Monitoring protocol to detect change in response to management, fire and invasion of the Monsoon Vine Thickets of the Dampier Peninsula

Prepared By Judy Fisher PhD* and Louise Beames**

Environs Kimberley is working with the Bardi Jawi and Nyul Nyul Rangers, facilitated by the Kimberley Land Council, to protect Dampier Peninsula's monsoon vine thickets (MVT's). The monitoring protocols will help rangers assess the health of MVT patches and inform fire and weed management.

Fisher Research is contracted by Environs Kimberley to develop the science behind the monitoring. The Environs Kimberley West Kimberley Nature Project is funded by Rangelands NRM WA with support from the State NRM.

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CITATIONS

FINAL DRAFT

The Protocols were to remain in final draft stage until the scientific papers are fully prepared and all analyses and methodologies were checked over by the author group to ensure they were consistent with determined optimum methods. References to the Final Draft prepared in 2011 are to be cited as below

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FINAL MONITORING PROTOCOL (THIS DOCUMENT)

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Bardi Jawi and Nyul Nyul rangers monitor, manage and protect their natural, cultural land and sea resources and are supported by Traditional Owners, funded through Working on Country, and facilitated by the Kimberley Land Council.

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Dampier Peninsula's Monsoon Vine Thickets

Introduction

Monsoon vine thicket (MVT) on the coastal sand dunes of the Dampier Peninsula, Kimberley region, Western Australia, are a culturally significant Threatened Ecological Community (TEC), listed as Endangered under the Commonwealth (EPBC Act, 1999) and Vulnerable (State of Western Australia). The Endangered listing recognises that the ecosystem faces a very high risk of extinction in the near future.

The MVT patches of the Dampier Peninsula span the Traditional country of Yawuru, Goolarabooloo, Jabirr Jabirr, Djabera Djabera, Nyul Nyul, Nimanburru and Bardi Jawi people. To these Indigenous groups of the Dampier Peninsula, MVT patches are the primary source of many bush foods, medicines, tools, culturally important Biidin or Jila (underground freshwater), ceremonial areas and law grounds.

Unique to the Dampier Peninsula, this dry rainforest is naturally fragmented and restricted. The 70 (79) MVT patches cover less than 2685ha; occur over less than one tenth of 1% of the Peninsula, yet contain almost a quarter of all the regions plant species. These fragmented patches rely on a functional mobile fruigivore network, and a healthy corridor of complementary ecosystems to retain their genetic and ecological connection.

The loss or dysfunction of the MVT patch ecosystem on the Dampier Peninsula is likely to have profound cultural, as well as ecological impacts.

Bardi Jawi and Nyul Nyul Indigenous ranger groups have worked with Environs Kimberley, Fisher Research and partners to develop monitoring protocols to inform management and determine the changes to fire regimes and the impact of fire and invasive species on Dampier Peninsula's MVT patches.

Dampier Peninsula monsoon vine thickets are uniquely found within and behind the swales of coastal dune systems. The thick green canopy clearly defines them from the surrounding pindan woodland.

Monitoring protocol to detect change in response to management, fire and invasion of the Monsoon Vine Thickets of the Dampier Peninsula

Background

The Broome Botanical Society (Black, Willing et al. 2010) conducted an extensive flora study of the Dampier Peninsula's Monsoon Vine Thickets (MVT) in 2000-2002. The report described the distribution, extent and condition of 62 of the coastal MVT patches of the Dampier Peninsula, recorded perennial flora, described patterns of composition and impacts of threatening processes. This report, a further search of the literature and discussions/workshops with Indigenous Ranger Groups (Bardi Jawi, and Bardi Jawi Oorany Rangers, Nyul Nyul Rangers), Traditional Owners, Broome Botanical Society members, Society for Kimberley Indigenous Plants and Animals, Environs Kimberley, and others with knowledge of MVT's, have provided extensive material to identify suitable protocols to detect change

Testing of the identified measurement techniques was first undertaken with Bardi Jawi Rangers, SKIPA and Broome Botanical Society in December 2010 and then again with Bardi Jawi and Nyul Nyul Ranger group in May 2011. The protocols were then refined for the late dry season monitoring in November 2011. Following some secondary refinement, the final protocol is now culturally appropriate, user friendly and optimal for measuring the relative health of MVT patches on the Dampier Peninsula, particularly their relationship to fire history, fire management, biodiversity and vegetation structural change and invasive species. Working with Indigenous Ranger Groups, who are supported and advised by Traditional Owners, has enabled the development of appropriate monitoring protocols that are locally meaningful (Ens, Towler et al. 2012), incorporate cultural knowledge and local observation and better support co-management with Traditional Owners (Moller, Berkes et al. 2004).

Bardi Jawi Rangers work with Environs Kimberley and Fisher Research to adapt and implement the monitoring protocol on the edge of a monsoon vine thicket on Bardi Jawi country.

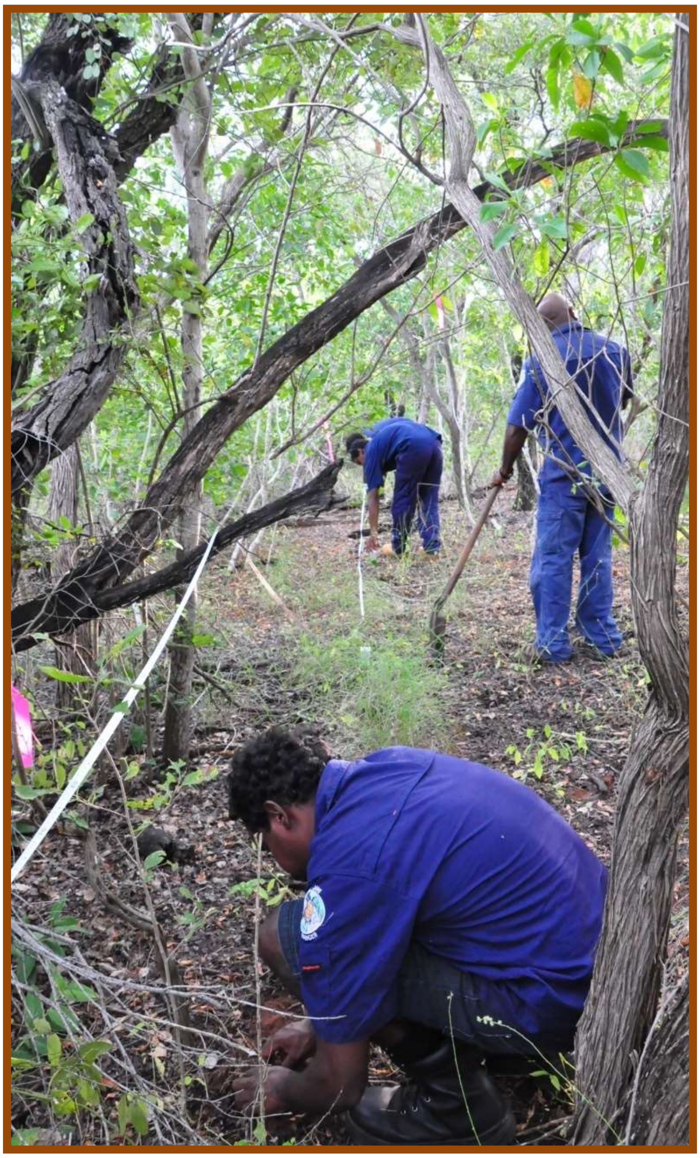
Measurement of ecological components of natural ecosystems provides the opportunity to quantify the state of the ecosystem before and after management and so detect change which may have occurred across time, while measuring progress towards meeting management objectives (Oakley, Thomas et al. 2003; Field, O'Connor et al. 2007). The development of, and implementation of, monitoring protocols provides the opportunity to report on outcomes of management actions and provide a framework to track change, detect the reason for change and then assess the appropriateness of management actions.

Monitoring protocols for 3 keystone indicators, **Structural Vegetation**, **Remnant Tree Understorey Succession** and **Ant Fauna** have been developed. Imbedded within all three protocols are additional protocols to measure litter depth and bare ground. These indicators have been chosen, following a review of the literature and input from experts, as the most appropriate initial measurements which will:

1. **Detect change** and so provide a measurement of change across time in the MVT patches (Russell-Smith and Edwards 2006; Yates, Elith et al. 2010; Harding and Williams 2010)

2. **Inform management practices**, through the identification of the impact of disturbance, in particular fire and invasion, on the MVT, and

3. **Measure the effect of management actions** that have been informed by the results of this study.



