Challenges for managing bats in the State Forests of New South Wales

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ABSTRACT

Bats have recently become an essential component of forest management in State Forests of NSW. A key driver has been research demonstrating that many species of bats prefer to roost in the hollows of large mature eucalypts and the 1990s listing of many bat species as threatened. Current bat management in State Forests of NSW is multi-pronged. Two "tiers" of management prescriptions are specified in the Threatened Species Licence issued under the *NSW Threatened Species Conservation Act 1995*. The 1st tier comprises forest wide prescriptions (e.g. high conservation value old growth, rainforest, riparian buffer and habitat tree protection) that are designed to protect key fauna habitat across the landscape. These are augmented by the 2nd tier, which are specific prescriptions triggered by records of certain species from pre-logging surveys. Bat management at State Forests is also informed by strategic research that has improved our understanding of habitat requirements and tested aspects of logging impacts and the effectiveness of management prescriptions. This paper argues that the current emphasis on pre-logging surveys has improved our knowledge of the distribution of bats, but that this emphasis and the rigidity with which the conditions are specified limits real conservation outcomes for bats. This is due to a number of factors such as dispersing modest survey effort over large areas, basing decisions about where to survey on untested habitat models and targeting surveys on a small proportion of the total bat fauna. Most importantly, pre-logging surveys yield little data on the effectiveness of prescriptions designed to minimise potential impacts of logging, yet their implementation represents an opportunity cost for considering other options. I suggest an alternative approach that shifts survey effort away from pre-logging surveys to monitoring across tenure. Data are presented to indicate how much sampling effort would be required to adequately describe bat assemblages at a landscape scale. In conjunction with scientific research, monitoring would provide much needed data on the changing status of bats and a strong basis for assessing the effectiveness of management prescriptions. The Threatened Species Licence conditions for logging can be reviewed in 2005 and this provides an opportune time to advance the management of bats, and other fauna, in a scientific and cost-effective way.

Key words: bats, monitoring, survey effort, forest management.

Introduction

Insectivorous bats (Microchiroptera) form a diverse, but inconspicuous group. The cryptic nature of bats means that it is difficult to assess their conservation status and prescribe effective management. Yet there is a clear need for their careful management by forestry organisations because many species are hollow-dependent (e.g. 28 species in NSW) and many are listed as threatened (e.g. 16 in NSW). Multiple use forests need to be managed in an ecologically sustainable way because they complement and connect reserve systems (Lindenmayer and Franklin 2002). Often they hold source populations that link with remnants fragmented by agriculture or other land uses. That such issues are now being considered in forest management illustrates the recent shift towards achieving ecologically sustainable forest management in NSW (Nicholson 1999). Achieving and demonstrating ecological sustainability in resource use is one of the great aims of applied ecology in a world of increasing population size (Lindenmayer and Recher 1998). An essential part of this process is the development of scientifically valid management tools where refinement and testing is an ongoing process (Smyth *et al.* 2000).

In this chapter I briefly describe the emergence of insectivorous bats as a management issue in NSW State Forests and then outline and assess the effectiveness of current management. Flying-foxes and blossom bats (Megachiroptera) are not addressed because of their fundamentally different requirements and habits. In highlighting current deficiencies, such as in survey efficiency, I propose a shift away from the current approach of numerous, rapid pre-logging surveys to more comprehensive landscape-scale surveys that are repeated over time; i.e. monitoring. The primary aim of such monitoring would be to obtain much-needed data on the effectiveness of wildlife prescriptions, which are designed to achieve conservation within a program of timber harvesting. I also illustrate how targeted research will need to identify the reasons for any changes in status and the habitat requirements of poorly known species.

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Past management of bats in state forests

In State Forests of NSW, the management of bats has undergone enormous changes in the last 15 years as their unusual habits have been slowly revealed. The revolution in the study of bats began in the 1980s with improved techniques for the survey of bats using harp traps and ultrasonic detectors (Tidemann and Woodside 1978; Crome and Richards 1988). At the same time miniature radio-transmitters were first used to document the roosting preferences of some bat species for hollows in large, mature *Eucalyptus* trees (Lunney *et al.* 1985, 1988; Taylor and Savva 1988).

Incorporating bats into forest management at State Forests followed in the early 1990s when surveys of bats became standard practice in State Forests that were subject to Environment Impact Assessments (e.g. Richards 1992; Smith *et al.* 1994; Hoye 1995). The process of broad impact assessment was overtaken by Regional Forest Agreements (RFA) in the mid-1990s, which aimed to identify and set aside high conservation value forest from logging. Comprehensive, Regional Assessment (CRA) surveys provided much of the data used in each RFA, with specialists employed to target bats. These surveys have vastly improved the picture of the distribution of bat species (but did not test for impacts), at least in the coastal forests of eastern Australia. Site records were collated and used to create models of species distributions to fill in the gaps between point localities, although the reliability of these models for bats has not been tested.

Despite this progress, distributional records provide little ecological information on the critical resources required by bats. The mobility of bats and the low cost of flight to cover a particular distance make it extremely difficult to reliably define the habitat of most bat species (Fenton 1997). Thus, there remained a primary need for the effective management of bats to be based on a sound understanding of their habitat requirements. In 1995, a program of research was initiated at State Forests to improve the understanding of the habitat requirements of bats, assess the impact of logging and to provide a scientific basis for their management (Law 1996).

