the end of the arid phase of the monsoonal cycle. Buffalo's dependence on free drinking water confines them to such oases in the worst of the Dry, leading to intense grazing

Measuring plant biomass at a Kapalga study site.

Buffalo love water, but many die bogged in mud during the Dry.

of the area and, in some years, to large numbers of deaths when the feed runs out.

The excessive trampling and grazing by buffalo around water sources during the Dry subjects plants to intensive selection. The Feral Animals Board of Enquiry found that high-protein grasses such as *Hymenachne* spp.,— which grazing animals prefer — become grazed out and replaced by less palatable plants like *Hyptis* and *Cassia* species. The more specialized native herbivores that need higher-quality forage probably suffer more from the vegetation change than buffalo, which can regain body condition each wet season.

Researchers from CSIRO have been studying the distribution, density, and movements of feral animals at Kapalga since 1976. Dr Ridpath uses vehicle transects to count buffalo. Each count, along a set course of 250 km, takes about a week to complete.

Although planes and helicopters have been tried, Dr Ridpath uses the ground counting technique because, over the relatively small area, it has proved more accurate and cheaper, and provides more details on the condition and habitat of animals.

The average density of buffalo in Kapalga turned out to be about 13 per sq. km, roughly equivalent to 5200 kg of living buffalo per sq. km. In the swamps and adjacent forest, buffalo can reach a density of at least 34 per sq. km. The average biomass figure for Kapalga is higher than that for equivalent habitats in southern Asia, where the plants and animals have co-existed for a long period of evolutionary time and developed mutual adaptations.

Although we know that in times past Australia had more, and in some cases larger, species of indigenous herbivores than exist now, the fossil record is not sufficient to enable scientists to infer what their density, habitat preferences, and diet were. So we don't know to what extent native plants, now being grazed by buffalo, may have once been adapted to grazing. Dr Ridpath suggests that such adaptations, if they did evolve, would have been lost after the large marsupial herbivores disappeared.

Over the past few years, the CSIRO researchers have set up an exclusion trial at Kapalga. Inside a 350-sq.-km fenced section, buffalo have been systematically removed since 1982, leaving an area that is virtually free of the animals. Now researchers are assessing the process of recovery of plants and wildlife inside the fence, comparing the fenced country with an equivalent area still inhabited by buffalo.

Measuring response

Dr John Taylor and Dr Gordon Friend, of the Division's Darwin laboratories, examined the effects of buffalo on vegetation and on the abundance of small animal species. They examined the ground surface of 30 sampling sites — laid out 125 m apart on a grid pattern — for features such as wallows, hoof imprints (or pugs), trails, and dung pats. From the viewpoint of native plants and animals, these ground surface features mean a marked change in the physical environment.

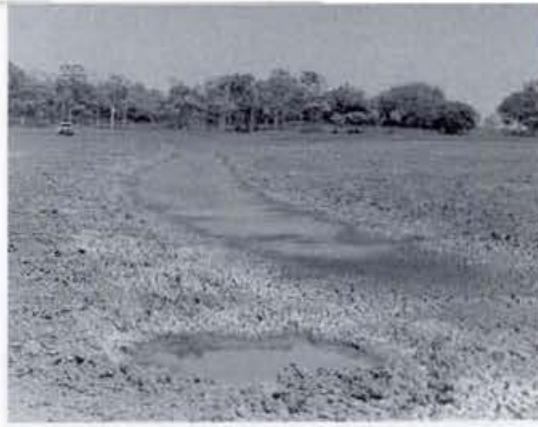
Sampling included observations of the proportions of ground surface covered by water, bare soil, vegetation, and litter, whether cracks or pugs occurred, and the depths of these indentations.

The Top End in the balance? Feral pigs being marked for study.

The team's observations of dung accumulations show that buffalo often camp in the few pockets of monsoon forests and wooded areas along the higher-elevation margin of the flood-plains in the Dry, and spend much time downslope (around wallows) in the Wet. Pugs cause a lot of damage to the soil around wallows, being deepest in the early dry season, while the soil is still wet. In monsoon forest camps, a top leaf-litter layer usually renders the pugs invisible.

However, these simple counts of buffalo features don't provide a reliable index of animal abundance. Estimates of the impact of feral buffalo require not only information about their local numbers, but also detailed information about when and to where they move.

Another problem further muddies the issue. Dr Taylor found that the vegetation pattern at some sites shifted from year to year. For example one site, dominated by 10-cm-high grassland one year, carried the



Cracked and pugged ground around a wallow.

Change in burning times

Although the water buffalo is a relative newcomer to the Top End environment, fire has always been acting on the landscape.

