A DECADE OF DEADWOODOLOGY AT WARRA

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Decadent. *Rotten*. *Waste*. *Residue*. *Unproductive*. The superposition of the words 'dead' and 'wood' gives rise to so many negative connotations, why would anyone feel the need to coin another word to describe the study of this stuff? Consider this. Dead wood (or coarse woody debris, CWD) represents a fair chunk of the embedded energy from perhaps several hundred years of photosynthesis by some of the most successful and enduring organisms on the planet (that's trees). And it's just sitting there on the forest floor, waiting to be recycled back into multitudinous new life-forms. Systems scientists have accepted that the term 'embedded energy' needed shortening to 'emergy' – check Google if you don't believe me – so my view is, why not have one word that captures an entire field of research surrounding dead wood? In this article, I elaborate on what it means to have spent much of the past decade working on matters deadwoodological (there's another new word!) in and around southern Tasmania's Warra Long Term Ecological Research (LTER) site (Figure 1).

But first, how did Warra get to be the focal point for so much ecological research in general, and deadwoodological research in particular? After all, Warra is just a typical 16,000 ha patch of the southern forests – a mix of lowland wet *Eucalyptus obliqua* forest, rainforest, buttongrass and montane scrub and rock, some of it allocated to reserves, some of it allocated to wood production. But that's the point – typicality is exactly what the people that set up Warra were looking for back in the mid-nineties. Mick Brown – then at Forestry Tasmania (FT) – and others were looking for somewhere to explore the ecology of Tasmanian terrestrial ecosystems in general, and Tasmanian wet eucalypt forest in particular, because it's these forests that form the backbone of Tasmania's native forestry industry. If we want to understand how to manage these forests well, we'd better be sure we understand how they work. Establishing Warra as an LTER site not only formalised its role as a premier site for terrestrial ecological research in Tasmania, it also linked it into a national and international network of LTER sites and researchers. To this day, Warra continues to host fundamental ecological and hydrological research projects, both long-term and short-term, as well as acting as a testing-ground for different forms of forest management. The number of individual research projects has climbed to nearly 170, and the number of published journal articles and book chapters arising has reached 119.

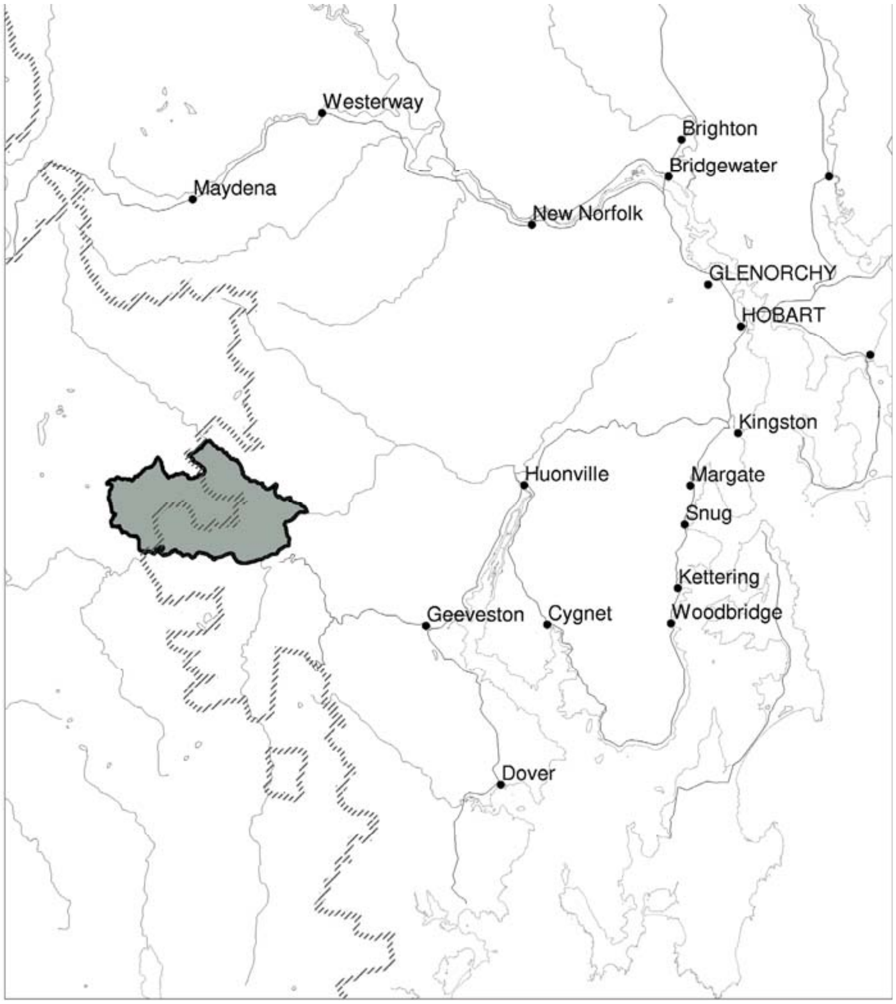

Figure 1. Southern Tasmania, showing location of the Warra Long Term Ecological Research site (shaded dark grey). The eastern boundary of the Western Wilderness World Heritage Area is shown as a hatched line.