Some management implications of recent research

The purpose of this paper is not to summarise recent advances in the research of bats. However, a brief outline of some the management implications stemming from research at State Forests is relevant. Research results have confirmed the importance of mature trees as roosts for many bat species, with large hollows usually required for maternity roosts (Law and Anderson 2000; B. Law unpubl. data). In at least some species, regrowth forest is now known to provide habitat for foraging and breeding, not just for commuting (Law and Anderson 2000). Another important step has been to demonstrate that tracks and riparian zones facilitate use of regrowth, but that the interior of dense regrowth forest is unsuitable for many species of foraging bats (Law and Chidel 2001, 2002). Sensitivity to fragmentation of forest was investigated in an area severely disturbed at the landscape scale by clearing for agriculture (Law *et al.* 1999). In a rural landscape, some (but not all) bat species maintained high activity levels in isolated forest fragments. On an individual species basis, research on the spider-feeding Golden-tipped Bat *Kerivoula papuensis* found recent management prescriptions correctly targeted the protection of core roosting habitat in riparian rainforest, but it also identified new foraging habitat in sclerophyll forest on upper slopes (Law and Chidel 2004). Ultimately, assessing the sensitivity to disturbance, effectiveness of management practices, such as wildlife prescriptions, and habitat requirements of key species are the broad areas where continued research is needed to better understand the processes at work in forests.

Current bat management in State Forests of NSW

Pre-logging surveys for bats and management actions triggered

State Forests of NSW operate under a Threatened Species Licence (TSL – e.g. http://www.racac.nsw.gov.au/rfa/pdf/npws_tsl_une.pdf) issued by the Department of Environment and Conservation (Meek 2004). The TSL specifies the set of regulations to be followed when forests are logged or burnt. Prior to logging a compartment (~ 200 ha), the TSL directs the surveys undertaken for a range of threatened fauna. Surveys are followed by the production of a Harvest Plan, which must incorporate the results of surveys and the relevant licence conditions. Since 1997, the surveys have been undertaken by regionally-based ecologists employed by State Forests. Bats occurring in woodland regions in the west of the state have received less attention and management in these areas differs as a TSL is not issued and pre-logging surveys are not usually undertaken.

In effect, the TSL contains two elements (Kavanagh 2002). The "1st tier" specifies prescriptions that apply throughout the RFA areas. They are applied routinely across the landscape for fauna in general, but they are highly relevant to bats. Perhaps the most important is the protection of riparian zones along streams (15 m either side of creek on 1st order streams, 20 m on 2nd order streams, 30 m on 3rd order streams and 50 m for all 4th order and higher streams – 1st order refers to the smallest streams mapped on a 1:25000 topographic map. Where two 1st orders meet they form a 2nd order stream and where two 2nd orders meet they form a 3rd order stream, etc). Undisturbed vegetation in gullies provides important habitat for roosting (Lunney *et al.* 1988; Law and Anderson 2000; Schulz 2000) and, in the case of larger streams, foraging bats (Law and Chidel 2002; Lloyd 2004). In some areas, 100 m wide corridors are strategically located (Recher *et al.* 1987). Hollow-bearing trees (> 10 per 2 ha) are retained in a scattered pattern *within* the net logging area (the area actually harvested). Recruits (> 10 per 2 ha), which are trees that show potential for hollow development and have a healthy crown, are also retained to provide hollows in the future. Other prescriptions include the exclusion of logging from high conservation value old growth forest, rainforest, rare forest types, wetlands, heath, rocky outcrops and some ridge and headwater habitat within every 500 ha area.

The "2nd tier" specifies prescriptions triggered when particular threatened species are detected during a pre-logging survey or when the species can be predicted from CRA-derived models to occur in a logging compartment. TSL guidelines for surveying bat species are listed in Table 1. A positive record resulting from any of these surveys triggers an associated management action that aims to protect core habitat elements from potential adverse effects caused by logging (Table 1).

Benefits of current management for bats

The net effect of the two tiers of management prescriptions is that a mosaic of informal reserves or buffers are protected from logging, amounting to 57 % of the total State Forest landscape (NSW Dept of Urban Affairs and Planning 1999). This satisfies the fundamental aims of retaining multiple roosts in an area and providing a diversity of forest structures. However, the question remains as to whether the retained habitat is sufficiently large to allow for temporal changes in roost and food requirements.

Pre-logging surveys have had their benefits. Over the last five years more than 1,000 records of threatened bat species have accumulated (Table 2), giving a vastly improved picture of bat distributions. Over the same period, subterranean surveys have recorded bats in 35 % of 137 mines (Table 3). Records of a subset of these threatened bats (i.e. those listed in Table 2) triggered additional protective measures, which specifically target those bat species that have relatively well-defined habitat requirements (Fig 1).

Limitations of current practices

Is site-based survey effort adequate?

Despite progressing the management of bats in State Forests, a large emphasis on pre-logging surveys and species-specific prescriptions has its pitfalls. The first is that, at any given site, survey intensity is relatively modest, considering that species records are required to trigger a management action. For instance, calculations by Law and Chidel (2004) suggest that to be 90 % confident of the presence of *K. papuensis* at a study site in southern NSW, five nights of trapping (with 2 traps) would be required, not two as specified in Table 1. Because trap success for *K. papuensis* is three times greater in northern NSW, the specified trapping effort may be sufficient in this part of

Table 1. Surveys required for bats in State Forests of NSW during the harvest-planning stage for individual compartments (also known as pre-logging surveys) and the management action triggered by recording presence of targeted species. Note that other management actions (1st tier) are also routinely applied across State Forests.