Fire in this region is more frequent, though less intense, than in southern regions. It occurs mainly during the Dry, but the timing of fires seems to have changed considerably since man first came to this country.

The wet season rains bring new growth, especially of plants like spear grass. Biomass increases considerably and, at the beginning of the Dry, the land carries a large amount of desiccating vegetation. This continues to die or dry out, increasing fuel loads and flammability.

In the pre-human era, lightning ignited the relatively dry vegetation in the early part of the Wet, from around October to December. Dr Braithwaite is studying the occurrence of fire in Kakadu National Park. From 40 years of meteorological data for Darwin, he worked out that only in the late fire season is fuel sufficiently dry and lightning adequate for this to be a significant ignition source.

More than forty thousand years ago, the Aborigines arrived in Australia and began to use fire, or 'munwag', to manage the resources of their environment. Mr Chris Haynes of the Australian National Parks and Wildlife Service has spent more than 10 years studying traditional Aboriginal fire practices and has identified the reasons behind what, to European man, has seemed a puzzling sort of pyromania.

Aborigines recognized the existence of biologically defined seasons, in each of which the vegetation has different characteristics of ignition and fire persistence. The type of vegetation association — open forest or woodland — also plays a part in Aboriginal fire management. Open forest is burnt carefully to protect fruit-bearing trees and other valued resources. But Aborigines have always burnt woodland indiscriminately, as it offers them few resources and they consider it worthless.

Specific strategies vary from no burning at all, including no use of firebreaks for protection, through only burning early in the Dry, to burning repeatedly throughout the season. What remains is a vegetational mosaic, fine-grained or coarse-grained according to the original habitat. This mosaic offers animals more refuges and surviving plant feed than would complete burns over large areas.

Dr Braithwaite used the time of year to characterize the different fire patterns in the early, mid, or late fire season. Burns early in the season correspond to the Aboriginal fire regime, late ones to the lightning or pre-human regime, and mid-season burns to the contemporary regime.

The burning practised by the present European inhabitants of the Top End generally starts well into the Dry and lasts till the end of the season. Combined with the effects of feral water buffalo and pigs, this has led to changes in the abundance of plant and animal species in the closed forest communities.

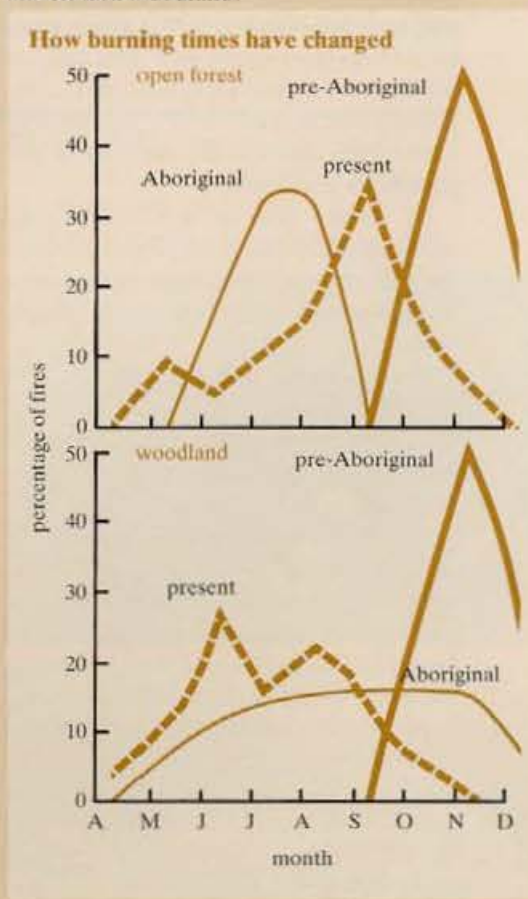
By burning earlier in the year, Aborigines ensured that fires left a lower scorch height on trees, were patchy, and were small in area. Later fires burn more fiercely and completely.

Dr Braithwaite looked at the vertical profile of woody trees in open forests and woodland. He found that middle-height non-eucalypt species — most of which were important sources of fruit to Aborigines — are now generally small and undeveloped in open forest. Many of these trees flower in the mid dry season and produce fruit later, which is one more reason why Aborigines burnt early.

As a consequence of contemporary practices, the open forest areas of the Top End appear to have suffered a massive reduction in abundance of these fruit-producing species. Mr Haynes also noted that mid-season burning in open forests has led to the disappearance of cypress pine from the area. Dr Braithwaite concluded that, in the dry habitats of Kakadu, changed fire regimes may have as much influence on the abundance and diversity of plants and animals as do buffalo in the wetter habitats.

