The remarkable "Adaptable Bat": a challenge to ecological concepts in the management of Australian forest bats

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ABSTRACT

The scientific merit of two opposing themes toward the conservation of Australian forest dwelling microchiroptera over the past four decades is reviewed. The initial theme throughout the 1960's and 1970's was of a vulnerable and threatened bat fauna – a contemporary view for which there is strong evidence. An opposing view, here termed the Adaptable Bat syndrome, emerged in the 1980's. Rather than being of conservation concern, bats were portrayed as resilient, adaptable ecological generalists that could not "reasonably" be considered at risk from human impacts. The Adaptable Bat is an unsophisticated perspective that has been utilised as an ideological counter-attack against societal concern with escalating environmental destruction. This perspective was adopted by some management agencies and many bat workers. It is a modified off-shoot of a more general assertion of the infinite resilience of nature and represents a societal mind set that can be described as the utilitarian ideology, i.e. the dominance of resource utilisation above all other considerations.

The chances of the long-term survival of bat fauna in forests used by the logging industry appear to be bleak because the ideology of the Adaptable Bat has dominated the agenda of biological assessments of the management, threat status and general biology of Australian bats for nearly 20 years. Perhaps the most significant lesson from the Adaptable Bat syndrome is that, like many issues in environmental management, the conservation of Australia's forest bats has everything to do with cultural, political and corporate influences, and very little to do with biological "facts".

Key words: Australian forest bats, microchiroptera, management, Adaptable Bat, utilitarian ideology, forest ecology, timber industry, forestry profession.

Introduction

This chapter examines the attitudes, arguments and assumptions about the biology, management and conservation status of the Australian bat fauna held by many conservation planners, managers, bureaucrats and industry lobbyists, fauna consultants and some biologists. Two diametrically opposed general attitudes toward the conservation management of Australian forest dwelling microchiroptera are evident over the past four decades. The dominant theme throughout the 1960s and 1970s was of a vulnerable and threatened bat fauna – a contemporary view for which there is mounting evidence. An opposing view arose and increased in momentum throughout the 1980s: rather than being of conservation concern, most forest dwelling bats were portrayed as resilient, adaptable generalists that could not "reasonably" be considered at risk from human impacts. Bats were said to be opportunistic dietary generalists, habitat generalists and were claimed to be highly adaptable in their selection of daytime roost sites. It was asserted that bats, as a group, were not a threatened component of the forest fauna and it was claimed that bats were coping well with the extensive environmental changes arising from European settlement. This theme dominated a burgeoning new literature; the "grey" literature of unpublished commercial environmental impact assessment reports and has become increasingly prevalent in the scientific literature.

In the remainder of this chapter, the prevalent view of a generalist and adaptable bat fauna will be referred to as the "Adaptable Bat" syndrome. We argue that such an attitude is a syndrome because the main arguments invoked in support are to an extent inter-linked and self-reinforcing, and the evidence for each is weak or non-existent. Though a dominant attitude over the past 15 years, it should be emphasized that an alternative view has run parallel, that forest bat species as a group are vulnerable and under threat from factors such as intensive forestry activities, land clearing and urban expansion.

Much of our assessment of the Adaptable Bat syndrome is drawn from extensive discussions over the past two decades with a wide range of bat biologists, land managers, bureaucrats and industry lobbyists, together with experience over the past 20 years as fauna consultants specialising in assessment of environmental impacts upon bats, primarily in NSW and Victoria.

The focus is largely on south-eastern Australia, as this is where the majority of debate about the impacts of forestry and other industries upon the microbat population has occurred. Only the microchiroptera are discussed, as the megachiroptera, specifically the flying foxes (*Pteropus* spp.) have been subjected to a separate and totally different set of commercial and cultural pressures (Eby and

Pp 81 - 93 in the *Conservation of Australia's Forest Fauna* (second edition) 2004, edited by Daniel Lunney. Royal Zoological Society of New South Wales, Mosman, NSW, Australia.

Lunney 2002). We have not attempted a comprehensive literature review but have deliberately focused on citing literature from the 1970s and 1980s where appropriate, to emphasise that information was often available to enable the formulation of alternative views to the Adaptable Bat, had social and political forces been different. In particular, we refrain from citation of the "grey" literature as this is generally not open to public scrutiny and would tend to disguise principles in debate about detail.

The Bionomics of Australian Forest Bats

It is first necessary to describe some key characteristics of microchiroptera which shape, or even dictate, the ways in which bats relate to their environment. Although this description must be generalised, it must be emphasised that the microchiroptera as a taxon exhibit remarkable diversity, much of which still remains to be discovered.

Perhaps the most basic element is that most microchiroptera, particularly in temperate regions, are not homeothermic, that is, they lack the physiological controls to maintain a stable body temperature and metabolic rate. This means that they must constantly seek out habitats that enable them to establish their body temperature at the level required by their metabolic state at various points in their annual and daily life cycle (Lyman 1970, Hill and Smith 1984: 78-86). The actual physiological patterns and the strategies utilised vary widely from species to species, and there is all too little research so that we just do not know enough to describe the thermoregulatory process in any Australian temperate zone species. Hence, we do not understand how and why these bats select their preferred roosting habitat at specific times of the year.

It has not been possible to identify the types of tree hollows required by a particular species, how many are used in a local area, the spatial arrangements of roosting and foraging areas and how these might vary at different times of the year. The difficulties of identifying the key resources for mobile fauna such as bats, presents a major management challenge. However, it has long been recognised that Australian forest-dwelling insectivorous bats consist of a diverse assemblage of species that differ markedly in size and morphology (Wood Jones 1928; Troughton 1940). There were reasonable grounds for assuming that species have equally diverse ecological requirements.