Survey Requirement	Species targeted	Management triggered
During pre-logging compartment traverse, trees with basal hollows are inspected for bat roosts	Tree-hollow roosting species	50 m exclusion zone around hollow tree
All mines and caves surveyed by physical inspection or ultrasonic call recording at entrance (30 mins at dusk)	Subterranean roosting species	Subterranean roost exclusion zones to protect internal microclimate – 100 m for unconfirmed roost, 50 m for confirmed roost, 100 m for significant roost, 10 m for cave, rock over-hang or mine not used by bats
Harp trap survey in modeled habitat for *Kerivoula papuensis* (2 traps per 200 ha of net logging area for a minimum of 2 consecutive nights)	*Kerivoula papuensis*	Exclusion zone of 30 m on 1st and 2nd order streams within 200 m of record
Harp trap/bat detector survey at permanent water-bodies	*Myotis macropus*	Exclusion zone of 30 m either side on permanent streams within 100 m of record

Table 2. The number of individual Threatened bats recorded during targeted (see Table 1) pre-logging surveys in State Forests of NSW. Source: State Forests of NSW Social, Environmental and Economic Report 2001/02.

Target Species	1997/98	1998/99	1999/00	2000/01	2001/02	Total
Falsistrellus tasmaniensis	8	12	11	12	20	63
Kerivoula papuensis	16	39	42	45	70	212
Myotis macropus	12	28	21	16	38	115
Scoteanax rueppellii	16	10	5	8	7	46
Miniopterus australis	17	64	167	25	62	335
Miniopterus schreibersii	8	82	156	44	76	366
Mormopterus norfolkensis	8	0	0	0	1	9
Saccolaimus flaviventris	0	1	0	1	0	2

Table 3: Data collated from pre-logging surveys in State Forests of NSW showing the number of derelict mines surveyed for bats, the % containing bats and the species present. Note that surveys of caves are not listed here. Very few caves (i.e. natural subterranean roosts) have required survey in State Forests (< 10 in the past 5 years).

Region and year	Number of mines	% with bats	Species recorded
Eden			
1999	4	75	*M. schreibersii, R. megaphyllus*
2000	3	0	-
2001	0	-	
2002	0	-	
2003	0	-	
South Coast			
1998	2	0	
1999	4	0	
2000	3	0	
2001	4	0	
2002	3	0	
2003	12	8	*M. schreibersii, R. megaphyllus*
Hunter			
1999	1	100	*M. schreibersii*
2000	0	-	
2001	8	25	*R. megaphyllus*
2002	0	-	
2003	9	22	*R. megaphyllus*
Mid-north coast			
2000	3	33	*R. megaphyllus*
2001	0	-	
2002	3	0	-
North Coast			
1999	2	100	*R. megaphyllus*
2000	22	41	*R. megaphyllus, M. schreibersii, M. australis, Chalinolobus sp.*
2001	1	0	-
2002	8	38	*R. megaphyllus, M. schreibersii, M. australis*
Northern Rivers			
1998	35	31	?
1999	0	-	
2000	0	-	
2001	0	-	
2002	10	0	
2003	0	-	
Total	**137**	**35**	

their range. Low survey effort is also likely to be an issue for the Large-footed Myotis *Myotis macropus* because it is sparsely distributed over streams in the forest landscape and considerable effort, even with all-night sampling, can be required to detect its presence (Anderson *et al.* submitted). Even where these species are detected, the mobility of the bats reduces the usefulness of prescriptions targeting the record locality (Table 1). Another issue for current surveys is that the requirement to search for bat roosts in tree hollows during ground traverses is usually unproductive. Given the highly targeted nature of these surveys, other bat species are only incidentally recorded.

Knowledge of habitat requirements directs survey and management

A good knowledge of habitat requirements not only allows surveys to be appropriately targeted, it also helps direct sensible management decisions. This is the reason why species with relatively distinct habitat requirements (e.g. *K. papuensis*, *M. macropus* and cave-dwelling bats) are targeted by pre-logging surveys (Table 1). For example, bats that use subterranean roosts offer clearly-defined structures (caves/mines) that can be targeted by surveys, and specific management actions can be taken if there is evidence of

Figure 1. Derelict mines are a reasonably common diurnal roost for a number of bat species in State Forests, such as these Eastern Bent Wing Bats *Miniopterus schreibersii.* Mines are surveyed for bats in pre-logging surveys. The presence of bats leads to the establishment of a buffer zone surrounding the mine to protect internal microclimate. Photo: B. Tolhurst.

roosting bats. Buffers are retained around known roosts to maintain the internal microclimate (Table 1). *Kerivoula papuensis* provides another example. It roosts most frequently in the nests of Yellow-throated Scrubwrens *Sericornis citreogularis*, which are birds of the rainforests and gullies (Schulz 2000; Schulz and Eyre 2000; Law and Chidel 2004). Thus surveys for this species target rainforest-lined creeks and the management action, triggered by their presence, is an extension of the area retained along creeks, where the bats commonly roost (Table 1). Because both *K. papuensis* and M. *macropus* frequent creeks, this is where pre-logging bat surveys are typically undertaken. Preferred trap-sites for *K. papuensis* are typically narrow or cluttered flyways near or along small creeks. Larger, faster-flying species rarely fly in such areas (e.g. Greater Broad-nosed Bat *Scoteanax rueppellii* – Lloyd 2004) due to their inability to forage successfully in dense vegetation (Figure 2).

In contrast to the species above, the habitat of most other bat species is poorly known. This presents problems both for targeting surveys and management. It is unclear what specific action should be recommended when a more poorly known and mobile species is recorded, such as the Eastern Falsistrelle *Falsistrellus tasmaniensis* or *S. rueppellii*. This is because these species roost in hollow trees, the characteristics of which are not well understood, and forage over extensive areas (B. Law and M. Chidel unpubl. data). Instead of species-specific prescriptions, the approach taken to meet the needs of these bats is a reliance on the 1st tier of prescriptions, applied across the landscape. Yet a major limitation of pre-logging surveys is that they provide no information on the reliability of these management prescriptions for bats.