Bardi Jawi Rangers implementing the ant monitoring protocol within monsoon vine thicket on Bardi Jawi country

Australian rainforest - Fire and Disturbance

Australia's monsoon tropical rainforests, including MVT, are generally restricted to areas naturally protected from fire. During the early dry season higher moisture levels in fuels, eg. litter and grasses, provide protection from savanna fires, however as the dry season progresses this moisture protection breaks down and leaves these areas more vulnerable to fire.

Indigenous Australians, including Bardi Jawi people of the Dampier Peninsula, are known traditionally to have kept fire away from the MVT patches to protect important fruit, water, bush tucker, medicine, materials for tools and cultural resources. The decline in Indigenous patch-scale land management, that was mosaic in geography and seasonality and guided by cultural and hunting practices, has resulted in destructive contemporary fire regimes and large scale degradation of ecosystems and biodiversity loss. In northern Australia, fires are now larger, hotter and more frequent and are causing significant and widespread damage to the typically small monsoon rainforest patches (Russell-Smith and Stanton, 2002; Flannery, 2012). Compounding this is the impact of other widespread human-induced activities; clearing, grazing by stock, feral animals and weed invasion. In particular; introduced grasses with unusually high biomass and fuel intensity are further promoting frequent fires (Woinarski 2010).

Rainforest trees, which are able to regenerate from a single fire, are generally not able to survive recurrent fires (Bowman 2000), and MVT patches contract and retreat rapidly under these conditions (Russell-Smith and Dunlop 1987; McKenzie 1991; Bowman 1993; Bowman 2000). Expansion, re-emergence and colonisation of monsoon rainforest, into neighbouring savannah communities, can occur where fire is naturally or actively reduced and excluded (Bowman 2000; Beard, Clayton-Greene et al. 1984; Russell-Smith, Stanton et al. 2004; Woinarski, Risler et al. 2004; Andersen, Cook et al. 2005) The re-emergence is often facilitated by the interaction between large in-tact and unburnt savanna trees and mobile frugivores (Fensham and Butler 2003; Environs Kimberley and Bardi Jawi Rangers, 2012). Important components of recruitment are the shading out of grasses by the tree canopy (Williams, et. al. 2011) and the increase in litter coverage and depth from enhanced vegetation structure.

Monsoon vine thicket vegetation is particularly vulnerable to fire disturbance.

Fire is the controlling factor for the distribution and size of MVT (Clayton-Greene and Beard 1985). MVT edges are particularly vulnerable to frequent fire leading to shrinking of MVT communities and expansion of surrounding communities (Bowman and Panton 1993) such as woodland. In order to manage and monitor future events and implement, effective conservation management of fire-sensitive MVT patches, an understanding of past fire events and vegetation structure within and at the edge of patches, and surrounding complementary ecosystems is required (Goudie and Sands 1989; Bowman and Panton 1993; Panton 1993; Russell-Smith, Lucas et al. 1993).

Loss and degradation of the small MVT patches through fire and other disturbance increases the distances between the patches and can compromise the ecological processes that are operating throughout all the remaining patches (the entire ecological community). Dampier Peninsula MVT, like Arnhemland rainforest, occur as small patches with pollinators and frugivores maintaining genetic links and ecological connection and are particularly vulnerable to fire intrusion at the edge of patches (Price, Woinarski et al. 1999; Palmer, Price et al. 2000; Shapcott 2000; Russell-Smith and Stanton 2002). A study of rainforest in the Northern Territory concluded that effective conservation of rainforest patches required active fire and feral management control, however to maintain the long-term genetic viability of the small scattered patches and populations, a landscape scale approach to their conservation management is required (Russell-Smith and Bowman 1992).

Events which occur at the edge of MVT patches are known to be dominant drivers of the dynamics within individual patches as they have the potential to affect the forest micro climate, tree mortality, carbon storage, faunal persistence and alter patterns of tree recruitment. Rainforest are highly sensitive to external fluctuations at their edges, with dry, restricted rainforest such as MVT particularly vulnerable to tipping points, where small environmental changes at the ecotones can have much greater consequences for the ecosystem (Laurance, Camargo et al. 2011; Laurance, Dell et al. 2011). Fire and weed disturbance at the edges of the MVT patches likely to leads to changes in the floristic composition, impacting on tree mortality and recruitment resulting in a rapid species turnover; declines in large-seeded, slow-growing, and old growth plants and an increase in a smaller disturbance–adapted and abiotically dispersed species such as grasses and weeds.

There is the potential that subcanopy species which rely on animal seed-dispersers and have obligate out-breeding to be the most strongly disadvantaged. As the tree community composition changes, wide-ranging impacts on the MVT vegetation structure, canopy-gap dynamics and plant and animal interactions will occur (Laurance, Nascimento et al. 2006).

Identifying useful measurements - Canopy cover and leaf litter

The understorey of MVT patches are generally damp and shady, have a lack of grass cover, a thin layer of leaf litter and scattered fruiting medium shrubs. Soils are deep dune sands, white except for a superficial dark grey organic layer, and covered by leaf litter up to 6 cm in depth. (Black, 2005). Absence of dense grasses within undisturbed Kimberley MVT patches usually affords them some protection from fire (Kendrick and Rolfe, 1991).

The understorey of monsoon vine thicket is typically free of grass, has a thick layer of organic litter. The large trees and often closed canopy creates for a shady, moist environment that promotes germination of other MVT species including vines, shrubs and trees.

The dense canopy of MVT is in striking contrast to the surrounding vegetation, creating a refuge that boasts a protective, shady and humid microclimate for many plant and animal species. (Black 2010). Black and others (2010) found that the canopy height of Dampier Peninsula's MVT was commonly around 8m but could be as low as 3m on exposed dunes. They did not investigate canopy cover, though described the ecosystem type as ranging from a mid high (6-12m) to low (3-6m) closed forest. Opening up of the normally closed canopies through fire, feral and weed activity allows further weed invasion and disturbance and further facilitates the entry of fire into patches.

Together, canopy cover and leaf litter are important determinants of quality and integrity. The shading and resource use of a healthy canopy prevent the incursion of annual and exotic grasses, while the leaf litter provides a moist, rich organic environment that favours the germination of vine thicket shrubs and trees.

Organic leaf litter is a reflection of fire frequency and timing and can provide information on the MVT's response to fire events (Bowman and Wilson 1988). The quality of the patch should be determined by its vegetative structure in relation to floristic diversity, tree size, number of large old trees, particularly fruit bearing trees, canopy cover, canopy health and the level of organic litter present (Beames, 2010)

Monitoring leaf litter and canopy cover provides information to determine relationships between disturbance events while providing measures of change over time.

Animal Species Interactions - Identifying useful measurements

From the literature, six broad groups were identified as having an important role in the ecology of MVT and could provide a useful measurement and bio-indicator for health and management; birds, bats, ants, land snails, spiders and herpetofauna (reptiles and amphibians).

Birds:

It has been found that birds in Northern Territory rainforests are able to track the availability of fruit resources among rainforest and during their travels they disperse the seed of visited plants from patch to patch. Lone MVT trees or small patches outside larger MVT's may play a role as a stopping off point for birds, influencing their movement patterns, and the dispersal and reproduction of MVT species. In order to conserve frugivorous birds and the plants whose seed they disperse, it is essential to maintain the networks required for such species (Price 2004). It has been found that frugivorous birds of Monsoonal rainforest require many patches of rainforest to maintain their populations and that there is a critical degree of connectedness required between patches in order to maintain bird species (Price, Woinarski et al. 1999). As fruit availability fluctuates widely at different locations, across the seasons, frugivorous birds must move over a large area in search of food making them instrumental in carrying seeds from one MVT patch to another and also in the establishment of new thicket species, often under isolated Eucalypts trees outside the monsoon thicket boundaries (Johnstone and Smith 1981). In collating Traditional Knowledge about MVT plants within Bardi Jawi country, the Bardi Jawi Oorany Rangers (2011) identified that fruiting times of trees vary from the eastern coastline patches to those on the western coastline, with the west ripening earlier than the east. Similarly, many species will fruit earlier in more southern patches, than those in the north.

Birds are an important part of monsoon vine thicket ecology; feasting on fruits and spreading the seeds from patch to patch. *Goodadood*, the Rose-crowned fruit pigeon (left) is a common frugivore in northern Dampier Peninsula MVT's while Channel-billed Cuckoo's (right) migrate each year from New Guinea and Indonesia and feed on the MVT fruits.