For example, species exhibit a wide range of foraging strategies as observed in the field (O'Neill and Taylor 1986) and inferred from predictions based on wing morphology (Dwyer 1965) and were shown to have equally varied echolocation call designs (e.g. Woodside and Taylor 1985). Further, ecological requirements were known to vary in different parts of a species' geographic range, during different seasons, or with changes in climatic conditions, as shown for the Bent-wing Bat *Miniopterus schreibersii* in NSW (e.g. Dwyer 1966). Clearly, there is a reasonable expectation that different species had specialist requirements, as suggested by studies of bat community structure in Western Australia (McKenzie and Rolf 1986). The bat fauna was obviously not a homogenous group in relation to ecological requirements. Obviously, flight is a characteristic not shared by other mammals and provides bats with a remarkable capacity for mobility. This has often been cited as conferring advantages over other fauna, as it has the potential to increase access to dispersed food and roosting resources (Law 1996; Fenton 1997). Burbidge and McKenzie (1989) cited these factors in accounting for the lack of extinctions of Western Australian bats compared to other vertebrates in that State. Lumsden *et al.* (1995) considered that mobility, colonial roosting and interspecific tolerance were factors that prevented regional extinctions of bats in a fragmented rural landscape in northern Victoria.

Although mobility has been invoked as a possible contributing factor to buffer bat species from decline, it also conveys vulnerability. Foraging areas are likely to be dispersed and could be in different habitats to day roost sites. The spatial arrangements of foraging areas and roost sites are difficult to define and are generally unknown. Such areas can only be identified with significant research effort. The viability of roost sites could be jeopardized if foraging areas within range of roosts are degraded or destroyed. Movements between roost site and foraging areas might also be disrupted by destruction or modification of intervening habitat.

Several studies indicate that vertebrate abundance and species number are highest in areas of high-quality habitat, that is, in structurally and floristically complex forest, often on high-nutrient soils. This has been demonstrated in south-eastern NSW for arboreal mammals (Braithwaite 1984), ground mammals (Cork and Catling 1996) and birds (Recher *et al.* 1991). Recher *et al.* (1991) described patterns of distribution of bird species in south-eastern NSW. They found that in addition to a group of usually abundant and widely distributed habitat generalists, some uncommon bird species also occurred in all habitats, but a preponderance of such species occurred on sites with the greatest structural and floristic complexity and high productivity. The limited available evidence suggests that bat communities might show a similar response to habitat complexity and forest productivity. Richards (1994) found relationships between increased bat species number, foliar potassium content, basal area of understorey vegetation and number of canopy trees at a range of sites in the forests of north-east and south-east NSW. However, although sufficiently detailed studies have not been undertaken to confirm this pattern for bats, it is anticipated as a general pattern for the distribution of vertebrates and arthropods (Recher *et al.* 1996). The highest number of bat species often coincides with the most intensive areas of human settlement, and are also the regions with the most intensive forestry and agricultural activities, such as the coastal districts of northern NSW.

Several aspects of bat biology have been identified that predispose bat populations to being particularly vulnerable to human-induced or other impacts. Bat populations are unlikely to recover from rapid population decline as they generally have low reproductive rates, long generation times, and high juvenile mortality. Consequently, bat populations are unable to survive elevated mortality rates or factors that reduce the size of a population (Hall and

Woodside 1989; Pierson 1998). Further, insectivorous bats are vulnerable to pesticide poisoning. The combination of a high rate of food intake due to relatively high metabolic rates, comparative longevity, and fat storage for torpor, makes bats susceptible to accumulation of pesticide poisons in body fat (Dunsmore *et al.* 1974).

A further research problem is that we have only recently started to come to grips with the complex speciation of bats and to develop an adequate taxonomy. As a simple example, what was in the 1960s generally considered a single species, *Eptesicus (Vespadelus) pumilus*, is now recognised as comprising at least nine species (Duncan *et al.* 1999). Many other genera have similarly been revised, or are in the process of revision, and further species are regularly added to the Australian fauna. This means that many historic accounts can only be considered unclear and so valid comparisons over time cannot be made, and even in any one study, what appears as a single species may not have been so.

This means that although there is no evidence of extinction of bat species on the Australian mainland, it is usually not acknowledged that there is effectively no information about the bat species present at the time of European settlement. There is thus no evidence of species extinctions, because there is effectively no evidence. Declines of other mammal species have been documented from specimens collected by early naturalists, and by assistance from the intimate knowledge of Aboriginal Australians (e.g. Krefft 1866; Burbidge *et al.* 1988). In marked contrast, very few specimens of bats were obtained by early collectors and many Aboriginal communities did not appear to recognise different species of bats other than "big bat" and "little bat" (Tunbridge 1991), and were not able to provide the same level of assistance in obtaining bat specimens compared to other mammal species (Krefft 1866). A further consideration is that many of the well-documented extinctions or dramatic range contractions of mammals following European settlement are of species that are morphologically very distinctive. In marked contrast, many bat species are superficially similar and are currently difficult to distinguish morphologically. The taxonomy of Australian bats is still far from resolved. Under these circumstances, it is most unlikely that extinctions or dramatic contractions in geographic range could have been detected (Parnaby 1991).

The Conservation Tradition and Australian forest bats

Although there has long been a concern for the conservation of biota, the contemporary perspective on biodiversity management has been developed and formalised at the international level, and in turn by virtually all governments. In relation to bats, the major international initiatives have arisen from the Chiroptera Specialist Group of the IUCN Species Survival Commission with the extremely proactive support of the NGO Bat Conservation International. In particular, identification of threats and development of action plans including microchiroptera have been developed at the world and Australian levels (Hutson *et al.* 2001; Duncan *et al.* 1999). Although indeed valuable, the Australian report has been criticised on the basis that it focuses on threatened species but gives too little attention to threatening processes (Lunney *et al.* 2003). The same is true of the world document and both are therefore too broadly generalised to provide much of value to our understandings of threatening processes.