The precautionary approach taken by species-specific surveys and management does not work well for bats. The current targeted surveys are ill-suited to sample the broader bat community, including many that are listed as threatened, and for these species there is no specific prescription to trigger.

Figure 2. A harp trap set on a cluttered flyway in riparian rainforest. Such sites are typically used in pre-logging surveys to target the threatened Golden-tipped Bat *Kerivoula papuensis,* but the vegetation in such places is usually too dense for many larger species of bats. Photo: B. Law.

The cost of surveying the wrong habitat

Although survey intensity on a compartment is modest, survey effort across a given region is considerable, primarily because a survey for many selected threatened species is triggered if modeled habitat (from CRA data) is present or there are previous records within a 5 km radius. To emphasize this point, it is estimated that, when collated for all fauna, over 2,000 pre-logging surveys were undertaken in the 2001/02 financial year (SFNSW 2002). These are usually individual surveys that targetted particular species, for instance one of the listed bat species or perhaps a frog, assuming a model predicts its occurrence in the area to be logged (Meek 2004). Although CRA fauna models were developed for predicting regional distributions, the TSL requires their rigid application at the scale of local sites. This sometimes requires field ecologists to survey unlikely areas and squander valuable resources (Meek 2004). Indeed, most of the bat models have not been thoroughly field tested to determine how they perform at a local scale (Pearce *et al.* 2001). Rigid management practices have been strongly criticised because,l although there can be initial success, the original purposes of management can become blurred, research and monitoring is often eliminated and the focus becomes the efficiency of regulatory control (Holling and Meffe 1996). Lindenmayer and Franklin (2002) also comment that it can be a real challenge to change prescriptions once they are found to be deficient.

Kerivoula papuensis is presented as an example as it is less mobile and its habitat is better defined than most other bat species (Schulz 2000; Schulz and Eyre 2000; Law and Chidel 2004). A quantitative evaluation of the CRA model is presented here based on State Forest pre-logging survey data collected post-model derivation (Table 4). Survey data have been collated from the Hunter, Manning and Northern Rivers State Forest regions (A. Fawcett, N. Amber and B. Cann, unpubl. data, 2003). The model is evaluated using recognized procedures (Pearce and Ferrier 2000; Farber and Kadmon 2003) that include estimating sensitivity (the probability of correctly predicting a presence), specificity (the probability of correctly predicting an absence) and the kappa statistic (a measure of pairwise agreement between observations with compensation for agreement by chance alone). The kappa statistic can be considered a measure of the overall reliability of the model. The model did not perform well for its sensitivity (35 %), which is the key criterion when its use is to direct targeted surveys. The model's specificity was reasonable at 75 %. The overall model reliability (kappa statistic) was calculated to be 0.09, which indicates the model performs poorly (kappa <0.21 indicates slight agreement between observations, kappa > 0.6 indicates substantial agreement). Models for bats with more diffuse habitat requirements are likely to perform even more poorly. Similar conclusions have been drawn for birds, with field tests indicating that habitat models for highly mobile species and habitat generalists are not very accurate (Pearce *et al*. 2001). For other groups of fauna, statistical models predict distributions quite accurately (Pearce *et al*. 2001). Interestingly, expert assessment of the *K. papuensis* model rated it as "good", while models for other bat species ranged from excellent (*F. tasmaniensis*) to acceptable (Eastern Bent-wing Bat *Miniopterus schreibersii*) (NSW NPWS 1999). Clearly, if habitat models are to be used, retaining some flexibility is essential, such that alternative models can be trialled (e.g. Schulz and Eyre 2000). Flexibility also needs to extend to prescriptions in general, whereby new data can be incorporated to improve management actions.

Arguments have also been put forward that there is little value in surveying for *M. macropus*, a species that forages over water by trawling for aquatic invertebrates and small fish (Dwyer 1970; Law and Urquhart 2000). The reasoning is as follows. Detection of this species results in an exclusion zone of 30 m either side of permanent streams within 100 m of a record (Table 2). However, all streams already have protection zones retained to reduce sediment transport from logging operations into waterways and recent research found that the Large-footed Myotis does not usually use small streams (< 3rd order – Anderson *et al*. submitted). Thus the expectation for small streams (< 3rd order) is that the species would not be detected and there would be no increase in the stream exclusion zone. For larger streams, the species is expected to be detected on some percentage of sites, but a 50 m exclusion is already in place (Fig 3)! Clearly, collection of field data for our native fauna is a useful endeavour, but wasting resources needs to be avoided.

Table 4. A classification table describing the observed presence and absence of Golden-tipped Bats and their predicted presence or absence at sites. Predictions are based on the CRA-derived fauna habitat model for northern NSW. Golden-tipped bat survey data are collated for Hunter, Manning and Northern Rivers State Forest regions. Only data collected post-model derivation are included.

	Recorded Present	Recorded Absent	Total
Predicted Present	21	61	82
Predicted Absent	39	183	222
Total Sites	60	244	304

Figure 3. This slow-moving 4th order stream in Kerewong State Forest provides foraging habitat for the Large-footed Myotis *Myotis macropus*. Because of its size, protection zones of 50 m either side of the stream are retained, meaning that the 30 m buffer triggered by the pre-logging detection of *M. macropus* is already fully catered for. Photo: B. Law.