Fire patterns and woody vegetation trends in the Alligator Rivers region of Northern Australia. R.W. Braithwaite and J.A. Estbergs. In 'Ecology and Management of the World's Savannahs', ed. J.C. Tothill and J.J. Mott. (Australian Academy of Science: Canberra 1985.)

Changes in fire patterns have affected the plants and animals of the Top End's open forests and woodland.



Inside the Kapalga exclosure. The photo on the left was taken in November 1980, before buffalo were removed. The right-hand shot shows the same area in November 1984.

annual leguminous shrub, *Cassia* sp., the next. The following year, the grassland reappeared. Some sites displayed a different dominant species each year of the study.

The flood-plains supported a high proportion of annual plants, thus resembling semi-arid systems elsewhere. In fact, the Top End's climate swings each year from desert-like conditions in the Dry to floods in the Wet — an important determinant of life there.

The pattern of wet season rainfall is unpredictable, but one thing is certain — the wet season will eventually arrive, first bringing storms, then the monsoonal trough, and occasional cyclones. The beginning and end of the Wet can vary by as much as 11 weeks from year to year, with a potential 22 weeks' difference in the length of the growing season. This, in turn, affects plant composition and also the distribution and abundance of animals.

Dr Taylor believes that the stop–go nature of the environment largely accounts for year-to-year fluctuations in botanical composition, whether buffalo are present or not.

One reason for suspecting that the presence or absence of buffalo on the open plains is not the only influence at work is that the reproduction of annual plants there is unlikely to be directly affected by buffalo trampling and grazing — in the Wet, many animals graze up in the woodlands. By the start of the Dry, when more buffalo feed on the flood-plains, most of the annuals have set seed. Comparisons of seed survival in the areas with and without buffalo will help to resolve this question.

But many perennial grasses probably dominated the plains before the advent of buffalo. The almost total elimination of buffalo in 1982 in half of Kapalga has been accompanied by a massive and sustained increase of the highly palatable *Hymenachne* species on the edge of the plains, where it had previously been barely noticeable. The CSIRO team observed that most of the regrowth came from runners under fallen logs, where they could not be grazed.

This dramatic recovery has not occurred in the other half of Kapalga, where buffalo remain and the weather pattern is identical. So both rainfall variation and buffalo activity seem to influence the vegetation of open plains and their margins.

Changes in fauna

Dr Friend's analysis revealed that, of 116 small animal species studied, 14 of them — including birds, reptiles, amphibians, and grasshoppers — responded in some way to the presence of buffalo. Certain birds and grasshoppers even seemed to benefit.

Grasshoppers favour areas of bare ground with cracked clay, so pugs and trails create an ideal habitat. Some birds, like the barn owl, make use of the trails that buffalo leave through vegetation to prey on small ground-dwelling animals that cross or run along the pathway. In this case, the prey is usually the dusky rat, *Rattus colletti*, which inhabits seasonally inundated sedgelands and often reaches high densities in areas of thick vegetation. Other birds, like the masked plover, prefer pugged areas, where the aquatic insects and worms on which they feed are plentiful. This species may also use buffalo dung in nest-building. Insect-eating birds scoop up the seething insect life in dung pats.

Pugs and wallows are also ideal breeding grounds for frogs, which breed during the Wet.

Many more animals, however, have been disadvantaged by the presence of buffalo. Dr Friend's data indicated that the species most affected are ground-dwellers, particularly those that prefer thick vegetation, such as the magpie lark. Species like the jacana, a small bird that walks on water lilies, have been disadvantaged by the disappearance of lilies in buffalo-affected areas.

Dr Friend drew up a profile of vegetation structure — from monsoon forest to river's edge — at Kapalga, indicating animal diversity in each habitat type. This showed that the monsoon and margin forests were richer in bird species than other areas, and the margins also harboured a high diversity of small animals. Grasshoppers, of course, were particularly abundant on the plains.

Although the margin appears to be the most important area for conservation, it is also the area most affected by buffalo. Dr Ridpath has estimated that the biomass of water buffalo and other feral ungulates — cattle, horses, donkeys, and pigs — is four to nine times greater there than on the seasonally flooded black soil plains and their narrow gallery forest margin in the adjacent upland woodland and open forest.

Since buffalo were removed from the southern part of Kapalga, a dramatic increase in understorey density has taken place, mainly due to young seedlings of eucalypt and paperbark emerging. Pandanus are also regenerating rapidly inside the fence, while on the other side new shoots are grazed down to the ground during the Dry.