Initial concern for bat conservation in Australia centred on a small number of cave dwelling species, which were the only microchiropteran species that had been studied. The vulnerability of the cave-dwelling species to human disturbance from visitation, or destruction or modification of cave roosts had been clearly demonstrated during the 1960s and 1970s for all of the limited number of species that had been studied. The vulnerability of subterranean roosting bats to disturbance at roost sites has long been recognised (Dwyer 1963; Hamilton-Smith 1968). Large numbers of individuals can be concentrated at relatively few roosting sites, and in some cases a significant proportion of a regional population can be concentrated in one cave roost (Dwyer 1966). Disturbance or destruction of such sites can have a major impact on an entire population. Subterranean roosting species are especially vulnerable to disturbance of maternity colonies during spring and summer, or when dependent young have not yet learned to fly, and during winter when bats are torpid (Hamilton-Smith 1974; CLMC 1992). Further, it is thought that only a limited number of caves are suitable as roost sites, and their destruction or modification could be highly detrimental to the survival of regional populations.

One of the major lessons of the research on these bats was that a detailed knowledge of the physiology and consequent environmental relationships of each species is vital to the development of effective survival planning. Another was the fundamental importance of microclimatic and microhabitat analysis in the development of such plans. Regrettably, this has not been properly recognised in most studies of forest bats.

Bats are a vulnerable and threatened group of forest fauna. The most relevant broad threats to forest-dwelling species are habitat destruction and modification and poisoning from accumulation of pesticides in body tissues. Other issues identified include a lack of public education (e.g. Woodside 1990), and the very serious lack of biological information (Richards and Hall 1998) including taxonomic uncertainty (Parnaby 1991).

It has also been acknowledged for more than 30 years that forestry activities pose a significant threat to bat populations (e.g. Cowley 1971; Routley and Routley 1975; Hamilton-Smith 1980; Law 1996; Recher 1996; Richards and Hall 1998). More recently, several authors consider that regional extinctions of hollow-dependent fauna such as bats are likely to result from forestry disturbances (Lunney and Barker 1986; Lunney *et al.* 1988; Norton and Kirkpatrick 1995; Recher 1996). Bats are likely to either rely on old-growth forest or have populations that are centred on forest with old-growth attributes (Scotts 1991; Recher 1996). It is also likely that old-growth forest elements such as hollows in old trees, and arthropod food resources from invertebrate communities associated with old-growth attributes, such as large logs and large trees (Recher *et al.* 1996), will prove to be critical for some bat species.

A reliance on old growth elements renders bats vulnerable because of the long lead times – at least several centuries – required for formation of critical old growth resources, and the fact that old growth elements are being rapidly destroyed over most of the Continent. The long time horizons spanning hundreds of years required for regeneration of critical resources for bats means that from a management perspective, such resources are effectively finite in terms of the short logging rotations and working life of managers. For example, the formation of both large hollows (Mackowski 1984) and well-developed understorey plants (Mueck *et al.* 1996) can take hundreds of years and the replacement of decayed logs on the forest floor can take over 1500 years (Recher 1996). Recovery of the full range of structural diversity, and therefore the full range of potential foraging substrates for bats, of clear-felled sites of old-growth forest would take 1500 to 2500 years, that is, several generations of the overstorey trees (Norton and May 1994).

The combined impacts of forestry operations is reduction of quantity, availability and suitability of foraging habitat, food resources and roosting resources for fauna, such as most bat species, that are dependent on old-growth attributes (Lunney *et al.* 1988; Kirkpatrick *et al.* 1990; Scotts 1991; Norton and Kirkpatrick 1995; Recher 1996). This arises from the modification of forest by simplifying forest structural and floristic complexity (RAC 1992; Mueck and Peacock 1992; Recher 1996), disruption of ecosystem processes (Norton and Kirkpatrick 1995), and adverse effects arising from the fragmentation of forest landscapes (Recher and Lim 1990).

Further dimensions of the problem arise from studies suggesting that hollow-utilising bat species are likely to require multiple roost trees in close proximity and are known to frequently change roost sites between different trees (e.g. Lunney *et al.* 1988; Lumsden *et al.* 1994; Lumsden and Bennett 2000). This is a common characteristic of the hollow-utilising bat fauna in other continents (Lewis 1995), and appears to be essential as a means of predator avoidance, for reduction of parasite loads, and as a response to altered social or climatic conditions (Lewis 1995). It is also likely to reflect the continuing search for the right microclimatic conditions at specific times. Radiotracking studies have found that individuals often change roost sites, daily or every few days, and it has been suggested that an individual is likely to show fidelity to an area containing a number of alternative roost trees, rather than to a single roost site. These conclusions have been reached by Lunney *et al.* (1988) for Gould's Long-eared Bat *Nyctophilus gouldi* in forest on the south coast of NSW; Taylor and Savva (1988) for four species in forest in Tasmania; Lunney *et al.* (1995) for the Northern Long-eared Bat *Nyctophilus bifax* in littoral rainforest in northern NSW; and by Lumsden *et al.* (1994) for the Lesser Long-eared Bat *Nyctophilus geoffroyi* and Gould's Wattled Bat *Chalinolobus gouldii* in northern Victoria.

Alternate roost sites used on consecutive nights are typically within a few hundred metres of one another. Taylor and Savva (1988) found that distances between roosts used over a period of several days by four Tasmanian species averaged about 500 m and ranged from 80m to 1.4km for 10 roost sites. The majority of movements reported for Gould's Long-eared Bat by Lunney *et al.* (1988) were less than about 500 m for both males and females. Lumsden *et al.* (1994) found that, for both the Lesser Long-eared Bat and Gould's Wattled Bat, about 70% of all roost relocations were within 300 m of the initial roost and, for both species, a significant proportion of movements were less than 100 m. Consequently, removal of hollow-bearing trees could have a dramatic impact on local populations, even if the hollows destroyed were not in use at the time of felling.