Future bat management in State Forests of nsw

Monitoring is often proposed as central to threatened species management and is frequently listed in recovery action plans (Lindenmayer and Franklin 2002; Clarke *et al.* 2003). It is my view that this approach should be extended to fauna in State Forests, so that we can increase our confidence about the usefulness of wildlife prescriptions. A monitoring design based on sound science with a high level of precision must be the goal (e.g. Simberloff 1999; Abbott and Burrows 2004). Environmental monitoring that is no more than data gathering or the accumulation of information has little value (Underwood and Chapman 2002). The re-allocation of considerable investment in pre-logging surveys into monitoring would provide much needed information on how the status of bat populations in the forest is changing over time. Not only do we not know which threatened bats are in decline, we also lack this information on other hollow-dependent species not listed as threatened. Clearly, it is sensible to be forewarned of any potential changes in the status of common species, as well as those currently listed as threatened.

One issue that needs to be stated up-front is that monitoring will also be a costly exercise. Commitment of funds over decadal time-frames, in a climate of institutional change, requires serious contemplation (Watson and Novelly 2004). For a monitoring program to be sustained will require an institution, at the very least, to commit it as "core business". Realistically, monitoring needs to be coordinated inter-departmentally and should span a number of land tenures, including production forests, reserves and perhaps Crown land.

The justification for any shift in management must be improved conservation outcomes, but this must occur within the constraints of cost-effectiveness (Margules and Austin 1991). It would be impossible under current resource allocations to undertake both pre- and post-logging surveys at the regionally intensive scale now practised for pre-logging surveys. Surveying fewer sites, but more intensively, would be a realistic aim for monitoring. A number of options is possible when changing management directions, including an intermediate phase where some pre-logging surveys, or their most useful aspects, are maintained.

Towards monitoring bats

A well-designed monitoring strategy could be used to determine whether bat species are declining, stable or increasing. It may be a surprise for many people to realise that there are virtually no long-term, systematic population studies on Australian bats, although estimates of population sizes of some cave bats are available from the 1960s (Dwyer 1966). Thus it is currently not known the extent to which the status of forest bats has changed. Designing an effective monitoring strategy for bats will be a challenge. Indeed, a recent workshop on monitoring trends in U.S. bat populations had few practical recommendations for monitoring "over-dispersed bats"; i.e. those that roost in tree hollows, foliage or crevices (O'Shea and Bogan 2000). Yet, a monitoring program has been initiated in the United Kingdom (www.bats.org.uk/nbmp/index.htm) and New Zealand (O'Donnell 2002), with the explicit aim of detecting changes in populations, albeit with a focus on subterranean roosting species. These species have an additional ecological attribute of diurnally roosting in large, stable colonies, which means that local populations are concentrated at one or a few locations. For the purposes of monitoring, this presents enormous advantages over other species, be they bats or birds, that are naturally dispersed.

It is not the purpose of this paper to outline the mechanics of a monitoring program. Many considerations would need resolving, especially ensuring that sampling has sufficient power to detect changes (Foster 2001). Whether monitoring sites are permanently located or whether their locations are regularly shifted in a random fashion needs to be debated. Another important consideration involves basic experimental design, whereby monitoring is also undertaken at control sites not disturbed by forest operations. These might be matched sites located in Reserves. Any measure or conclusion about the effectiveness of wildlife prescriptions must stem from comparisons of population trends in production forests with control forests.

Monitoring bats at a landscape scale

The scale over which many vertebrates move complicates the interpretation of trends through time, especially in relation to disturbance events. Given that bats fly and feed to varying extents across the landscape, a landscape scale is needed for monitoring. Sampling of forest birds at large spatial scales has been shown to have more power to detect temporal trends than small spatial extents, especially when combined with multiple visits to sites (Mac Nally 1997).

In the context of forestry, I suggest monitoring should take place at the scale of a compartment (200-400 ha) or group of adjacent compartments. Current management practices, such as the retention of many habitat features (riparian buffers, over-catchment connection corridors, targeted habitat for threatened species), also focus at a large, compartment scale. Compartments are management units where logging is interspersed with habitat retention zones, with compartment boundaries often formed by natural features of the environment such as creeks and ridges. In other words, compartments are heterogeneous environments of varying disturbance histories and vegetation communities. Thus, trends in species abundance before and after a disturbance need to ensure that compartment-scale heterogeneity is sampled. The key issue here is the persistence of species through time in each compartment or similar landscape unit. The use of the term persistence here acknowledges that a short-term decline in abundance may occur after logging, but that recovery would be the goal in the medium term.

What survey effort is required?

Harp traps and ultrasonic detectors are the basic equipment required for surveying bats. Each of these survey techniques has its own limitations. However, there are continual developments in how such equipment should be best deployed and results analysed. Examples include optimising trap and detector placement, calibrating detector sensitivity and improved objectivity in call identification (Helman and Churchill 1986; de Oliveira 1998; O'Farrell *et al.* 1999; Reinhold *et al.* 2001; Johnson *et al.* 2002; Law and Chidel 2002). Standardisation of survey methods is essential for any monitoring program.

A key issue, expanded on here, for adequate bat surveys is the number of sampling units (traps and detectors) to deploy in a study area, especially if the aim is monitoring at a landscape scale. There are few data on what is an appropriate level of survey effort for a site of given size. When weather conditions are favourable, 2-3 trapping nights have been recommended for a "site" (Richards 1992; Mills *et al.* 1996). Indeed, Mills *et al.* (1996) suggested that it may be more effective to increase trap numbers at a site than to trap for additional nights (i.e. to reduce trap avoidance behaviour). For ultrasonic detectors, sampling the entire night will maximize the number of species detected (Law *et al.* 1998; Duffy *et al.* 2000), especially rare species, which by definition are uncommonly recorded. But how many traps and ultrasonic detectors should be used to capture a reliable picture of the bat fauna for a site 200-400 ha in size?