This variability in fruiting time allows and requires Dampier Peninsula's MVT patches to function, as described for patches in the Northern Territory (Price, 2004; Bach and Price, 2005), as a network ecosystem, relying on the movement of frugivorous (fruit-eating) birds, bats and mammals and ensuring sufficient species migration and gene flow to maintain the plant and animal communities in their fragmented state.

A survey of birds of the Kimberley rainforests between 1987 and 1989 found the Dampier Peninsula MVT patches had a distinct and different avifauna compared to all other rainforest patches within the Kimberley, identifying the significance of the MVT patches to provide habitat for a different suite of bird species to other Kimberley rainforests (Johnstone and Burbidge 1991).

Bats

Bats are ecologically significant mammals with a significant role to play in tropical ecosystems, having high functional and taxonomic diversity (Jones, Jacobs et al. 2009). Bat populations are particularly sensitive to environmental disturbance in particular habitat loss and fragmentation due to their important role in maintaining the ecological integrity and links between individual MVT patches (Meyer, Aguiar et al. 2010). In tropical ecosystems key ecosystem services, such as pollination, seed dispersal, and control of arthropod populations are provided by bat communities (Kalka, Smith et al. 2008; Kelm, Wiesner et al. 2008), with bats' responses to habitat disturbance being associated with those of other taxa, demonstrating their importance in tropical ecosystems and their vulnerability to disturbance (Meyer, Aguiar et al. 2010). Bat species exhibit seasonal shifts, with some moving over short distances (Stoner 2001; Stoner 2005) while others migrate over longer distances (Fleming and Eby 2003). Despite their crucial ecological importance in tropical ecosystems knowledge, the limited knowledge about bat seasonal habitat shifts is only available from a few tropical locations (Meyer, Aguiar et al. 2010). Bat species composition in most tropical ecosystems are dynamic rather than static which is thought to be due to cyclic environmental fluctuations such as changes in humidity, rainfall and the effects of unpredictable fire (McKenzie and Rolfe 1986). The Kimberley bat fauna includes aerial insectivores, foliage gleaners, predatory species, nectar feeders and species which eat fruit and blossoms. A study of bats which included mangroves of the Dampier Peninsula found 28 species at the 4 sites studied, with only one site having an overlap in observed guilds, for all other sites and species no overlap in observed guilds were found (McKenzie and Rolfe 1986).

Bats are also key seed dispersers, though the ecological interactions between bats and monsoon vine thickets on the Dampier Peninsula remain largely unknown.

Little is known about the bat fauna of Dampier Peninsula MVT. During a survey of the mammalian fauna of the Kimberley Rainforests (1987-1989) only one MVT patch within the Dampier Peninsula was partially surveyed with full mammalian surveys being confined to the North Kimberley Rainforests (Friend, Morris et al. 1991). The lack of knowledge in this area makes it very difficult to make informed decisions when identifying and assessing the ecological value of each MVT patch and the resultant impact on neighbouring MVT's and surrounding communities following disturbance.

Ants

Ants influence soils, vegetation and other faunal groups through their interactions with key ecological processes such as nutrient cycling, energy turnover, seed dispersal and seed predation (Andersen and Majer 1991). The ant fauna of the Dampier Peninsula is unknown, as the ant survey conducted as part of the Kimberley Rainforest Survey (McKenzie et al. 1991) did not include the Dampier Peninsula. The surveys identified that the Kimberley rainforest ant communities differed markedly from those in the surrounding habitats, with a high species turnover between patches (Andersen and Majer 1991). Likewise the insect assembly of Dampier Peninsula is unknown, with the Kimberley Rainforest Surveys also excluding rainforest patches in the Dampier Peninsula. A possible relationship may occur between insect populations and disturbance as the fewest insect species were recorded from the smallest, driest rainforest patches (Naumann,Weir et al. 1991).

Ant community responses to disturbance has been well studied with the communities able to be used as valuable bio-indicators of disturbance impacts and management (Alan N 1992; Andersen 1995; Andersen, Braithwaite et al. 1998; King, Andersen et al. 1998; Agosti, Majer et al. 2000; Agosti, Majer et al. 2000; Underwood and Fisher 2006). Ant community composition, in the Australian context, has been found to be particularly sensitive to changes in land management and can provide very different information to that provided by the measurement of vegetation alone (Andersen and Majer 2004). Disturbance factors which have the most direct impact on ant community composition are changes in habitat structure, microclimate and food availability (Andersen 1995). Changes in habitat structure through disturbance particularly reduces the abundance of “cryptic species” which forage mainly within soil and litter, and the large foraging species which actively hunt prey, the “specialist predators”. Changes in vegetation structure, such as becoming more open at the edges, influences the ant community composition, as vegetation plays a key role in regulating microclimatic conditions including thermal tolerance, food availability, nesting sites and competitive interactions between species (Vasconcelos, Leite et al. 2008; Wittman, Sanders et al. 2013).

Forest structure and leaf litter volume in Amazonian rainforest have been found to influence ant community composition. Fire, which reduces structure and leaf litter, can affect ant species composition for up to 10 years post fire (Silveira, Barlow et al. 2013). Fire alters shade regimes, surface temperatures, resource availability, vegetation structure and species richness with many studies finding links to these ecosystem components and ant community composition (Greenslade and Greenslade 1977; King, Andersen et al. 1998; Ratchford, Wittman et al. 2005; Vasconcelos, Leite et al. 2008; Wittman, Sanders et al. 2013). Fire also creates more open and fragmented habitats increases the susceptibility of the ecosystem to invasion by plant and ant species (Holway, Lach et al. 2002).

An understanding of ant community composition provides a good bio-indicator to determine, identify and assess how habitat type and fire may influence the interactions between the MVT patches, their edges and the surrounding woodland, and will be useful in assessing and guiding management.

Land Snails

The Kimberley rainforest snail community was found to be made up of camaenid and non-camaenid species (Solem and McKenzie, 1991). In general the non-camaenids have extensive ranges; however most of the Kimberley camaenids have very short ranges, with a median distance of 20 km. The results indicated that geographic gaps between sampled rainforest patches are large enough to indicate that many additional species would be found with further sampling in these patches. The number of species found within a single patch was found to be determined by a complex interaction of factors including the "quality" of the patch which refers to the extent of damage to the patch which could be caused by clearing, fire or cattle. In fact an abundance of land snails occurred in most rainfall patches except those damaged by stock or fire (Solem 1991). The geographic pattern of the species composition of non-camaenids was related to rainfall gradients, while the patterns for camaenids was related to distance separating patches. The camaenid pattern demonstrated multiple centres of endemism, attributed to their low dispersal capability, with most of these genera being endemic to the Kimberley region. Similar patterns of distribution of the non-camaenids occur to that of more mobile organisms such as birds and perennial plants. On the other hand a high proportion of camaenoid species occurred in only a single rainforest patch which is unique (Solem and McKenzie 1991).

As only 3 of Dampier Peninsula MVT patches were sampled (Solem and McKenzie, 1991), new surveys of the land snails within the un-sampled thickets may reveal new knowledge and information not only about their presence and absence but also about the ecological relationships which exist within and between individual MVT patches. A fauna survey conducted in the MVT at James Price Point in 2009 recorded two species of land snail which both belong to the Camaenidea family. Several spirobolid millipedes similar to the genus *Austrostrophus* were collected from this MVT patch and appear to represent an undescribed taxon. This survey also found that the faunal assemblages of the MVT patches are distinct from neighbouring plant communities (Biota Environmental Sciences Pty Ltd 2010).

Spiders

Spiders were surveyed as part of the Kimberley Rainforest Surveys in 1988. Each individual MVT patch was found to have biogeographic significance. 38% of the spider species found, only occurred at one patch, and all except one MVT patch had at least one unique species (Main 1991). It was found that spiders, particularly litter dwelling spiders are vulnerable to disturbance by fire and grass invasion at the edges of the patch. None of the MVT patches within the Dampier Peninsula were sampled for this study so based on the results of the other Kimberley MVT patches studied, they may well contain unique and possibly unknown species.

Limited knowledge exists on the *Arachnida* of the Kimberley, and none within the Dampier Peninsula MVT patches (Hunt 1991). Future survey work is required to address this problem It is recommended monitoring of spider species and abundance would be a useful condition assessment, and that spider surveys should be conducted before disturbance to any MVT patches.

Reptiles and Amphibians

The Dampierland Limbless Slider (*Lerista apoda*), is only found on the Dampier Peninsula near and within MVT's.