Radiotracking studies have found that roost hollows are preferentially selected in the largest available trees by all species which have been studied, e.g. Goulds Long-eared Bat (Lunney *et al.* 1988), Chocolate Wattled Bat *Chalinolobus morio* (Lunney *et al.* 1985), Goulds Wattled Bat and the Lesser Long-eared Bat (Lumsden *et al.* 1994) and the Forest Bat *Vespadelus pumilus* (Law and Anderson 2000). Significantly, all species have wide distributions, are regarded as common, have been presumed to be ecological generalists and would not be considered as threatened even though large, hollow-bearing trees are a threatened resource throughout most Australian landscapes. These species have not been cited as being of "conservation concern" and even include species that have been considered to be of least conservation concern (e.g. the Lesser Long-eared Bat), yet all are clearly vulnerable to decline or elimination of roost sites.

Although the foraging ecology of Australian forest bat species is poorly known, an indication of the likely complexity of foraging patterns and requirements of species can be gauged from detailed studies of northern hemisphere temperate zone insectivorous bat species. It has been suggested (e.g. Kunz 1974) that bats could adjust their nightly foraging distances from the roost of large colonies to reduce competition for food resources via greater dispersal of individuals than occurs in smaller colonies. Kunz (*loc. cit.*) suggested that adult females foraging further from maternity roosts during the period when young begin to fly could also reduce competition. Adams (1995) demonstrated that adult Little Brown Bats *Myotis lucifugus* shifted foraging activity from less cluttered microhabitats when young to more cluttered microhabitats when they became old enough to undertake foraging flights. Racey and Swift (1985) found that the foraging ability and feeding efficiency of newly volant young is significantly less than that of adults. Young initially foraged within 100m of the roost, and progressively increased foraging distance and foraging time, which reached distances of adults (about 5km) after about two weeks (Racey and Swift 1985). Other mechanisms that would reduce intraspecific competition for food resources include dispersal of individuals to numerous smaller colonies during seasons of reduced insect availability (Kunz 1974). This has been documented for the Large Bentwing Bat in NSW (Dwyer 1966). The increased energy demands on adult females throughout pregnancy and lactation can decrease foraging distances from the roost (e.g. Racey and Swift 1985). Daily energy requirements for females at peak lactation have been estimated to be double that of early lactation for some species (Kurta *et al.* 1989). Foraging time has been observed to decrease during late pregnancy, when the increased body weight of gravid females is thought to constrain flying ability and the energetic rewards of feeding (Kurta *et al.* 1989). Adam *et al.* (1994) found that foraging distances of the endangered Virginia Big-eared Bat *Plecotus townsendii* were most restricted during pregnancy, and the maximum distance observed of females from the maternity roost was about half that of males (3.6km compared to maximum male distance of 8.4km).

Although some genera (e.g., *Miniopterus, Tadarida*) appear to cover a much larger foraging range, the evidence cited immediately above suggests that many of the vespertilionid bats of our temperate forests may well need to find the necessary food within a relatively small radius from their roost.

Introducing the *Adaptable Bat* concept

The belief that our forest bats, as a group, are an adaptable, resilient component of the mammal fauna gathered momentum throughout the 1980s, despite mounting scientific evidence to the contrary. In particular, there was a growing conviction that as a whole, the bat fauna could not seriously be considered to be threatened and that there were very few, if any, threatened bat species in south-eastern Australia. We suggest that the rise of the Adaptable Bat parallels the emergence of forest bat conservation as an issue of public concern around the mid 1980s, by which time it had to be addressed by forest managers, e.g. the Eden EIS prepared for the Forestry Commission of NSW (Smith 1986). The Adaptable Bat gained substantial impetus in NSW following the *Endangered Fauna (Interim Protection) Act, 1991*. In 1992, nearly half of the State's bat fauna was listed as threatened, and bats comprised about one tenth of all extant vertebrate species listed as threatened in NSW (Lunney *et al.* 2000). The Act, and its successor, the *Threatened Species Conservation Act 1995* (TSC Act), which incorporated the listing of threatened species made in 1992 into its schedules of Endangered and Vulnerable species, imposed a legal requirement to evaluate impacts of a wide range of development proposals on threatened bats. This brought bats into the direct focus of a range of industry groups additional to the logging industry, particularly coastal housing construction, rural land clearing, highway construction and mining operations along with a host of minor industries.

The fact that a wide range of bat specialists contributed to the species assessment process for the Act and that a large proportion of bat species were considered at risk is a clear statement that the bat fauna was considered to be far from resilient and adaptable. Vested financial interests in tandem with those who were ideologically opposed to "environmentalism" mounted a major counter-offensive against the view that much of our fauna, including bats, were threatened by human activities. In this respect, the "Common" Bentwing Bat came in for special attention from fauna consultants in NSW (Parnaby 1996). A mythology arose that had the effect of trying to marginalise concern about its conservation by claiming that it was abundant, had a distribution that spanned half the globe from Australia to Europe, was found in urban Sydney, and had no special requirements for protection of foraging habitat. Although the scientific literature clearly demonstrated the vulnerability of this species, it was used as a lever in an attempt to discredit the entire species threat assessment process undertaken for the TSC Act.

The general arguments used in support of the Adaptable Bat, are outlined below and are discussed in detail in later sections. One argument is that no bat species is known to have become extinct since European settlement. The implication, usually not stated, is that if bats have escaped the levels of extinction documented for others mammal groups such as rodents, bandicoots and small macropods, then they are over the "extinction hurdle" and are therefore somehow secure. Further implicit in this argument is the misconception that the worst threats from European settlement occurred early in the history of settlement, and that if the bat fauna is secure now, it must somehow be secure into the future! But as has been already demonstrated, we just do not know how many species really existed in the past.