To progress this issue, I have used trapping data to determine the minimum number of traps required for an adequate assessment of bat species richness for one logging compartment. Data have been derived from trapping a logged/unlogged mosaic of dry sclerophyll forest (340 ha) near Eden in southern NSW (Law and Chidel 2001). The study used 16 harp traps split evenly between regenerating and unlogged coupes. Adjacent harp trap sites were separated by a mean distance of 265 m and each trap was set for 2 consecutive nights. A species accumulation curve was developed, taking the number of sampling units (traps set for two consecutive nights) as sampling effort. The sample order was randomized 100 times using EstimateS software (Colwell 1997; Moreno and Halffter 2000). This analysis revealed that 2 traps (sites) will record 67 % of species and that seven traps are required to record > 90 % of species trapped over the entire site (Figure 4). It needs to be noted that all traps were set on flyways (vehicle trails of various width passing through the forest) within logged or unlogged forest. Consequently, these results will not be applicable where flyways are absent for trapping.

A similar analysis of the number of ultrasonic detectors required for an adequate assessment of species richness (presence/absence) was also undertaken. Detectors are more flexible than traps in the kind of location that they can be deployed (Law and Chidel 2002). Here I use detecting data from a logged/ unlogged mosaic of forest (390 ha) in northern NSW, where 23 detectors (Anabat, Titley Electronics) were located either on-tracks (flyways), off-tracks or in narrow riparian zones (Law and Chidel 2002). Detectors remotely recorded calls for the entire night over two consecutive nights. Species accumulation curves (EstimateS software) indicate that one detector (for two consecutive nights), set on a track, records 60 % of species detected from the area and that 5 detector sites are required to record > 90 % of species (Figure 5). Detectors off-tracks and in riparian areas (in this case small, 2nd order streams) were less successful at accumulating species. This lower success rate was primarily due to the high level of clutter off-tracks and intermediate clutter along the small rainforest-lined creeks. Many bat species avoid flying in clutter (Law and Chidel 2002), and clutter also reduces the length of call sequences recorded, thus increasing the difficulty of identifying species.

These calculations are concerned with changes in species richness or presence/absence. Where it is desirable to have a more detailed understanding of how the populations of different species are changing through time, power analysis is required to determine sample size (number of counts), duration (years of monitoring) and frequency of survey. For the Long-tailed Bat *Chalinolobus tuberculatus* in New Zealand, which is surveyed along transects with ultrasonic detectors, a program running for > 10 years with 50-100 transects surveyed once or twice per year has been recommended (O'Donnell and Langton 2003).

Additional targeted surveys and monitoring

In addition to landscape-scale monitoring, it is expected that targeted pre-logging surveys would still be required for subterranean roost sites and possibly some other cases. This is the only feasible method for identifying the presence of significant roosting sites. An example from pre-logging surveys is the recent discovery of Australia's largest known colony of Eastern Horseshoe Bats *Rhinolophus megaphyllus* (>10,000 bats) in a sandstone cave (Law *et al.* 2002). State Forests has now established a program of minimal disturbance monitoring at this roost, using specialist

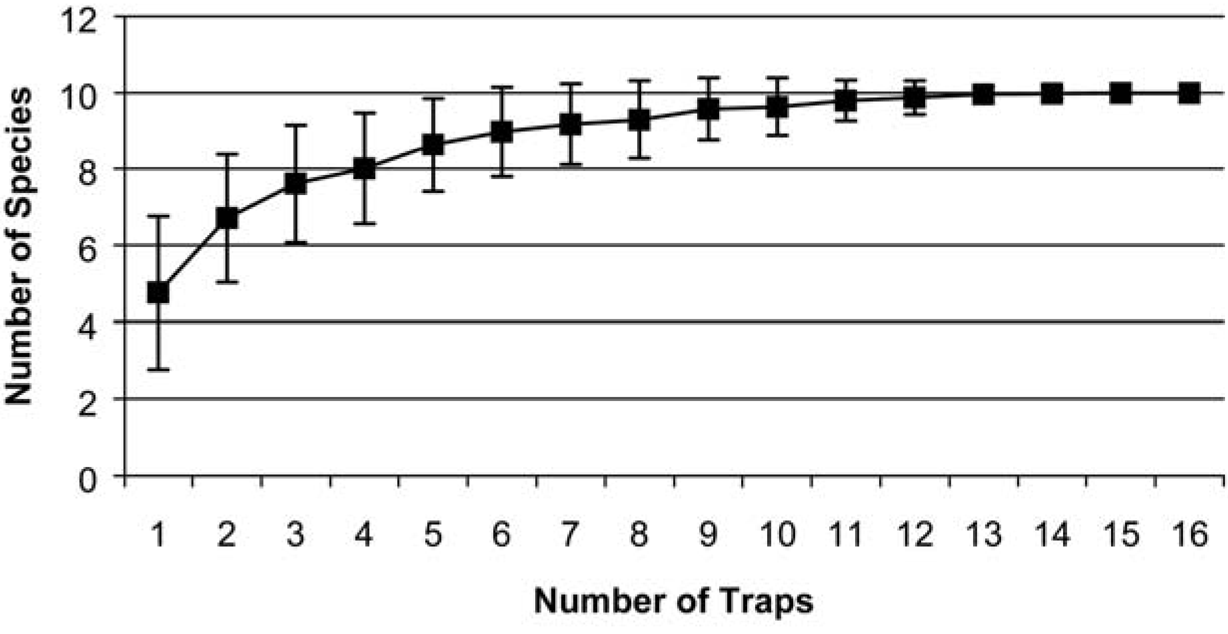

Figure 4. Bat species accumulation curve against the number of bat traps deployed for two nights over a 340 ha area in East Boyd State Forest, Eden, NSW. All traps were set for two consecutive nights and were positioned on flyways in a logged and unlogged forest mosaic. Values are means ± standard errors.