Reptiles and Amphibians were also surveyed during the 1988 Kimberley Rainforest Surveys (Kendrick and Rolfe 1991) with only one MVT patch on the Dampier Peninsula subject to a less intensive survey. Of the 62 species of reptiles and amphibians recorded from Kimberley rainforest patches, one frog and 11 reptiles were endemic, but none of these were entirely restricted to rainforest habitat.

Notably, of all the 48 Kimberley-wide MVT patches surveyed, where observations of species were confined to specific MVT patches, at most, this was one or two species, excepting Dampier Peninsula MVT patch which, though not sampled intensively, contained 3 species not observed elsewhere in the survey.

Though not observed in the 1988 survey; the six of the seven records of the endemic species *Simoselaps minimus* (Dampierland burrowing snake) are within MVT patches and adjoining dune swales suggesting a strong association of this species with the ecosystem. Also endemic to the Dampier Peninsula, *Lerista apoda* also occurs in MVT and possibly in the sandy junction between the dunes and adjacent pindan.

The limited survey of the region illustrates how little is known about the herpetofauna and also about its relationships to MVT. The significance of MVT patches to local herpetofaunas may be greater than their small geographic range indicates (Kendrick and Rolfe 1991). Fire is seen to be a threat to the integrity of MVT patches and their fauna, with patches potentially providing local refugia for herpetofauna recolonization from adjacent burnt areas (Kendrick and Rolfe 1991).

Limited Knowledge

Limited, fragmented and no knowledge exists on bats, mammals, ants, insects, invertebrates, birds, land snails and other ecosystem components of MVT patches of the Dampier Peninsula. These ecosystem fundamentals play an integral role in maintaining the integrity of the unique MVT patches, with the relationships within and between each patch highly significant to the maintenance of ecological integrity within and across all patches. The interdependence of individual patches suggests that disturbance to any one thicket will have a knock-on effect to all other thickets. For example bats respond to a wide range of environmental stressors and disturbances such as habitat loss, fire and fragmentation, and bat responses to habitat disturbance have often been found to be associated with the responses of other taxa within the ecosystem and their interrelationships with rainforest patches (Jones, Jacobs et al. 2009; Bass, Finer et al. 2010; Meyer, Aguiar et al. 2010). The Indigenous relationship with the Dampier Peninsula MVT ecological system is highly culturally significant and interrelated. If any part of the network of MVT is lost or changed the ecosystem itself will alter and is at risk of extinction, as is the traditional practices associated with the MVT ecosystem.

Development of Monitoring Protocol - Sites

Sites chosen for the development of the MVT Protocol were based on the sites for which Bardi Jawi and Nyul Nyul Rangers have developed (with endorsement of Traditional Owners) and are implementing management plans in collaboration with the Environs Kimberley West Kimberley Nature Project. These ranger groups were trained in data measurement and collection for all protocols and have conducted the measurements with assistance from Environs Kimberley staff, Society for Kimberley Indigenous Plants and Animals, Broome Botanical Society and the author.

Nyul Nyul Rangers and Environs Kimberley staff implement the Vegetation Structure Protocol in Pindan woodland close to one of their MVT management sites on Nyul Nyul country.

Monitoring Question

That the impacts of fire, invasive species and management actions on MVT patches can be detected through the monitoring of the ***Structure of the Vegetation***, ***Individual Tree Understorey Structure*** and ***Ant Community Composition*** and associated invertebrates. Fire, disturbance and invasion impacts are most likely to occur at the edges of the MVT patches. The strongest relationship between these factors and change is likely to be detected by incorporating measurements inside, at the edges and outside the MVT patches.

In order to detect change which may occur following fire, weed invasion and management actions in the MVT patches, a measure of the structural vegetation composition inside, at the edges and outside the Monsoon Vine Thickets offer the opportunity to detect such changes. A vegetation structure protocol will detect change in the MVT patches, and will provide measures of change in community structure, canopy-gap dynamics and litter dynamics.

The incorporation of an ant monitoring protocol into this study will provide insights into plant–animal interactions. Limited knowledge exists on the relationship between MVT trees which occur outside the MVT patch. These trees may have been within the patch boundary in the past or they may be examples of MVT species which provide a stepping stone for mobile species such as birds and bats to traverse and disperse MVT species between individual thickets (Agosti, Majer et al. 2000; Underwood and Fisher 2006; Obrist and Duelli 2010; Malcolm 2011)

These protocols provide a greater understanding of the nature of change within, at the edge and outside the MVT. To date limited to no ecological knowledge exists on the relationships between MVT and fire, edge effects and invasion, so literature for other tropical MVT patches and rainforests has been utilised to determine the most effective measurements to monitor change in Dampier Peninsula MVT patches. As more knowledge becomes available on interrelationships between invasion and fire and the interactions occurring within the MVT patches, at the edges and within the surrounding plant community, measurement protocols may need to be adapted. It is important that the opportunity exists to modify and adjust the measurement parameters as new knowledge becomes available, while ensuring that consistency in measurements continues to exist across time.

In its current state this protocol is a start point in knowledge acquisition within an understudied, ecosystem, and provides the opportunity for expanding and/or altering measured variables as new knowledge becomes available. The protocols developed within this project provide the opportunity to enhance the knowledge base and understandings of the complex interrelationships within Dampier Peninsula MVT patches. Enhanced ecological knowledge gained from these measurements will provide an opportunity to link the western scientific knowledge of MVT with Traditional ecological knowledge and so enhance and incorporate the knowledge of the two understandings to better conserve the ecosystem.

The three MVT protocols identified and developed within this project provide the opportunity to grow and develop this document with additional protocols potentially being added into the future, as more knowledge and capacity becomes available.

How may management be modified as a result of monitoring?

As new data is collected and a greater understanding about MVT patches and their relationships to fire and weed invasion is developed, alternate management actions in relation to fire management practices and weed control may become appropriate. It is only with long term monitoring, that is repeated surveys over time, that it becomes possible to detect and measure change and its influences on MVT patches. As the MVT patches contain culturally significant sites, flora, fauna and associated traditional practices, increased knowledge of the effects of disturbance on the ecosystem will assist in conserving the ecological and cultural values of Dampier Peninsula MVT ecosystem

Manner in which Protocol will be able to detect the desired change

Detecting changes in structural integrity, including the openness of the canopy, alterations in life form composition, changes in cover values and abundance of weed species, changes in litter depth and cover, changes in the composition of the ant fauna will provide measurements for the responses of the MVT patches and their edges to events, whether they are management events or disturbance.

Long term custodians of the monitoring program

The ultimate custodians of the data are the Indigenous Ranger groups, and their supporting native title bodies, who have collected the data in order to enhance the management of MVT patches on their country.

The monitoring protocol may also be adapted and used by other Indigenous Ranger groups or community groups to support and assist the management of MVT on their country.

Environs Kimberley can assist with adapting the monitoring protocol and can continue to assist with storage and interpretation of data where cooperative research agreements are in place.

PROTOCOL #1

Vegetation Structure Protocol

Measurement of plant functional traits and their relationship to vegetation structure and other important features including litter depth, bare ground and fire scars will provide bench marks to establish and determine the impacts of change in the MVT patches and surrounding communities (de Bello, Lavorel et al. 2010; Vandewalle, de Bello et al. 2010). Incorporating sites which cross ecotones, will assist in determining the effect of disturbance on the MVT patches and will provide data to develop evidence based recommendations for future weed control and fire management planning and implementation.

Re-measuring these same sites once management practices have changed, or following a fire, will determine how effective management has been. Measurement of attributes incorporated into this protocol such as litter depth, fire damage identified through fire scars, fire stumps and disturbance and coverage of bare ground will provide additional knowledge about the interactions occurring within the MVT patches, and provide evidence for management recommendations.

Sampling Method

Initial protocol measurements and analyses describe the current status of the vegetation structure within the MVT patches, at the edges of the MVT patches and in the neighbouring pindan woodland community. Ongoing monitoring of these protocols will detect changes through time and provide information on disturbance/fire, and invasion, the effectiveness of the implemented management recommendations, while identifying relationships between MVT structure, fire and weed invasion.