It is often claimed that bats are highly adaptable in selection of daytime roost sites and did not have specific roost requirements because of the diverse array of daytime roost sites in which individuals of a species were found, which often included buildings. For example, in relation to roost site selection:

> "Bats are generally quite adaptable when looking for a place to roost and they are found in a large variety of situations including caves, tree hollows, under bark, buildings, old mine shafts, and bird's nests." (DCFL 1988, pg 33)
>
> "The majority of the remaining microchiropteran bat species recorded in the TMA [Tenterfield Management Area] are considered generally to rely on tree-hollows for roost sites, although many species also shelter under exfoliating bark, or in a variety of sites, including buildings, rock crevices, Sugar Glider nests, birds nests, and "the exhaust pipe of a tractor" (*Chalinolobus gouldii* Dixon 1989). Thus, for several species, roost site choice appears to be opportunistic, and timber harvesting may not be of particular consequence." (Fanning 1995, p 86)

Most south-eastern Australian species have been found in a wide range of vegetation types, which has been interpreted as proof that nearly all are habitat "generalists", i.e. they do not have specific habitat requirements. This view is articulated by Richards (1995, pg. 40):

> "In general the bat fauna could be grouped into species that were generalists and found in many habitats, or specialists that were restricted to just a few. This is a pattern that is expected throughout south-eastern Australia...."

Bat species were viewed as opportunistic dietary generalists, i.e., with very few exceptions species were not considered to have specific dietary requirements. This view prevailed, despite the lack of properly designed and sufficiently detailed dietary studies for any species that would enable dietary specialisation to be detected.

The Political Economy of the *Adaptable Bat*

The extent to which the *adaptable bat* concept is clearly an advantageous one, at least in the short and mid term, to the forest industry (and some others) needs at least some assessment here in helping us to understand how the concept has evolved.

Current environmental policies demand that those seeking to undertake major industrial, resource harvesting, construction or other major projects must undertake and make available to scrutiny an 'independent' environmental impact assessment. This sets up a process where scientists are expected to provide 'answers' to any questions about the environmental impact of the project concerned. This is indeed a problematic policy. First, the emphasis is upon 'answers' rather than defining the many questions that demand continuing inquiry throughout the life of the project (cf. Feinsinger 2001).

More importantly, the scientists are engaged and paid (often as little as possible) by the proponents of the development, and this inevitably generates a working relationship within which the scientists feel an obligation to the proponent. This means that they might do what they can to satisfy the proponent, but there are even more subtle effects. They certainly try to avoid being the messenger bearing bad news, because although such messengers are not shot, they might face a significant threat of failing to gain further contracts. Moreover, they are aware that their assessment must be supported by strongly developed, even incontrovertible, evidence.

In the case of bats, there is generally little research evidence to provide such an assessment of any one bat species in any one specific part of its range. So, they might say there is no evidence, they might manage to even avoid the bat question, or they might resort to the *adaptable bat*.

This has happened widely enough that, as pointed out elsewhere in this chapter, it has acquired a hegemonic authority, that is, it has become a dominant set of beliefs and practices that is widely agreed and even has the appearance of common-sense reality (Williams 1983). It is not a deliberate conspiracy, but arises out of a complex intellectual process, aspects of which have been briefly summarized above as they have related to this concept.

Another dimension of the problem is the 'economic fundamentalism' of modern developed nations, which is particularly marked in Australia, and leads politicians (and the administration) to be unwilling to accept barriers to economic growth and development. Thus, even many of those employed in agencies that operate on a mandate of environmental and biodiversity protection fail to challenge the 'adaptable bat' (or similar heresies).

Assessing and Comparing the *Adaptable Bat* concept

Despite the high level of uncertainly associated with the lack of key ecological data required for effective management of each bat species, the Adaptable Bat concept, if accepted, has very specific management implications. If it is accepted that bats are adaptable generalists, it follows that no specific management actions are required, beyond retention of a few hollow bearing trees and riparian habitat belts, both of which will already be required either for erosion control or arboreal birds or mammals. For example, if bats are adaptable, opportunistic feeders, they will prey on pretty well any insects that are available and protective measures for feeding resources are not required. Thus, fauna prescriptions for logging publicly owned native forest in NSW contain no specific measures for protection of foraging resources for bats, with the exception of very limited areas for the Large-footed Myotis *Myotis macropus* and Golden-tipped Bat *Kerivoula papuensis* (see logging prescriptions for NSW public forest areas in *Forestry and National Park Act* 1998 Annexure B). If bats are habitat generalists, high quality habitat can be destroyed, and bats are expected to be able to survive quite well on adjacent low quality habitat. Logging prescriptions have generally not addressed the needs of virtually the entire bat fauna, both in NSW and elsewhere in Australia.

If the *adaptable bat* concept were proven accurate, it would mean that there was little or no conservation issue and the widespread concern about future prospects for the Australian bat fauna would be unwarranted. On the other hand, if it is incorrect, then it may in the long run prove to have been a very costly error. So, each of the major expressions of adaptability will now be analysed and evaluated.

Habitat Selection and Adaptability

Despite the claims for the adaptable bat, there is currently no evidence that bats are habitat generalists. The wide range of vegetation types in which many bat species have been recorded (see the species accounts of Strahan 1983; 1995) is cited to support the view that many, and perhaps the majority, of species are therefore habitat generalists. There are many flaws in this argument, a fundamental one being that such categories, whether rigorously defined botanically or not, are more correctly termed biotopes and there is no particular reason why bat species will necessarily respond to this demarcation of the environment. Bats need a specific diversity of microhabitats to meet their physiological needs, and broad range biotopic classifications provide no relevant information on this question.