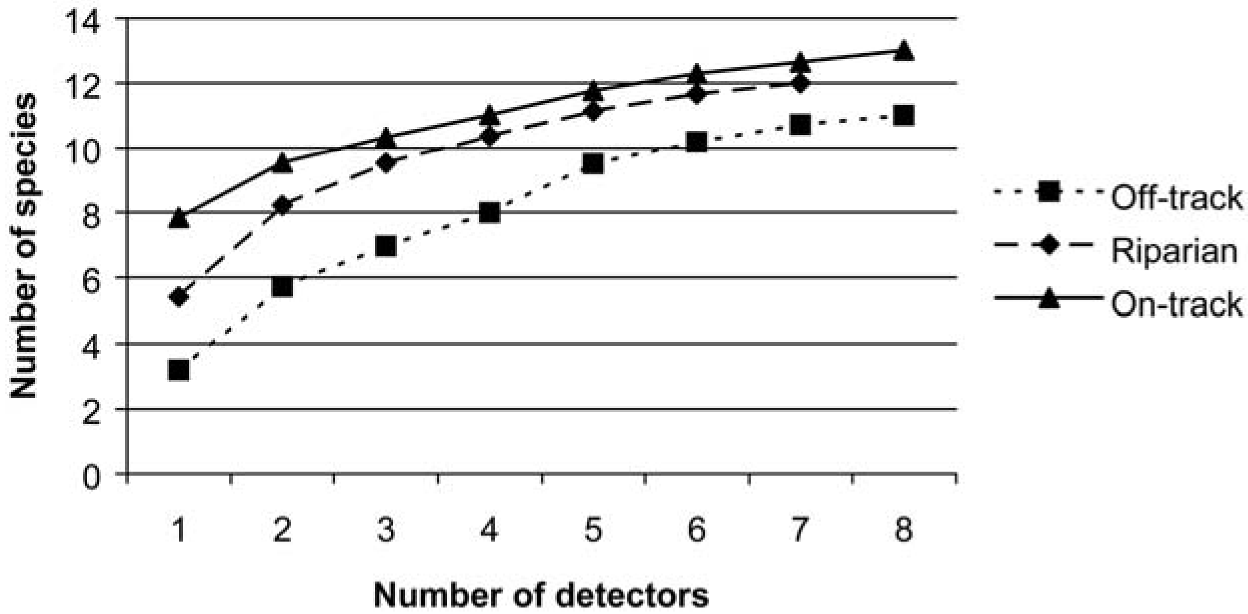

Figure 5. Bat species accumulation curve against the number of bat detectors deployed for two nights over a 390 ha area in Chichester State Forest, Dungog, NSW. Detectors were set for two consecutive nights located either on tracks, on small creeks or off-tracks in a mosaic of logged and unlogged forest. Values are means; standards errors are omitted for clarity.

equipment consisting of infra-red beams and a data-logger. Detection of subterranean roosts could be incorporated into pre-logging compartment traverses for rare plants and other special habitat features (e.g. glider feed trees). The cost of continuing subterranean surveys is not likely to be prohibitive as on average only 24 mines are surveyed across State Forests per year (Table 3).

Management at a landscape scale

Instead of triggers for site-based management prescriptions based on pre-logging surveys, bat-specific prescriptions would need to be automatically applied across the landscape to augment 1st tier prescriptions. The overall aim would be to maintain forest structural diversity as well as retain multiple roosts in an area, habitat that is sufficiently extensive to allow for temporal changes in roost and food requirements. In effect, this mirrors the existing "landscape approach for large forest owls" (Kavanagh 2002; http://www.racac.nsw.gov.au/rfa/pdf/npws_tsl_une.pdf). The aim of the landscape approach is to ensure that a network of habitat is maintained within the area being planned for harvesting, especially in areas where there is known, or likely to be, important habitat for owls. The habitat to be retained under this approach is identified using habitat models. Given the lower reliability of bat habitat models, retention might continue to focus on landscape features such as riparian zones, rainforest, rare forest types, headwater and ridge habitat and habitat trees within net (actual) logging areas. This could be supplemented by special habitat features required by bats, as they become known. Thus a shift in management to monitoring need not exclude useful prescriptions. The proposed landscape monitoring and continued research will provide the needed information on the effectiveness of this management approach.

Other requirements for the successful management of bats

The contribution of research

In addition to the shift towards monitoring bats at a landscape scale, there remains a clear role for research. As Burrows and Christensen (2002) state, monitoring is no substitute for scientific research. Results from monitoring accumulate slowly over time. Yet, most forest bat species are still poorly known and targeted research is needed to reveal much about their habitat requirements and biology, which can be used to test and refine management practices. This is the essence of adaptive management.

Research will be particularly important for rare species that may be difficult or impossible to monitor in sufficient numbers (Taylor and Gerrodette 1993). Targeting known populations with specialised techniques could be the best approach to this problem. For example, population estimates have been derived for the Large-footed Myotis using mark-release-recapture techniques (Jolly-Seber open population model) on bats banded since 1997 at one roost in northern NSW (Figure 6). This technique has the advantage over raw trapping data by estimating the number of unmarked bats in the population as well as those temporarily using other, unknown roosts. In other words, shuttling of bats into or away from the trapped roost is incorporated into this open population estimate. Monitoring at this site found that the local population doubled from 80 bats in 1997 to 160 bats in 2001 (Figure 7). The population was apparently stabilising at this level, despite logging in 1999 in parts of the catchment where the bats forage (B. Law and M. Chidel, unpubl. data). While conclusions about the full impact of logging are not possible at this early stage, the technique appears to be reliable and cost-effective. Relatively small standard

Figure 6. A banded large-footed Myotis *Mytois macropus* targeted by pre-logging surveys because its habitat requirements are well known; i.e. it fishes for aquatic invertebrates and small fish over waterways. Monitoring changes to its population, for example by banding, could provide better conservation outcomes for the species than reliance on pre-logging surveys. Photo: R. Stevens.

errors have been achieved using mark-recaptures, despite the fact that trapping involves just a single night per year.