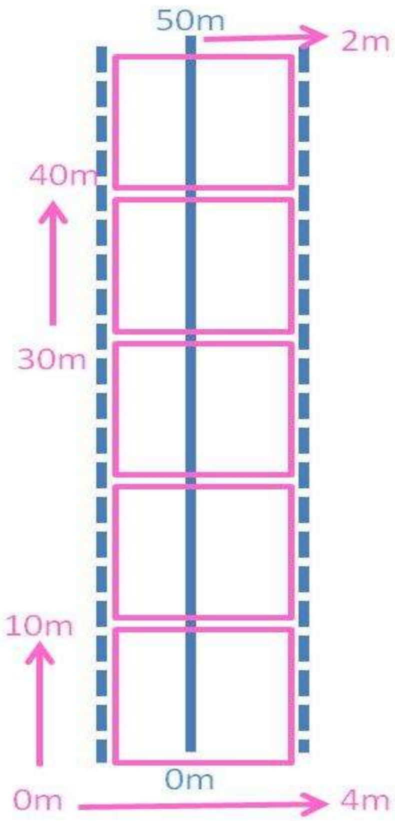
Transects provide the opportunity to measure gradients in the vegetation and are useful to show changes in vegetation structure across plant community types, in this case the MVT and neighbouring pindan woodland community (Bowman and Dunlop 1986). As the MVT patches utilised in the pilot study were narrow and linear this method provided the opportunity to obtain measurements totally within the MVT.

Vegetation pattern is sampled by running a 50 metre transect through:

1. the middle of the MVT
2. the edge of the MVT and
3. the neighbouring plant community

The transect lines monitored for Gnylmarung/Gubin MVT occurrence on Nyul Nyul country are good examples of how to best lay out the transect lines. The green lines are the outer mapped edge of the MVT patch.

Location of transect lines; Outside, on the edge and in the middle of Monsoon Vine Thicket at Gnylmarung/Gubin in Nyul Nyul Country.



Along the 50 metre transect, measurements are conducted to 2 metres on either side of the transect line, resulting in a quadrat size of 10m x 4m, i.e. 5 quadrats along the 50 metre transect. Due to the often narrow, linear nature of Dampier Peninsula's MVT patches it became necessary to take measurements along the entire 50 metre transect rather than at spaced intervals along a longer transect line,

Transects are 50m long and recorded as four continuous quadrats.

Quadrats are 10m x 4m and cover 50 metres, i.e. 5 quadrats 10m x 4m at each site.

Seasonal Timing

Percentage of vegetation cover within the quadrats is the measurement unit utilised and is able to be used to detect change following, for example; fire events and management actions which involve changes in weed species density and cover. The MVT vegetation cover measurements at different structural scales were quite different at the end of the wet season compared to the end of the dry season. Repeat measurements at individual locations will need to occur at a similar time of the year to the initial measurement time. ***Ideally each site should have an initial measurement at both the end of the wet season and the end of the dry season.***

Data Collection Methods

1. Vegetation structural measurements should be conducted **within** the MVT, **at the edge**, and **outside**, in the surrounding vegetation community, over two seasons, i.e. at the end of the dry season and after the wet season.

2. The % cover within the quadrat of all species, both native and introduced will be recorded in vegetation structural categories of tree species height i.e. 10 metres +, 5-10 metres, < 5 metre, shrubs, climbers, grasses/herbs and seedlings.

3. For canopy trees also record, the species, the diameter at breast height and canopy health of each individual tree.

Measurements of diameter at breast height (DBH) of large trees by the Bardi Jawi Ranger Trevor Sampi (above) and measurements of canopy health and cover by the Nyul Nyul Rangers (below)

4. Attributes to be measured are considered to be strong indicators of change in the MVT (Bowman and Wilson 1988) with presence and cover values to be measured for litter depth, bare ground, fire stumps, fire scar and disturbance.

5. Recording sheets have been adapted for each language group (Bardi Jawi and Nyul Nyul) using information collected on the ground and through previous linguistic publications. This is so that plants can be readily identified by the recorder, in commonly used language names, but still be identified by their scientific names.

Field Equipment

GPS, recording sheet, flagging tape, tape measure, metal posts to mark end points of the transect, pencil, rubbers, pen, recording sheets, sheets with example canopy cover measurement categories (Used for the initial monitoring is the standards developed within the Victorian Vegetation Quality Assessment Manual: specifically, Appendix 4: Proportion of expected healthy cover present and Appendix 5: Canopy projective foliage cover guide.

Monitoring Frequency

If a fire event were to occur within the monitoring area, measurements would ideally be taken immediately post fire and then repeated the following year at the same time. To measure the effect of change related to management actions, measurements pre and post management actions are suggested, keeping the season of re-measurement constant.

Sampling Size

For each thicket 3 x 50metre transects are required. 1x from inside the MVT, 1x across the edge of the MVT patch and 1x in the neighbouring pindan woodland.

This level of replication at the site level will ensure that the conclusions drawn to influence management can be applied across the spatial area of the MVT patch, and will also be applicable to other MVT patches and outside the specific area sampled (Harding and Williams 2010). As there are many variables which cannot be accounted for or known at the beginning of the project, the calculation of the number of samples is an educated assessment. It is recommended that the adequacy of the number of samples is reviewed at least every five years (Harding and Williams 2010).

Analysis of Structural measurements

These comprehensive measurements will provide the opportunity to analyse differences between sites within, at the edge of and outside MVT patches, and with this same set of categories across different MVT patches. The analyses described below will determine if trends or differences which occur in measured attributes are statistically significant.

Analyses should be calculated on the following factors:

1. Weed versus native species
2. Cover values of the differing structural categories
3. Resilience and succession through seedling comparisons
4. To examine shifts in ecological categories across the ecotones species should be grouped and analysed according to their life form category/functional traits.

5. Total cover and richness (number of species) and diversity-related indices should be computed for all categories at each site and compared across sites.
6. Analysis of variance (ANOVA) is used to examine differences within the above categories at each site and across sites.
7. Standard deviation, standard error and variance calculations are used to calculate variability within and between sites, attributes and monitoring events.
8. Multivariate analysis is utilised to compare thickets with each other and across the three vegetation locations (middle, edge and outer).

Data Storage

Field data will be entered into an electronic database, including GPS locations, with checks made of the accuracy of electronic records checked against the field records.

Data custodian

The ultimate custodians of the data are the Indigenous Ranger groups, and their supporting native title bodies, who have collected the data in order to enhance the management of MVT patches on their country.

The monitoring protocol may also be adapted and used by other Indigenous Ranger groups or community groups to support and assist the management of MVT on their country.

Environs Kimberley can assist with adapting the monitoring protocol and can continue to assist with storage and interpretation of data where cooperative research agreements are in place.

DATA SHEETS FOR PROTOCOL #1 FOLLOW

1: Bardi Jawi adapted data sheet

Barrdi Jawi MVT vegetation monitoring

Bardi Jawi Vegetation Monitoring

2: Nyul Nyul adapted data sheet

Nyul Nyul MVT Vegetation Monitoring

Nyul Nyul MVT vegetation monitoring

Monsoon Vine Thicket Plant Assessment - Bardi Jawi Country		PAGE 1		PAGE 1

Details

Site name		Date	
	S	Description	
GPS Location	E	Person	
Temp		Humidi	

Transect 0 - 10 m

Site Features

Transect Number	0 - 10 m		
Litter cover		Charcoal Cover %	
Litter depth (cm)		harcoal Lgth x Wdth(m x cr	
Bare Ground Cover %		Disturbance % (What kind)	
No. of Fire stumps		Total Canopy Cover	
Fire stump width x height (cm x cm)			

Canopy Trees

Veg. Structure	No.	Cover %	DBH (cm)	Height 10m+	Height 5-10m	Health %
Albay (Ficus virens)						
Biilal (Corymbia dampieri)						
Joongoon (Mimusops elengii)						
Marroolal (Corymbia bella)						
Marool (Terminalia petiolaris)						
Mangarr (Sersalisia sericea)						
Madoor (Terminalia						