Dietary Requirements and Adaptability

Claims that most species are "dietary generalists", "generalist feeders" or "feed opportunistically" are an important part of the concept of the Adaptable Bat. In the management context, these claims have an unequivocal meaning: it is implied that they will eat pretty well anything on offer, and so no specific conservation measures are required to protect food resources.

The issue of diet specificity might appear to be straightforward, but in fact this is a confused and complex issue. The issue is confused because these terms, while appearing self evident, are actually vague and open ended. The clear implication is that such species do not have a selective (i.e. specialist) diet. However, a species can be a dietary specialist, yet feed opportunistically. For example, a species could be a beetle specialist, meaning that it preferentially feeds on beetles, even though other insect orders might be more readily available in its foraging areas, yet will opportunistically feed on whatever family of beetles are encountered. Alternatively, a species could feed selectively on a particular size range of insects but take a wide range of insect orders in proportion to their availability. Such a species has a selective (specialist) diet on the basis of prey size, but is opportunistic in terms of insect taxa eaten. In a broad sense, a species can be said to be a selective feeder if it preferentially takes prey items in a different proportion to what is available – if the taxa in the diet occur in the same proportion as the food available, it is not a selective feeder.

The usual basis of the claim of opportunistic dietary generalist is that Australian dietary studies, limited though they are, have found a wide range of invertebrate orders in the stomachs or faeces. The classic study of Vestjens and Hall (1977) has been widely cited in such a context. They studied stomach contents of museum preserved specimens and found that a range of insect taxa were present in most of the species studied. The problem here is that the very research design is generalist and so will inevitably produce a generalist result.

Hall and Woodside (1989: 878) summarise the prevalent view that insectivorous bats have a generalist diet. Referring to overseas studies they state:

> "Many bats specialize in certain prey taxa (Ross 1967; Black 1974; Belwood and Fenton 1976; Belwood and Fullard 1984) or prey size (Belwood and Fullard 1984), while other bats (or the same bats at other times) are opportunistic (Fenton and Morris 1976; Anthony and Kunz 1977; Bell 1980). In Australia, there are very few specialist feeders among the vespertilionids. Robson (1984) showed that *Myotis adversus* tends toward a fish eating diet and D.P. Woodside, K.J. Hews-Taylor and S.K. Churchill (unpublished observations) note that *Kerivoula papuensis* specializes in orb-weaving spiders."

In our view Hall and Woodside accurately reflect the dominant view of that time. The concept that Australian bats were predominantly dietary generalists is all the more remarkable given the fact that, not only were the dietary requirements of virtually all Australian microchiroptera unknown, but that it was acknowledged that dietary selectivity could occur not only from specialization on invertebrate taxa, but also on prey size. Despite this, the only test of specialization that is applied is the restricted test of specialization based on prey taxa.

The classic study of O'Neill and Taylor (1989), probably the most detailed yet on the diet of Australian bat assemblages, has evidently been widely interpreted as support that most forest bat species are likely to be opportunistic generalists, largely because these are the claims made by those authors. However, their study actually provides evidence that 3 of the 8 species studied were dietary specialists in terms of preferentially selecting insect orders. Further, they provide evidence that most of the 8 species preferentially selected prey species on the basis of size – larger bats *selected* larger sized prey. The pattern of selectivity of prey size was even more specific – a given sized bat species preferentially selected smaller sized beetles than moths. Their paper illustrates the confusion and contradictory evidence that typified discussions of dietary selectivity.

A current Asian research study measures the percentage of recorded occurrences and of volume in stomach contents for each of the relevant taxonomic orders. This has again demonstrated that most species are either specialists in beetles and some other chitinous insects (e.g., cockroaches) or in moths and other soft-bodied species. Further, the extent to which a bat falls into either of these categories is clearly related to patterns of dentition and this in turn sets constraints upon prey size. The major surprise of the study was the discovery of a vespertilionid bat which is predominantly vegetarian and feeds almost exclusively on a single plant species – a classic demonstration of the dangers of generalized assumptions and of dietary specialization (Wai Wai Myint, in progress).

Roost Selection and Adaptability

The most important argument to support the claim that bats are very versatile in roost selection and have generalist roost requirements is the wide range of situations used as daytime roost sites by individuals of a particular species. Observations which are inferred or stated as indicative of bats having adaptable roost requirements include the range of roost situations reported for individuals of a particular species, e.g. under loose bark, in buildings, under bridges, under stones. The premise of underlying adaptability is seriously flawed partly because it is based on a perception of roost utilisation which does not acknowledge the complexities of the situation, and also because the context of the observations is not fully considered.

Roost requirements of many species are known to differ among the sex and age classes, and to vary according to different physiological demands induced by reproductive condition, seasonal climatic differences and different weather conditions, all underlain by the problems of body temperature regulation. This is illustrated by Lumsden *et al.* (1994) for the Lesser Long-eared Bat, a common species previously thought to be highly adaptable (e.g. Maddock 1983). They found that although some individuals, particularly males, roost in a range of relatively unprotected sites such as in fence posts, buildings and under slabs of bark in disturbed agricultural areas, all maternity roosts were located in cavities in the largest available trees in forest areas.

Further, because we are dealing with the widespread problem of body temperature through one strategy or another, it is instructive to make a comparison from the intensive ecological studies on cave-dwelling bats. Bats not only select very different caves at different seasons and differing physiological conditions, but they select an even wider diversity of specific roost sites within any one cave.

Major Environmental Change and Adaptability

The presence of bat species in highly modified landscapes is often invoked as proof, or at least a strong indication, that bats must have adapted well to the large scale changes that followed European settlement. The three types of landscape typically discussed are landscapes degraded by agriculture, logged public forests, and urban areas.