Following removal of buffalo, pugs and dung pats disappear on the flood-plains after one wet season, due to the self-mulching nature of the cracking clay soils there. Trails and wallows need vegetation and

A thick growth of *Hymenachne* in an area cleared of buffalo.

A water lily, one of the plants that reappeared when Kapalga was cleared of buffalo.

infilling, and may persist for a longer period. Wallows have revegetated in one wet season, but they take another three or four wet seasons to fill in. In the margins, however, where trampling and grazing have eliminated topsoil and exposed the infertile subsoil, regeneration will take much longer.

Nevertheless, some changes in fauna caused by buffalo removal should be fairly rapid. For example, on the plains of the fenced-off area, some species of grasshoppers have already increased in abundance. Although a few animal species may suffer following buffalo removal, many species, especially ground-dwellers, will benefit. Dr Friend has recommended that birds and grasshoppers be included in monitoring of the changes produced. Harder to document will be the effects on species that have become locally rare or extinct as a result of the long-term effects of buffalo.

Because buffalo and pigs inhabit the same areas, each species must exert an effect on the other. The CSIRO scientists have noted that, in the enclosed section of Kapalga, pig numbers have increased since buffalo disappeared. Perhaps the buffalo-shooting program in the Top End may encourage a formerly subdued pest protagonist — the feral pig.

Larger-scale monitoring

In the area of Kakadu National Park outside Kapalga, Dr Richard Braithwaite has been monitoring the effects of buffalo in monsoon forest, woodland, and open forest. The Australian National Parks and Wildlife Service helped fund Dr Braithwaite's study as part of a wider data-collection project to assist in the establishment of management policies.

Dr Braithwaite, together with the late Mr George Dudzinski of the Division of Mathematics and Statistics, chose 30 study sites. These included nine near each of the East, South, and West Alligator Rivers; and, of each nine, three were located in monsoon forest, three in open forest, and three in woodland. The remaining three sites were up on the Arnhem Land escarpment. Some sites were so inaccessible that team members had to use a helicopter to reach them.

The survey team visited the sites twice each year — during the height of the wet and dry seasons — for 3 years, beginning with the Dry of 1980. They noted that buffalo were most numerous in those areas of monsoon forest adjacent to their feeding grounds on the wetlands and flood-plains. Any impact on such a site, therefore, has probably been high for most of the last 100 years.

Dr Braithwaite found that frequented sites had a lower tree canopy than similar sites little used by buffalo. Further, trees had a narrower diameter than expected. Large trees had disappeared altogether.

Dr Braithwaite's explanation is that, in affected forests, the heavy, wide-hoofed animals have compacted the soil and reduced water infiltration, which has reduced the recharge of groundwater supplies to plant roots. In consequence, big trees die in the dry season and fall, smashing a hole in the forest canopy. Through this hole, more light enters, which encourages a profusion of lower-level growth and smaller trees, and paves the way for an invasion of non-rainforest species.

Not only tree height, but flowering, fruiting, and leaf growth may change as a result of soil compaction. In addition, trampling may have impaired the ability of the soil to absorb any nutrient input from buffalo dung.

The Kakadu study also examined the effects of buffalo activity on small animals. Buffalo affected 72% of the species studied. The results indicated that the 'opening up' of patches of monsoon forest may have favoured a number of these species. Others, like the orange-footed scrubfowl, have their food — soil-dwelling and leaf-litter insects — trampled by buffalo. Dr Braithwaite pointed out that species disadvantaged by the presence of buffalo, like the orange-footed scrubfowl, may be pushed into extinction in the rare monsoon forest habitat, whereas the more resilient species, common throughout other habitats, may never have been in danger at all. Furthermore, damage to the monsoon forest itself may be permanent.

Disease control and redomestication

What of the problem of buffalo being a potential reservoir of cattle diseases?

The National Co-ordinated Brucellosis and Tuberculosis Eradication Scheme aims at ridding Australia of bovine TB and brucellosis by the year 1992. Good progress towards eradication of TB has been made in most parts of the country.

Officers of the Brucellosis and Tuberculosis Eradication Campaign Unit are carrying out a program of shooting buffalo in areas of the Top End where mustering

Stumped by buffalo

The logistics of regular sampling of sites on the flood-plains provided a few challenges for the CSIRO team. In the late dry season, the plains are hard and cracked, and conventional vehicles can be used for these few months. At the height of the Wet, the plains are inundated by up to a metre and a half of water. Field workers use airboats during this period. In the Dry–Wet and Wet–Dry transition months, the flood-plain is a mosaic of dry and flooded patches, and neither conventional vehicles nor airboats can move about. This is when amphibious wheeled craft, like the Canadian 'Argo', or all-terrain cycles prove most successful.