Middle Storey - Shrubs and Trees Less than 5m

Middle Storey Less than 5 metres	% Cover	SEEDLING NO.S	Middle Storey Less than 5 metres	Cover %	SEEDLING NO.S
Alarrgarr (Dodonea platyptera)			Irrgil (Hakea aborescens)		
Albay (Ficus virens)			Jalgir (Canarium australianum)		
Ankoolmarr (Croton habrophyllus)			Jarnba (Exocarpus latifolus)		
Badarrbadarr (Mallotus nesophilus)			Jarridny - Willing (Hakea macrocarpa)		
Bilooloorr (Santalum lanceolatum)			Jiimany (Ehretia saligna)		
Biilal (Corymbia dampieri)			Joom (Bauhinia cunninghammi)		
Birimbiri (Diospyros humilis)			Joongoon (Mimusops elengii)		
Billanggamarr (Gyrocarpus americanus)			Madoor (Terminalia ferdinandiana)		
Gaardga (Corymbia polycarpa)			Mangarr (Sersalisia sericea)		
Gamooloon (Persoonia falcata)			Manowan (Eucalyptus miniata)		
Goolmi (Grewia breviflora)			Marroolal (Corymbia bella)		
Goolnji (Celtis philippensis)			Marool (Terminalia petiolaris)		
Goolyi (Caesalpinia major)			Ngalinginkil (Premna acuminata)		
Goorralgar (Flueggea virosa)			Moolinyj (Glycosmis trifoliata)		
Gorrgorr (Brachychiton diversifolius)			Ranyji (Ficus opposita)		
Iidool (Pandanus spiralis)			Wongai, Soap & other Wattles		

Grasses and Herbs / Vines & Climbers

Grasses/Herbs	Cover %	Climbers	Cover %
Irrooloo - Razor Grass (Chrysopogon pallidus)		Gooloonggooloowarr (Tylophora sp.)	
Spinifex		Ngaming ngaming (Abrus prectorius)	
Oonbi - Annual Cane Grass (Sorghum		Ngoorla (Capparis lasiantha)	
Aristida		Oondal (Tinospora smilacina)	
Lemongrass (Cymbopogon		hairy vine	
Herbs			

Weeds

Buffel Grass			
Butterfly Pea			
Hairy Merremia			
Passion Vine			
Siratro			

Fuel Load

Fuel Load	Length (m) For LESS than 5cm diameter	Length (m) Greater than 5-10cm diameter	Length (m) x diameter (??)cm	
Standing dead wood			x	
Lying down dead wood			x	

Transect 10- 20m

Site Features

Transect Number	10- 20m		
Litter cover		Charcoal Cover %	
Litter depth (cm)		Charcoal Lgth x Wdth(m x cm)	
Bare Ground Cover %		Disturbance % (What kind)	
No. of Fire stumps		Total Canopy Cover	
Fire stump width x height (cm x cm)			

Canopy Trees

Veg. Structure	No.	Cover %	DBH (cm)	Height 10m+	Height 5-10m	Health %
Albay (Ficus virens)						
Biilal (Corymbia dampieri)						
Joongoon (Mimusops elengii)						
Marroolal (Corymbia bella)						
Marool (Terminalia petiolaris)						
Mangarr (Sersalisia sericea)						
Madoor (Terminalia						

Middle Storey - Shrubs and Trees Less than 5m

Middle Storey Less than 5 metres	% Cover	SEEDLING NO.S	Middle Storey Less than 5 metres	Cover %	SEEDLING NO.S
Alarrgarr (Dodonea platyptera)			Irrgil (Hakea aborescens)		
Albay (Ficus virens)			Jalgir (Canarium australianum)		
Ankoolmarr (Croton habrophyllus)			Jarnba (Exocarpus latifolus)		
Badarrbadarr (Mallotus nesophilus)			Jarridny - Willing (Hakea macrocarpa)		
Bilooloorr (Santalum lanceolatum)			Jiimany (Ehretia saligna)		
Biilal (Corymbia dampieri)			Joom (Bauhinia cunninghammi)		
Birimbiri (Diospyros humilis)			Joongoon (Mimusops elengii)		
Billanggamarr (Gyrocarpus americanus)			Madoor (Terminalia ferdinandiana)		
Gaardga (Corymbia polycarpa)			Mangarr (Sersalisia sericea)		
Gamooloon (Persoonia falcata)			Manowan (Eucalyptus miniata)		
Goolmi (Grewia breviflora)			Marroolal (Corymbia bella)		
Goolnji (Celtis philippensis)			Marool (Terminalia petiolaris)		
Goolyi (Caesalpinia major)			Ngalinginkil (Premna acuminata)		
Goorralgar (Flueggea virosa)			Moolinyj (Glycosmis trifoliata)		
Gorrgorr (Brachychiton diversifolius)			Ranyji (Ficus opposita)		
Iidool (Pandanus spiralis)			Wongai, Soap & other Wattles		

Grasses and Herbs / Vines & Climbers

Grasses/Herbs	Cover %	Climbers	Cover %
Irrooloo - Razor Grass (Chrysopogon pallidus)		Gooloonggooloowarr (Tylophora sp.)	
Spinifex		Ngaming ngaming (Abrus prectorius)	
Oonbi - Annual Cane Grass (Sorghum		Ngoorla (Capparis lasiantha)	
Aristida		Oondal (Tinospora smilacina)	
Lemongrass (Cymbopogon		hairy vine	
Herbs			

Weeds

Buffel Grass			
Butterfly Pea			
Hairy Merremia			
Passion Vine			
Siratro			

Fuel Load

Fuel Load	Length (m) For LESS than 5cm diameter	Length (m) Greater than 5-10cm diameter	Length (m) x diameter (??)cm	
Standing dead wood			x	
Lying down dead wood			x	

Monsoon Vine Thicket Plant Assessment - Nyul Nyul Country | PAGE 1 | PAGE 1

DETAILS

Site name		Date	
	S	Description	
GPS Location	E	Person	
Temp		Humidity	

SITE FEATURES

Transect Number	0 - 10 m		
Litter cover		Charcoal Cover %	
Litter depth (cm)		Charcoal Lgth x Wdth (m x cm)	
Bare Ground Cover %		Disturbance % (What kind)	
No. of Fire stumps		Total Canopy Cover	
Fire stump width x height (cm x cm)			

CANOPY TREES

Veg. Structure	No.	Cover %	DBH (cm)	Height 10m+	Height 5-10m	Health %
Albay (Ficus virens)						
Bilawal (Corymbia dampieri)						
Mamajen (Mimusops elengii)						
*Marroolal (Corymbia bella)						
Marool (Terminalia petiolaris)						
Mangarr (Sersalisia sericea)						
Kabiny (Terminalia ferdinandiana)						

* = Commonly used, or Bardi Names where Nyul Nyul Names are unavailiable

MIDDLE STOREY - SHRUBS AND TREES LESS THAN 5M

Middle Storey Less than 5 metres	% Cover	SEEDLING NO.S	Middle Storey Less than 5 metres	Cover %	SEEDLING NO.S
*Alarrgarr (Dodonea platyptera)			*Jalgir (Canarium australianum)		
*Ankoolmarr (Croton habrophyllus)			Nilly Nilly (Exocarpus latifolus)		
*Badarrbadarr (Mallotus nesophilus)			Willing (Hakea macrocarpa)		
Birrmankal (Santalum lanceolatum)			*Jiimany (Ehretia saligna)		
Bilawal (Corymbia dampieri)			Jigal - Joom* (Bauhinia cunninghammi)		
*Birimbiri (Diospyros humilis)			Mamajen (Mimusops elengii)		
*Helicopter tree (Gyrocarpus americanus)			Kabiny (Terminalia ferdinandiana)		
*Bloodwood (Corymbia polycarpa)			Mangarr (Sersalisia sericea)		
Wongatt (Persoonia falcata)			*Manowan (Eucalyptus miniata)		
Goolm (Grewia breviflora)			*Marroolal (Corymbia bella)		
Goonj (Celtis philippensis)			Marool (Terminalia petiolaris)		
*Goolyi (Caesalpinia major)			*Ngalinginkil (Premna acuminata)		
Koowal (Flueggea virosa)			Albay (Ficus virens)		
Kawoorrkawoorr (Brachychiton diversifolius)			Jirrib (Ficus opposita)		
Manbang (Pandanus spiralis)			Wongai, Soap & other Wattles		
*Irrgil (Hakea aborescens)					

GRASSES AND HERBS / VINES & CLIMBERS

Grasses/Herbs	Cover %	Climbers	Cover %
*Irrooloo - Razor Grass (Chrysopogon pallidus)		*Gooloonggooloowar (Tylophora sp.)	
Spinifex		Jinjalgurany (Abrus prectorius)	
*Oonbi - Annual Cane Grass (Sorghum		*Ngoorla (Capparis lasiantha)	
Aristida		*Oondal (Tinospora smilacina)	
Lemongrass (Cymbopogon procerus)			
Herbs			

WEEDS

Weeds		Weeds	
Buffel Grass			
Butterfly Pea			
Hairy Merremia			
Passion Vine			
Siratro			

FUEL LOAD

Fuel Load	Length (m) For LESS than 5cm diameter	Length (m) Greater than 5-10cm diameter	Length (m) x diameter (??)cm	
Standing dead wood			x	
Lying down dead wood			x	