One limitation of monitoring, unless designed as a properly balanced and replicated experiment (i.e. management and control treatments evenly replicated), is that causal factors behind a change in status will usually remain unresolved. This is where well-designed research fits in to identify the processes at work behind a change or negative trend. There is a strong case for a clear diagnosis of the process(es) causing a species to decline before effective steps can be taken to alleviate the decline (Caughley 1994; Dickman 1996).

Research is also required to tackle more complex questions, such as how populations change with disturbance and not just the presence/absence of species or habitat use as measured by bat detectors. Such studies have already been initiated at State Forests (B. Law unpubl. data) and, in addition to investigating the effects of logging, they include other disturbance regimes, such as hazard reduction burning. Long-term ecological studies are widely recognized to be of fundamental importance to understanding the complexities and processes at work in ecosystems such as forests (Cody and Smallwood 1996; Lindenmayer and Recher 1998).

A need for management plans

Some place the development of management plans for bats as the highest priority conservation action, so that immediate action can be taken. However, in my view our knowledge base for bats is so poor that it would be impossible to determine the success of these actions without the further ecological research and monitoring already outlined. Bats that concentrate in large numbers at key subterranean roosts provide a special case where the formulation of management plans would be useful. It should be recognised that the effective management of bats is an adaptive process that requires simultaneous input from monitoring and research. There is a National Bat Action Plan (Duncan *et al.* 1999), which gives a broad outline of many of the issues, but it has been criticised because of its focus on threatened species, most of which do not occur in NSW (Lunney *et al.* 2003). This plan has little application to the issues in NSW State Forests as outlined in this chapter.

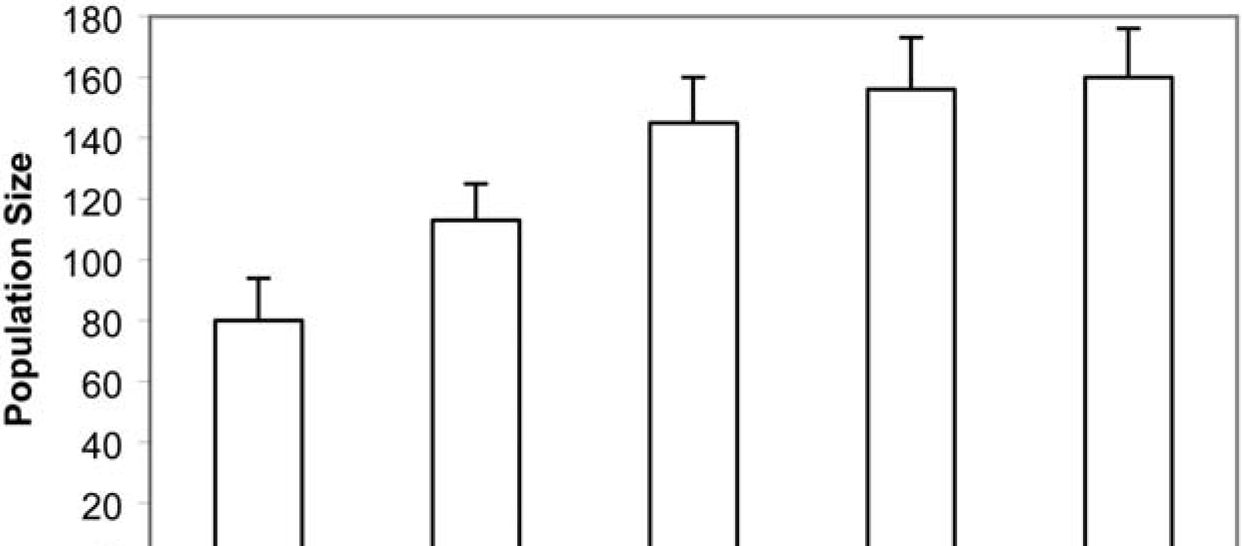

Figure 7. Local population size of the Large-footed Myotis *Myotis macropus* at Kerewong State Forest, northern NSW. The population estimate is based on mark-release-recapture data from bats banded at one roost in April each year (B. Law and M. Chidel unpubl. data).

Conclusion

Within the last 15 years bats have become an important part of forest management at State Forests of NSW and changes over that period have seen substantial improvements in management practices for bats. Progress in bat management could be advanced further by moving towards a well-designed program of landscape scale monitoring of the changing status of bats, including those bats not well catered for in current surveys. This approach is also needed for other fauna. The intuitive public appeal of monitoring information means that results should be reported regularly in State Forests annual reports, such as the Social, Environmental and Economic Report (SFNSW 2002). State Forests are currently initiating research (with an ARC-linkage Grant) into how a rigorous, cost-effective forest monitoring program for key fauna groups could be designed. The key principles proposed here for coastal forests of NSW could be extended to State Forests west of the Great Dividing Range, where the knowledge base for bats is less developed. Indeed, the western region is already moving down the path of establishing plots for long-term monitoring. For the remaining coastal forests, a shift to monitoring will be determined by review of the Licence conditions within the TSL, which could take place during the five-year review in 2005. This review period is a major opportunity to advance the management of bats (and other fauna) in a scientific and cost-effective way.

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