Another problem was constructing a site marker that could survive the curiosity and impatience of buffalo. When an animal weighing anything from 400 to 600 kg — armed with large incurved horns — decides that it will not tolerate grid markers in its vicinity, few such man-made structures can survive. Buffalo removed or bent many of the markers, which consisted of long metal stakes, welded plates, car springs, and a solid metal core, with little apparent effort.

All-terrain cycles and an 'Argo' — two of the researchers' means of transport.

herds for testing is difficult and the possibility of disease spread is high. These include the Arnhem Land plateau and heavily wooded areas. Redomesticated animals, that can be mustered and tested regularly for disease, will be excluded from the program.

Although many buffalo are free of TB, pockets of infection do exist and TB could spread to commercial stock from the feral population. Other cattle diseases that have been kept out of the country, like rinderpest, could also spread via free-ranging buffalo carriers.

One fear expressed by a number of vets and agriculturalists is the possibility that buffalo spread stock diseases to feral pigs. As well as lice, kidney worm, and tapeworm, pigs carry TB-like lesions, and could also act as agents of anthrax, swine fever, and other serious exotic diseases. At the end of each dry season, when many buffalo, especially old cows, die from 'bogging' or malnutrition, feral pigs feed on the carcasses. Fortunately, evidence from studies by Dr Reg Barrett, then of the Division of Wildlife and Rangelands Research in Darwin, and Dr Leigh Corner of the Division of Animal Health in Parkville, Vic., has shown that feral pigs are not a significant source of TB infection for cattle.

The problem of eradication of buffalo in the northern wetlands is tied up with the animals' 'hideability'. Strange as it may seem, these massive creatures can evade close scrutiny by man in the margins and open forests of the subcoastal plains. To attempt eradication would require the very extensive use of helicopter-borne marksmen. Although this is an efficient way of greatly reducing feral buffalo numbers, complete eradication will be virtually impossible, as the CSIRO researchers found in their Kapalga enclosure.

Apart from environmental and stock health effects, buffalo have been accused of inhabiting and damaging land that could otherwise support conventional grazing of cattle. But scrub cattle in the region become emaciated and die out in the savage climatic swings of the Top End, while feral buffalo generally thrive.

During the wet season, buffalo revel in the floods, frequently submerging themselves to search for water-weeds. In the Dry, they manage on coarse feeds that other cattle breeds shun. At Kapalga, Dr Ridpath estimated that introduced buffalo outnumber introduced cattle by around 100 to one. They are enterprising, adaptable, and thrifty feeders: so it's not surprising that some land-owners are farming redomesticated herds — bringing the prodigals back to the fold. The Northern Territory Buffalo Industry Council has about 30 members at present and is likely to expand quickly.

In Dr Tulloch's experience, buffalo quickly adapt to handling by man — far more quickly than scrub cattle. His advice has been useful in the management of buffalo abattoirs, and simple steps such as hosing down yarded animals to calm them have helped improve efficiency and meat quality.

Any large-scale buffalo industry would need to promote the meat and develop a stable market for it. Buffalo meat is a little different from what we know as beef, being less fatty and having more protein and minerals per unit weight. Because of its leanness, it is used extensively in the smallgoods industry, and in West Germany it is imported as a luxury 'game' meat. In Brazil, many cattle-farmers are replacing cattle with buffalo because of their resourcefulness in feeding, their tick resistance, and their high calving rates. Free-ranging buffalo are little affected by cattle tick or buffalo fly, a pest that they introduced to Australia.

Buffalo-farmers can test their animals for TB and brucellosis, and can apply 'behaviourist' techniques on young animals — mild electric shocks always elicit respect for fences. These, plus a knowledge of buffalo habits, should make farming them no more difficult than cattle-farming. Some pastoralists, however, have reported problems with fencing, as the adult feral animals continually damage any standard fences they encounter. Mr Barry Lemcke and Mr Rob Wesley-Smith, of the Northern Territory Department of Primary Production, are researching these problems at the Department's experimental farm 50 km east of Darwin, near the Adelaide River.

Farming of buffalo requires careful consideration of stocking rates, which should be conservative but flexible enough to accommodate year-to-year variation in climate and rainfall. Areas particularly sensitive to buffalo activity — billabongs, river channels and levees, the heavily forested margin of the plains, and especially the pockets of monsoon forest — need to be protected. The damage to the open plains by grazing, pugging, and trampling is most devastating in the Wet, when soil is more readily compacted and grasses removed — roots and all. As the Kapalga work showed, plant species like *Hymenachne* may disappear altogether. Rotational grazing based on native and, possibly, improved pastures seems the best solution to the problem.