SITE FEATURES

Transect Number	10- 20m		
Litter cover		Charcoal Cover %	
Litter depth (cm)		Charcoal Lgth x Wdth (m x cm)	
Bare Ground Cover %		Disturbance % (What kind)	
No. of Fire stumps		Total Canopy Cover	
Fire stump width x height (cm x cm)			

CANOPY TREES

Veg. Structure	No.	Cover %	DBH (cm)	Height 10m+	Height 5-10m	Health %
Albay (Ficus virens)						
Bilawal (Corymbia dampieri)						
Mamajen (Mimusops elengii)						
*Marroolal (Corymbia bella)						
Marool (Terminalia petiolaris)						
Mangarr (Sersalisia sericea)						
Kabiny (Terminalia ferdinandiana)						

* = Commonly used, or Bardi Names where Nyul Nyul Names are unavailiable

MIDDLE STOREY - SHRUBS AND TREES LESS THAN 5M

Middle Storey Less than 5 metres	% Cover	SEEDLING NO.S	Middle Storey Less than 5 metres	Cover %	SEEDLING NO.S
*Alarrgarr (Dodonea platyptera)			*Jalgir (Canarium australianum)		
*Ankoolmarr (Croton habrophyllus)			Nilly Nilly (Exocarpus latifolus)		
*Badarrbadarr (Mallotus nesophilus)			Willing (Hakea macrocarpa)		
Birrmankal (Santalum			*Jiimany (Ehretia saligna)		
Bilawal (Corymbia dampieri)			Jigal - Joom* (Bauhinia cunninghammi)		
*Birimbiri (Diospyros humilis)			Mamajen (Mimusops elengii)		
*Helicopter tree (Gyrocarpus americanus)			Kabiny (Terminalia ferdinandiana)		
*Bloodwood (Corymbia polycarpa)			Mangarr (Sersalisia sericea)		
Wongatt (Persoonia falcata)			*Manowan (Eucalyptus miniata)		
Goolm (Grewia breviflora)			*Marroolal (Corymbia bella)		
Goonj (Celtis philippensis)			Marool (Terminalia petiolaris)		
*Goolyi (Caesalpinia major)			*Ngalinginkil (Premna acuminata)		
Koowal (Flueggea virosa)			Albay (Ficus virens)		
Kawoorrkawoorr (Brachychiton diversifolius)			Jirrib (Ficus opposita)		
Manbang (Pandanus spiralis)			Wongai, Soap & other Wattles		
*Irrgil (Hakea aborescens)					

GRASSES AND HERBS / VINES & CLIMBERS

Grasses/Herbs	Cover %	Climbers	Cover %
*Irrooloo - Razor Grass (Chrysopogon pallidus)		*Gooloonggooloowar (Tylophora sp.)	
Spinifex		Jinjalgurany (Abrus prectorius)	
*Oonbi - Annual Cane Grass (Sorghum		*Ngoorla (Capparis lasiantha)	
Aristida		*Oondal (Tinospora smilacina)	
Lemongrass (Cymbopogon procerus)			
Herbs			

WEEDS

Weeds		Weeds	
Buffel Grass			
Butterfly Pea			
Hairy Merremia			
Passion Vine			
Siratro			

FUEL LOAD

Fuel Load	Length (m) For LESS than 5cm diameter	Length (m) Greater than 5-10cm diameter	Length (m) x diameter (??)cm	
Standing dead wood			x	
Lying down dead wood			x	

Protocol # 2

Remnant Tree Understorey Succession Protocol

Knowledge of the manner in which individual remnant MVT trees, outside the MVT patches are able to recover a structural understorey will provide new knowledge of the role of individual trees in maintaining connectedness between patches. Plant species recorded will provide valuable data on the utilisation of these trees by birds both for dispersal of seed and as a food source (Johnstone and Smith 1981). These individual trees may provide a stepping stone for mobile species such as birds and bats to traverse and disperse thicket species between individual thickets (Malcolm 2011). *Knowledge of the renewal capacity and plant species presence underneath individual trees has the potential to provide knowledge of the species required for the reconstruction of disturbed edges of the MVT. These re-establishing species are likely adapted to germination and establishment in more disturbed understorey habitats compared to the middle of the MVT patches, providing resilience to future disturbance. An understanding of the dispersal and re-colonisation mechanisms of MVT and non MVT species will provide valuable information on species important to the maintenance and integrity of MVT's eg. bats and birds.*

Bardi Jawi Ranger Philip McCarthy observes Birimbiri (*Diospyros humilis*) seedlings growing on the edge of healthy unburnt woodland and under the healthy canopy of *Marroolal* (*Corymbia bella*) woodland trees.

Sampling Method

Vegetation and attribute measurements are to be conducted inside the drip line of the tree canopy. Vegetation structural measurements will be conducted measuring cover, height and number of individuals for each species. The attributes to be measured include N-S, E-W lengths of the dripline, fire scar, fire stumps, disturbance, litter depth and cover and bare ground cover.

Data Collection Methods

1. Vegetation structural measurements are to be conducted within the drip line of the individual tree over two seasons, i.e. at the end of the dry and after the wet season.

2. The % cover of all species within the drip line, both native and introduced are recorded, measuring the height of individual species, % cover of species and number of individuals of each species.

3. Attributes measured are fire signs, fire scar, fire stumps, litter depth and cover and % cover of bare ground which are considered to be strong indicators of change in MVT patches (Bowman and Wilson 1988).

Field Equipment

GPS, recording sheet, tape measure, pencil, rubbers, pen, recording sheets, sheets with example canopy cover measurement categories.

Monitoring Frequency

Monitoring should be conducted at the end of the wet season and the end of the dry season and should be conducted bi-annually to gain an understanding of succession processes.

Sampling Size

At least three tree measurements should occur at each MVT patch. This level of replication at the site level will ensure that the conclusions drawn to influence management can be applied across the spatial area of the patch, and will also be applicable to other MVT patches and outside the specific area sampled (Harding and Williams 2010). As there are many variables which cannot be accounted for or known at the beginning of the project, the calculation of the number of samples is an educated assessment. It is recommended that the adequacy of the number of samples is reviewed at least every five years (Harding and Williams 2010).

Analysis of Remnant Tree Understorey Succession data

These comprehensive measurements will provide the opportunity to analyse establishment and survival of species underneath outlying tree species. The analyses described below will determine if trends or differences which occur in measured attributes are statistically significant.

Analyses will be calculated on the following factors:

1. Weed versus native species
2. Cover values of individual species and all species
3. Resilience and succession through seedling comparisons
4. Shifts in ecological categories of species will be examined by grouping and analysing species according to their life form category/functional traits.
5. Total cover and richness (number of species) and diversity-related indices will be computed for each tree and comparisons made between individual trees.
6. Analysis of variance (ANOVA) will be used to examine differences within the above categories for each tree and between trees.
7. Standard deviation, standard error and variance calculations will be used to calculate variability within and between trees, attributes and monitoring events

Data Storage

Field data will be entered into an electronic database, including GPS locations, with checks made of the accuracy of electronic records checked against the field records.

Data custodian

The ultimate custodians of the data are the Indigenous Ranger groups, and their supporting native title bodies, who have collected the data in order to enhance the management of MVT patches on their country.

The monitoring protocol may also be adapted and used by other Indigenous Ranger groups or community groups to support and assist the management of MVT on their country.

Environs Kimberley can assist with adapting the monitoring protocol and can continue to assist with storage and interpretation of data where cooperative research agreements are in place.