Some bat species still persist in highly modified landscapes, where 70% or more of the native vegetation has been destroyed by agriculture. This has been interpreted as evidence that bat species have adapted to such changes but perhaps more relevant, implicit in such claims is the assumption that, to all intents and purposes, these species will remain a permanent part of these landscapes and are over any “extinction hurdle”. These claims are premature. Populations might currently be stable, yet unlike populations in a less disturbed environment, be unable to sustain foraging activity during the increased pressures resulting from environmental changes, such as climatic extremes, perhaps in combination with other factors such as fire and drought. Such extremes might occur only over a time scale of decades or centuries and would not be detected by short-term research programs, even if they were to be implemented, that rarely exceed a few years’ duration.

A wide range of bat species have been reported roosting in buildings in Australian urban areas, and this includes maternity colonies of some species, e.g. Goulds Wattled Bat in Melbourne (Dixon and Huxley 1989). The fact that bats roost in buildings in urban landscapes is often cited as the ultimate proof of the adaptability of the bat fauna. These claims and assumptions are unjustified because they have been made in a near vacuum of understanding about the ecological nature of urban occupation by bats, and because they are an oversimplification as the context of such occupation is unknown for most species.

For example, the presence of colonies of the Large Bentwing Bat in buildings in urban Sydney has often been invoked to discredit the perceived vulnerability of this species. However, a recent assessment of this species (Hoye and Spence 2003) supports the need for caution in interpreting the presence of such species in urban environments. They conclude that the species appears to have significantly declined and the pattern of roost utilisation has altered over the past two decades. Whereas year-round occupation was documented in the past, the species is now evidently absent over the summer months. Maximum colony numbers 20 years ago are double the maximum now recorded. Although the exact cause of decline is unknown they found that winter mortality rates from collisions with vehicles is thought to place significant pressure on urban bats, in contrast to bats sampled in rural areas.

A related issue that has added to the perception that bats are highly adaptable is the presence of a diverse urban bat fauna in Europe, which not only has a long history of close human settlement and highly modified landscapes but many bat species appear to be largely reliant on human structures (including buildings) for daytime roosts (Stebbings 1988). However, the progressive renovation of old buildings and construction of modern buildings has often resulted in ‘bat-proofing’, and there has been a drastic decline in many of these populations (Stebbings 1988, Hutson *et al.* 2001). For a similar reason, combining both renovation and the fact that most building stock is relatively recent, Australia has never had a large number of urban bat colonies. In many recent European studies, urbanization is recognized as a *threat* to the survival of bat species (e.g. Yalden and Morris 1975; Roer 1980), as is the destruction of “natural” landscapes and habitat (Schober and Grimmberger 1993). Clearly, there are serious difficulties with asserting that bats are highly adaptable simply because of the presence of some species in urban areas. It is certainly true that some buildings may provide very appropriate microhabitats for some bats, but this is really of very limited value at the species population level. One cannot cite the occasional use of an urban habitat as any evidence of adaptability, especially when one sees how any one bat species only selects a very specific habitat, e.g., the preference of *Tadarida* to roost against sun-heated metal.

Finally, let us consider the impacts of timber harvesting, particularly contemporary clear-felling. The persistence of bat species in forest areas which have a long history of logging is often either implied or invoked as proof that such species are not adversely impacted by logging operations or, alternatively, as proof that they can survive current logging regimes. Further, it is often inferred that such species will be able to survive in logged forest in perpetuity. These claims are flawed for many reasons. Such claims are generally based either on animals captured in bat traps, or recordings of echolocation calls, neither of which provide information about the activity of the bats during capture or recording, nor about the extent of survival. Obviously, the significance of records of a species from sites in logged forest cannot be interpreted without a detailed knowledge of the ecology of the species involved, and at the very least, on being able to determine the activity of the individuals in logged forest. These arguments also ignore the dynamic and highly complex long-term changes induced in forest ecosystems by human activities, many of which will not become apparent for decades or centuries.

Summarising the *Adaptable Bat*

The Adaptable Bat, though breathtakingly vacuous, has been a truly adaptable, resilient and successful piece of propaganda and it is informative to examine its construction. The usual claims cited to justify the assertion of adaptability – dietary, habitat and roost generalists- have several important characters in common. The simplicity of each claim belies a much more complex situation, an appreciation of which reveals that each claim is quite misleading. The "evidence " cited in support has considerable logical appeal and the whole matter appears to be self-evidently true. In fact, the appeal to common-sense is a normal element of intellectual hegemony, even though common-sense is well-known to be anti-scientific. Each claim appears to be clear-cut but in fact is based on a concept that is vague and open-ended or even demonstrably false. Thus the Adaptable Bat relies on coarse and biologically inappropriate interpretation of key terms, e.g. to qualify as a habitat specialist, a species is only to be found in one or two "habitats" and habitat is defined in terms of a broad vegetation type.

The arguments reviewed above either do not support the perception of the Adaptable Bat, are too limited to shed any light either way, or contradict it. Thus, there is little or no support for the view that bats are adaptable and are not an extinction prone group, nor is there any convincing evidence that they are therefore not likely to be adversely impacted by the massive inroads of modern civilisation. In particular, there certainly does not seem to be any convincing scientific basis for adopting this as the default view, let alone allowing it to be a continuing, and often dominant, hegemony.

Nevertheless, one of the more powerful dynamics in the manufacture of the Adaptable Bat syndrome is not reflected in the written word but in the strong psychological impact of constant aggressive assertions of adaptability during meetings, workshops and conversations between bat consultants and government and industry operatives. During such interactions, the non-compliant consultant, or the misguided bat specialist, is left with absolutely no doubt about what is considered to be acceptable, balanced and reasonable – and this just happens to be the Adaptable Bat! Consequently, if you advance a contrary view to the Adaptable Bat syndrome, you are seen as being unreasonable, unrealistic, extreme, and generally unsuitable – you will not be asked back! If you persist in your point of view throughout the meeting, you are seen as being unnecessarily negative and disruptive, and a general irritant. Such people are likely to be abruptly reprimanded with the self-righteous impatience of those who know better.