Dr Fogarty, in his report, recommended that land resource surveys are needed over areas where buffalo-farming is feasible. Such surveys would map and describe:

- ▷ land characteristics — including slope, drainage vegetation types, and soil types — for each different habitat
- ▷ existing buffalo damage
- ▷ elements susceptible to damage, like billabongs and swamps
- ▷ areas suited to conservation or recreation

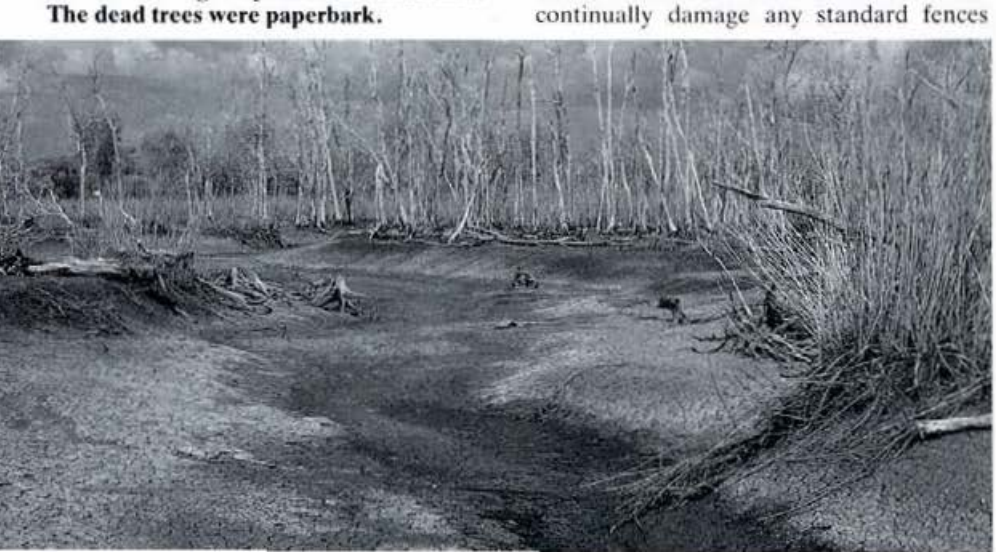
Since buffalo were removed, a dramatic increase in understorey density has taken place.

This information would help farmers plan fence layout, stocking levels, pasture improvement, and rehabilitation of damaged areas.

The unpredictable dynamic ecosystem of the northern wetlands poses new problems to ecologists, most of whom learned their trade in temperate areas. Assessments of the impact of feral animals have to be sorted out against a background of variable rainfall and other natural variations.

While there is no doubt that buffalo have caused extensive damage to the flood-plains

An area damaged by salt-water intrusion. The dead trees were paperbark.



This tower is used to count buffalo.

and their margin forests, a higher level of management than exists now will allow the continued development of production, increase disease control, and ensure environmental rehabilitation. The option of grazing properly controlled, disease-free herds of buffalo in this environment deserves more attention. After all, a tropical species in the tropics makes a lot of sense.

Mary Lou Considine

More about the topic

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Life in the Wet–Dry tropics

'Troppo' is a term often used to describe inhabitants of Australia's Top End. The swings from arid 'winters' to humid, oppressive 'summers' have been blamed for this malady. But not only can fierce climatic contrast initiate slightly deranged behaviour in humans, it also constrains the existence of plant and animal life.

Australia is the only developed country with tropical lands. Our humid tropics are warm rainforest where the climate is more even than in our Wet–Dry tropics. Much less ecological research has been carried out in Australia's tropics than in temperate areas, where most of our ecologists work.

The Wet–Dry tropics are defined as low-latitude areas receiving a mean rainfall of 600–1600 mm over 4–7 months of the year. They lie within the consistently hottest region of Australia and have not much daily or seasonal respite from the heat.

The non-living environmental components of the Australian Wet–Dry tropics differ from their temperate counterparts in at least five important respects:

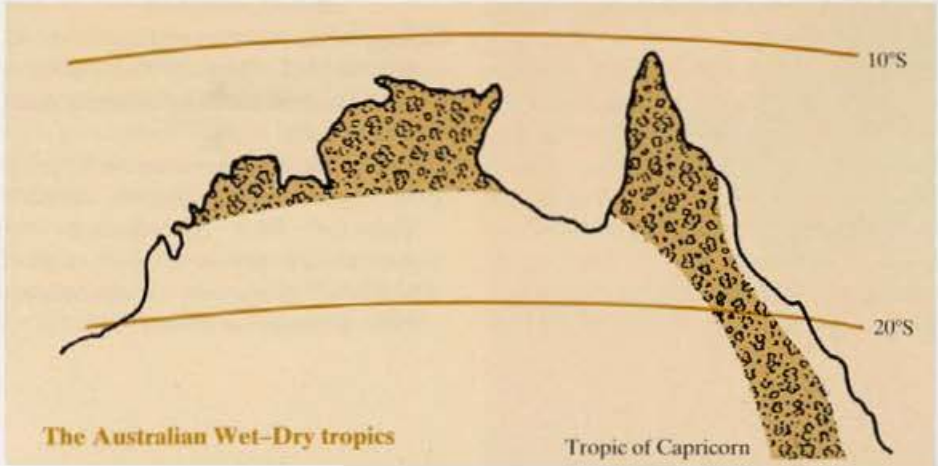
- ▷ little change in hours of daylight during the year
- ▷ constantly high temperatures
- ▷ very pronounced seasonality of soil moisture
- ▷ variability of soil moisture adequate for plant growth early in the wet season, and the duration of its availability
- ▷ low fertility in most soils

The annual alternation of low and high soil moisture amounts to a change between desert- and rainforest-like conditions. As important as this alternation is the variability of onset and cessation of the Wet, and thus growing conditions, during the high-rainfall season.

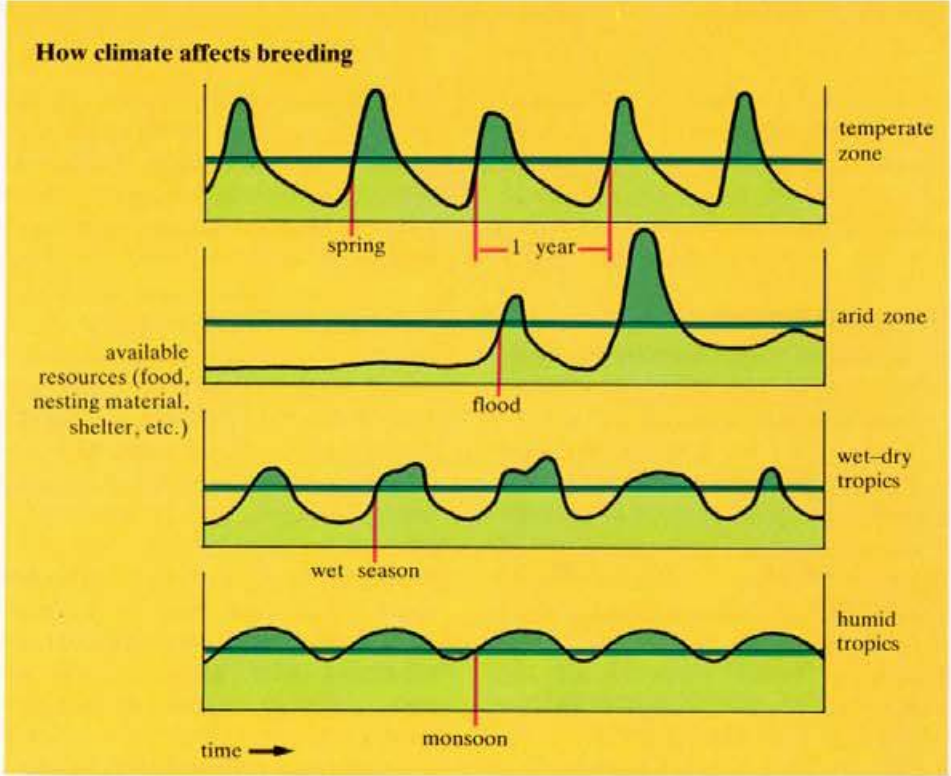
Annual rainfall at Darwin has ranged from 840 to 2800 mm since 1869, with the length of the growing season varying from 17 to 39 weeks. Dr Taylor, who, together with Mr Tulloch, analysed rainfall data for Darwin for the period 1870–1983, calculated that the date by which the first 60 mm of rain in the Wet had fallen varied by up to 11 weeks over a 25-year period. Much of the rain falls in occasional intense storms, and the relatively impermeable surface crusts may prevent absorption of up to 60% of rain-water, lost as run-off.

Dr Taylor carried out the rainfall analysis after starting his vegetation work at Kapalga. He concluded that rainfall variability has important implications for the design, conduct, and interpretation of plant and animal surveys, monitoring programs, and field experiments in the Wet–Dry tropics. Rather than regarding successive years as replicates, researchers have to view yearly 'seasons' here as a series of regular and extreme wet and dry pulses of differing intensity and duration.