DATA SHEETS FOR PROTOCOL #2 FOLLOW

Data sheet for Protocol #2

Excel Data Sheet for Protocol #2

DATA SHEET FOR PROTOCOL 2

Date:	Assesser Name:				**Remnant Tree Measurements**	
Closest Thicket Name:						
Waypoint / GPS Location						
Tree number:	Litter depth [mm]:			Dripline		
Species:	Distance to thicket [m]:			N - S Diameter [m]:		
Height [m]:	Fire signs:			E - W Diameter [m]:		
Species	Cover [%]	Number of species	Height [cm]	Comments		

Protocol #3

Ant Fauna

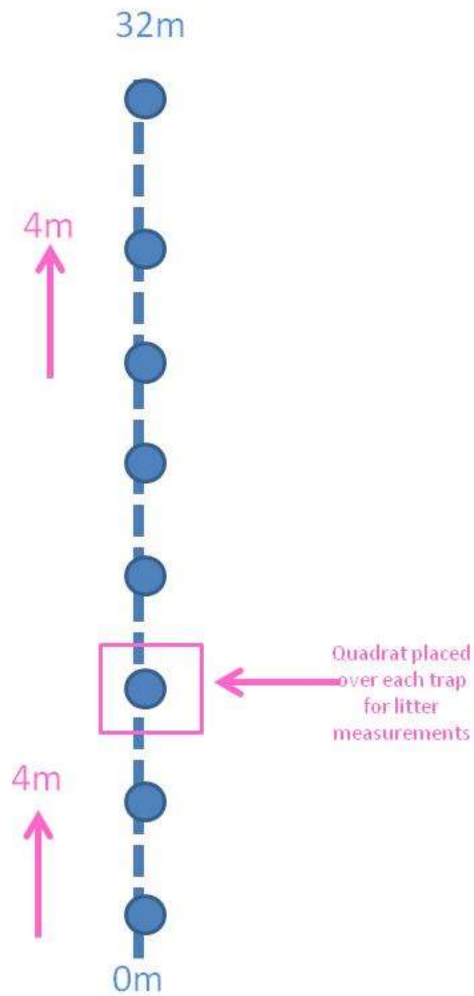
Ant community composition has been found to be a good bio-indicator of ecosystem change (Alan 1992; Andersen 1995; Andersen, Braithwaite et al. 1998; King, Andersen et al. 1998; Agosti, Majer et al. 2000; Agosti, Majer et al. 2000; Underwood and Fisher 2006). A monitoring protocol for assessment of ant community populations within, on the edge and surrounding MVT patches, as a key indicator of change, has the potential to provide scientific knowledge to analyse ecosystem health in conjunction with fire disturbance history. This will provide an understanding of animal plant interactions, so adding value to the work being conducted on vegetation structural change, tree succession and fire history. As ants are not highly mobile they provide a good indicator to enhance the information collected at these sites, incorporating measures of ant-plant interactions.

Aim

To understand the relationship between ant communities in the middle, edge and outside the MVT patches to complement fire, vegetation structural measurements and remnant tree understorey succession studies. The aim of the study is to establish the relationship between fire management, environmental variables and the health of the MVT patches.

Sampling Method

A stratified design of 24 traps should be used, with a line of 8 traps, equal distances apart, in each of the following locations: middle of the MVT patch, inside the edge (10 metres inside the MVT) and outside the MVT patch.



Traps should be filled to at least 1/3 full with undiluted coolant and labelled twice; first with a slip of paper inside the bottle (write in pencil), and secondarily, on lid and base of the bottle in permanent marker. It is best to prepare all the ant traps first before heading out into the site.

Nyul Nyul Rangers and Environs Kimberley staff prepare the ant traps, labelling and coolant prior to going out on site.

Data Collection Methods

Ant traps will be located at the middle, edge (10 metres inside the thicket) and outside each thicket. At the time of opening the traps, 5 litter depth measurements are to be recorded at each corner of a 1 sq metre quadrat placed over the trap, and at the trap location.

Trevor Sampi Bardi Jawi Ranger, coordinator Todd Quartermaine and Gemma Chaquebor measure litter and grass cover at each corner of the quadrat placed over the ant trap

Traps are to be placed into the ground with the top of the trap lying level with the soil. To do this litter will be moved sideways from the trap location leaving a funnel shape of litter from the litter to the trap.

Traps remain open for 7 days. Lids are to be placed on the traps when removed.

In the event of rain, this period may need to be shortened, with 72 hours being the minimum required time for the traps to be open. All traps to be are to be left open for the same length of time, so if rain is to occur in one area, all areas will need to be closed early as well.

Additional measurements

Litter depth, canopy cover, canopy gaps, % ground covered by vegetation, % ground covered by soil, % ground covered by litter, GPS Locations, disturbance history

Photo record for each of the three locations at each site

Nyul Nyul Ranger Brendon Smith and Louise Beames (Environs Kimberley) record litter cover and depth, and canopy cover along the transect

Hand Collection Techniques

Hand collection occurs once the traps have been set, and involves two people collecting for half an hour each (or 4 people for 15 minutes), i.e. total collection time of one hour, at the middle, inner edge and outside the thickets.

Shake foliage over a white sheet or an upturned umbrella to maximise the numbers and types of ants found.

Methods:

1. Direct searching via scraping litter, looking into logs, searching in and around bark of trees

2. Cloth, or upturned pale coloured umbrella, should be placed under shrubs which are to be shaken with specimens falling free being collected with forceps dipped in ethanol. Specimens are to be placed in a bottle containing ethanol.

3. Ensure that paper labels (written in pencil) remain inside the bottle clearly identifying the capture site.

4. Wipe any excess ethanol from the side of the bottle and label the lid and sides of the bottle with permanent marker.

Collect ants with a bottle 1/3 full of ethanol - this quickly preserves the ants and aids capture

Field Equipment

Trap bottles 42mm inner diameter, 100mm deep, 30ml coolant in each bottle, labelling equipment, trowel, forceps, ethanol, bottles for hand collection, white cloth or pale coloured umbrella. Labels inside bottles written with pencil

Monitoring Frequency

Two seasons of data collection should occur, after the end of the wet season and towards the end of the dry season. Repeat sampling should occur at the same times of the year, but following a period of management actions or if a fire event were to occur.

Sampling Size

The method described provides sufficient sample size for one MVT patch; if more MVT patches were to be measured the same sample size should be utilized at each site. For comparison across MVT patches; at least four individual thickets should be sampled.

Analysis of Data

1. Sort ants and identify to species level and provide names wherever possible.
2. Develop a checklist of ants for each ring of 8 traps, by combining the collection data for the 8 traps and hand collection at that location.
3. Calculate the mean number of individuals/ plot
4. Calculate Shannon-Weaver diversity and evenness indices for pit fall trap samples
5. Conduct a Principle Components Analysis (PCA) to compare ant species composition between each Monsoon Vine Thicket, and between the inside, edge and outside plots.
6. Utilise Species presence/absence data to compare and contrast ant content of plots, to highlight similarities and dissimilarities
7. Conduct a correlation analysis on the matrix of physical variables, namely canopy cover, canopy gaps, litter volume, litter depth, vegetation cover, bare ground cover
8. All variables significantly correlated with variables of interest , namely ant species richness, diversity, evenness and vegetation type to be noted
9. Litter measurements will enable calculations on litter volume which will be valuable for comparisons across locations that is middle, edge and outer. This data will provide data to enhance the vegetation structural measurements and could be used in addition to the ant study but also as a separate “protocol” for vegetation condition of thickets.

Data Storage

Field data will be entered into an electronic database, including GPS locations, with checks made of the accuracy of electronic records against the field records.

Data Custodian

The ultimate custodians of the data are the Indigenous Ranger groups, and their supporting native title bodies, who have collected the data in order to enhance the management of MVT patches on their country.

The monitoring protocol may also be adapted and used by other Indigenous Ranger groups or community groups to support and assist the management of MVT on their country.

Environs Kimberley can assist with adapting the monitoring protocol and can continue to assist with storage and interpretation of data where cooperative research agreements are in place.

DATA SHEETS FOR PROTOCOL #3 FOLLOW

Ant data sheets - protocol #3

Ant collection data sheet #1 Protocol #3

Litter cover - Ant transects - Protocol #

Date Trap set:				**Assesser Name:**						
Site Name:				**Weather:**					**Ant Pit Trap Collection**	
			Canopy %		**Ground Cover [%]**					
Trap	**GPS**	**Litter cm**	**Cover%**	**GapY/N**	**trunk**	**soil**	**litter**	**Dist.**	**Date out**	**Comments**
M1										
M2										
M3										
M4										
M5										
M6										
M7										
M8										
E1										
E2										
E3										
E4										
E5										
E6										
E7										
E8										
O1										
O2										
O3										
O4										
O5										
O6										
O7										
O8										
Trap Number codes:										
M = Middle of thicket			E = Edge of thicket			O = Outside of thicket				
Dist. = Disturbance:										
G = Grazing		F = Fire		T = Track						

Date						
Site name						
Trap No.	**GPS**	**Litter 1**	**litter 2**	**litter 3**	**litter 4**	**date out**
M1						
M2						
M3						
M4						
M5						
M6						
M7						
M8						
E1						
E2						
E3						
E4						
E5						
E6						
E7						
E8						
O1						
O2						
O3						
O4						
O5						
O6						
O7						
O8						

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