Consultants and bat specialists alike quickly develop an intuitive understanding about the boundaries of "acceptable" ideas – and this is not likely to include anything that will be unacceptable to powerful vested financial interests. This does not imply that bat specialists and consultants are necessarily prostituting themselves, as the limits of respectable thought are probably largely unconsciously absorbed. We suggest that an additional important dynamic is the general lack of assertiveness, or confidence that we have witnessed in many specialist participants in land management procedures. Some specialists feel that they have no right to hinder economically important projects, on the grounds of adverse impacts on bat species. It's as though they feel that they have not been sanctioned by society to present their real perspective of likely impacts, but rather, must go through a more limited charade. Too often, we have been involved in impact assessment procedures where the idea that the proposed "development" should not go ahead, isn't even on the agenda.

A central issue is the dominance of the utilitarian ideology in the subculture of several key professions, industries and government agencies involved with resource management. For example, the Australian forestry profession continues to be criticised for failing to adequately embrace changing community values in regard to non-timber values of public forests, for example, by treating fauna conservation as a constraint on wood production (Routley and Routley 1975; French 1983; Shaw 1983; Recher 1986; Lindenmayer and Franklin 1997).

On reviewing the core research strategies, the essential concepts were well in place in the Australian and overseas literature on temperate zone insectivorous bats by the mid 1980s that would have enabled the formulation of robust alternatives to the Adaptable Bat. In particular, the view that hollow-utilising forest bats were a vulnerable group that could be expected to have specific ecological requirements and that faced impending threats from habitat destruction and modification was certainly a view expressed at the time, e.g. ABRG (1985) and Ahern (1982).

Specifically, the potential threat from loss of roost sites in hollows in old trees should have been apparent. The logic behind the idea that a hollow-utilising species such as the Lesser Long-eared Bat could be regarded as an adaptable generalist that does not have specific roost requirements simply because individuals have been found in a diverse range of daytime roost sites has always evaded us. A tree hollow has a microclimate, as does a cave, and it is a simple step from the demonstrated specific microclimate required for maternity colonies demonstrated for cave roosting species, to a scenario of specific requirements for say, a maternity colony in a tree hollow. Consequently, that a hollow-roosting species might have specific hollow requirements, at least at some stage in the reproductive cycle, would hardly have been a novel concept. Tree hollow microclimate in eucalypts was examined by Calder (Calder *et. al.* 1983). The long time periods required for the formation of hollows in eucalypts and the severe problems resulting from hollow loss from logging operations was demonstrated by Mackowski (1984) and identified specifically in relation to bats by Cowley (1971).

In relation to diet, perhaps Australian workers were unduly influenced by the idea that insectivorous bats were opportunistic generalists (e.g. the review of Fenton 1982). However, the concept that Australian insectivorous bats potentially include a range of species that were dietary specialists, species that were generalists and species that were opportunistic generalists but were dietary specialists during some seasons had a reasonable foundation: diet was poorly known for virtually all species, and the overseas literature clearly indicated that this issue was unresolved. At the very least, one would have thought that a more appropriate Australian response would have been to consider the issue as unresolved.

It is significant that the legacy of a vulnerable and potentially threatened bat fauna that dominated the views of Australian cave bat workers in the 1960s and 1970s did not appear to transfer to hollow-utilising bats as a dominant view during the 1980s, despite the increasing environmental concerns being expressed by the broader community. Perhaps it did transfer initially, but was remolded by a broader counter-attack against environmental concerns and the resulting demands for "precautionary use". Perhaps people were influenced by the Big Country Mystic: for example, even if old trees with hollows were being rapidly eliminated over large areas, both from rural die-back, land clearing and intensive forestry, there was probably a view that there were plenty more "elsewhere" in this vast country, despite the fact that only some 5% of the Australian land mass is forested. Whatever the reasons, by the close of the 1990s, the Adaptable Bat was still very much alive, was creeping into the scientific literature, especially from authors employed by publicly funded forestry authorities, and continues to distort public debate about bat conservation and management.

Even more pervasively, it distorts research strategies and methodology. Many of the claims invoked to support the Adaptable Bat can be found in the environmental assessment literature, appropriately modified for other fauna groups.

It could even be argued that the Australian Federal Government's Bat Action Plan (Duncan *et al.* 1999) is also the result of similar pressures, given the small proportion of species listed as threatened compared with a much higher proportion of the fauna that might be expected given a less politically influenced assessment process. A panel of bat experts convened by Environment Australia settled on a threatened status for 18 Australian bat species (Parnaby 2000). The final list determined by a sub-committee was 9 species. A cynic could match an industry pressure group for each species dropped from the initial 18, e.g. the Ghost Bat *Macroderma gigas* and Orange Horseshoe Bat *Rhinonicteris aurantius* with the mining industry that was reworking old adits across northern Australia; the Western Falsistrelle *Falsisrellus mackenziei* with the politically sensitive logging industry in Western Australia; the Spectacled Flying Fox *Pteropus conspicillatus* with North Queensland orchardists and perhaps the Eastern Little Mastiff-bat *Mormopterus norfolkensis* with coastal urban expansion in NSW. A conspicuous example is the extraordinary omission of the Ghost Bat, recognised as vulnerable for nearly four decades, and the nonsensical reasons given to justify its demotion from the threatened fauna list. Of course, there may have been other motivations, for example, a desire to ensure that the lists of Federally recognised threatened species were kept low, e.g., not higher than about 10% of the relevant faunal group.

This chapter has been considerably reduced from a previous and fully documented draft out of some sympathy for the reader. But the evidence for our arguments in this paper is overwhelming. If we are to achieve adequate conservation strategies and programs, and to genuinely meet our obligations under such international agreements as the 1992 Convention on Biological Diversity, then we must develop a much more rigorous and searching approach to the problem.

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