Soils, rainfall, and even fire occur patchily in time and space in the Wet–Dry



The Wet–Dry tropics include the Top End, Cape York Peninsula, and a strip inland from the Queensland coast.



A generalized picture of how breeding patterns differ between climatic zones. In temperate areas, the annual 'spring flush' lifts levels of food and other resources above the minimum required for breeding (green line). In arid zones, this only happens after infrequent floods, and animals breed opportunistically. In the Wet–Dry tropics, the onset of rain is less regular than in temperate areas and breeding patterns are more variable. The humid tropics have consistently high rainfall, and breeding resources for animals there are available most of the year.

tropics. Scientists have described 26 major soil types for the 25 000 sq. km of flat and rolling land between the Adelaide and East Alligator Rivers in the Top End. All of this patchiness results in a dynamic seasonal and geographic balance of living things.

Because of the continually high temperatures in the tropics, process rates in vegetation — respiration, decomposition, and nutrient cycling — are higher than in temperate areas. The relatively rapid breakdown of plant litter leads to rapid release of nutrients and many are lost from soils by leaching. So soils are generally infertile, except for those black soils of alluvial origin like the seasonally flooded soil of the plains and their narrow gallery forest margins.

Annual grasses and herbs are particularly abundant in the semi-arid tropics, and escape water stress by compressing their life cycle into the period when moisture is adequate, surviving the dry season as dormant seeds. Mr Chris Lacey of the Division of Forest Research discovered that eucalypts and other tropical woody plants develop tap roots and extensive underground rhizomes to cope with drought and fire. Many tropical savannah grasses and forbs use a type of photosynthesis called the C_4 photosynthesis pathway, which allows them to tolerate severe water stress and low soil fertility.

'Cold-blooded' animals, whose body temperature varies with that of their surroundings, are well suited to the constant warmth of the tropics. Insects, especially termites, seem to play an important ecological role in the Top End and plants there have developed extensive and elaborate defences against them. Insects adapt to the absence of low temperatures by often avoiding or modifying diapause (a sort of hibernation), live longer as adults, and escape the severity of the Dry by seeking moist refuges.

In western African grasslands with a similar latitude and climate to those of northern Australia, the annual intake of vegetation by termites has been measured as reaching almost 100 tonnes per sq. km. The equivalent calculation has not been done for the Top End, but the figure is probably similar. By comparison, a dense population of feral buffalo grazing the subcoastal plains and adjacent woodlands in the Top End has an annual consumption of about 27 tonnes per sq. km. Tropical termites are also significant in the global budget of the gases they produce — methane, carbon dioxide, and molecular hydrogen.

Warm-blooded animals, such as mammals, face greater risks of overheating in the high temperatures. Sweating, for example, is less effective in high humidities than in cooler, drier regions. Rather than expend energy in costly physiological responses — lowering metabolic rate or speeding up breathing — animals use behavioural adaptations of escape and avoidance of the high temperatures. Water buffalo use wallows and shade to avoid the midday heat and, like magpie geese, rats, and feral pigs, escape annual drought by seeking out the shrinking numbers of billabongs and swamps.

Similarly, animals adjust their breeding strategies according to season. For plant- and fruit-eating species, resources peak in the middle of the wet season, while for seed-eaters, they peak at its end and in the early Dry. For instance, the seed-eating little corella is short of food in the Wet but breeds in the Dry. Some species — like the agile wallaby, water buffalo, magpie goose, and rats— respond opportunistically to the climate, regulating their breeding to the erratic and sometimes subdued pulsing of resources in tropical ecosystems.

Weather can also cause catastrophic mortality. Periodically, sudden severe floods cause a mass death of rats and Dr Ridpath has seen drought in the early wet season kill up to one-third of the buffalo population.

Until now, unlike the southern ones, the northern wetlands have been comparatively little touched by the activities of man. The CSIRO scientists warn that the real and suspected effects of present changes in fire regimes, possibly of mining and the use of national parks, but most of all, of introduced exotic plants (like salvinia, mimosa, and mission grass) and domestic and feral animals (especially buffalo) all hint at a different future.

In the past, the managers who survived longest in this environment — the Aborigines — maximized the availability of resources without reducing their sustainability over long time spans. They maintained a diversity of resources through mosaic burning and exploited a wide variety of food sources.

Dr Ridpath, Dr Taylor, and Dr Tulloch believe that the extreme variability of the Top End environment requires a flexible response in terms of management. For agriculture, analogy with natural situations strongly suggests the value of using tropical species highly adapted to the tropics — buffalo, and fruits like mangoes — and also the value of farming a diversity of produce.

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