Deadwoodology came early to Warra. By 1999, Rob Taylor (my predecessor as Conservation Biologist at FT) had established the log-decay project, with Caroline Mohammed and colleagues from the University of Tasmania (UTas) and with Tim Wardlaw, also from FT. The main aim was to monitor elements of the rich biodiversity inhabiting logs – chiefly saproxylic (dead-wood-associated) beetles –

as the logs gradually decomposed. Twelve *E. obliqua* trees were deliberately felled for the purpose, so that the process could be followed right from its start. The initial funding was for only three years. But the project lives on, and we have recently completed the second five-year cycle of emergence-trapping (Plate 1), bringing the total number of beetles collected from these twelve logs to 17,488, and the number of beetle species to 455. Through other research at Warra we now know that these logs are still likely to be in a sampleable condition two centuries hence. Only at Warra could such a long-term study be contemplated: researchers come and go, but the logs endure and the research lives on.

Plate 1. One of twelve logs in the Warra log-decay project. This is a 'regrowth'-sized log, encased in an emergence trap to sample saproxylic beetles (photo by the author).

At the same time as the log-decay project got under way, Marie Yee started her doctoral research at UTas, also in and around Warra. Marie's work focused on *E. obliqua* logs in an intermediate stage of decomposition, corresponding to what we now call decay-class three (on a scale of one to five). Logs at this stage can be thought of as being in their ecological prime of life: the chemical cocktail that the living tree produces to ward off pests and pathogens has largely gone, yet the log still retains most of its original volume and structure, but only half of its original mass. It's in logs like this that some of the most remarkable assemblages of beetles can be found – if you know how to look for them. Marie did, and her research was one of the first in Australia to document this fauna. She detected distinct differences between the species assemblages living in larger-diameter logs (derived from 'old-growth'-type trees) and smaller-diameter logs of a size typical of those derived from 'regrowth'-type trees. In doing so, she highlighted one possible conservation issue: if the future production forest becomes increasingly dominated by regrowth, where will the species that live in old-growth logs find a home? With Marie subsequently taking up a position as Conservation Planner at FT, this was a pertinent question.

Marie's research finding was a familiar story to me – but not in a Tasmanian context. I started working at FT in 2001, fresh from having finished my own doctoral research on saproxylic beetles in the lowland tropical rainforests of northeast Queensland, and with a background of working on similar themes in the woodlands of England. My English experience had taught me how dire could be the consequences of centuries of use and abuse of native forests on the dead-wood habitat, and on the species dependent on it. I could see the beginnings of a similar trend in the Daintree too, though this had been curtailed with the near-cessation of logging a decade previously.

My arrival in Tasmania coincided with a growing interest in renewable energy. Forestry Tasmania was actively exploring options for generating electricity from harvest residues. Irrespective of how the environmental credentials of fuelwood-harvesting stack up, it is a widely-accepted part of normal forest management in northern Europe and North America, so why not in Tasmania too? There was one snag. The experience of Fennoscandian ecologists was that their intensive forestry, including fuelwood-harvesting, had denuded their forests of CWD and had contributed to a high percentage of their 1400 saproxylic beetle species (plus many other life-forms) being red-listed; trying to get ecologically-useful amounts of CWD back into their forests through changed practices was proving expensive and not very effective. Considering the complications introduced to forest management in southern Tasmania by the single threatened saproxylic beetle species, the Mount Mangana stag beetle (*Lissotes menalcas*), we could scarcely imagine how having scores or hundreds of such species might impact on operations. Much better to get to grips with understanding the system now, so that we could explore ways to avert the risk of such a calamity while still maintaining a viable forestry industry.

And so a formal research programme was born, endorsed by FT management. It had the explicit aim of learning enough to make scientifically defensible policy decisions on fuelwood-harvesting. Along the way, the research would also build our understanding of fundamental forest ecology, and would help guide a range of other forestry-related management issues. The logical place to start with such a research programme was a review of the likely ecological impacts of fuelwood-harvesting – so this was the first thing that former FT Conservation Planner Jeff Meggs and I did. The review led to the recognition of some key research themes.

One focused on understanding the biodiversity associated with CWD, into which Marie's research and the log-decay project fitted neatly. These projects were soon augmented by those of two further doctoral students from UTas. Anna Hopkins explored the wood-rotting fungi of 'old-growth'-type and 'regrowth'-type *E. obliqua* trees at Warra, while Kate Harrison studied the saproxylic beetles living in the same trees. A little later, Genevieve Gates began her doctoral research on macrofungi associated with CWD and litter in forests of three different ages at Warra. These studies, like Marie's, were able to demonstrate that there was something quite special, ecologically, about old trees and the large logs derived from them. This seems to relate partly to their more complex, microclimatically-buffered internal structure. It also relates to time itself – older trees have endured more fungal and borer attacks and have accumulated more fire damage than have younger trees; the impacts of these events from the distant past are still played out in the logs arising from these trees. Additionally, all these studies – and many others besides, on taxa as diverse as liverworts and mites – documented the existence of a vast array of hitherto-unknown species associated with these habitats. Many of the beetles collected during these studies have ended up in FT's Tasmanian Forest Insect Collection (TFIC), which has consequently grown to become a comprehensive reference collection of databased Tasmanian forest beetles (118,479 specimens, comprising 1912 species, many of them new to science).

You may be wondering why we didn't just resolve the big management question by looking at what effect past fuelwood-harvesting had had. Well, we tried – but up to now, nobody had done much fuelwood-harvesting in Tasmania. We did find a few areas of the southern forests that had been subjected to experimental fuelwood-harvesting back in the 1980s, and we duly sampled these areas for saproxylic beetles, comparing them with similar areas that hadn't experienced fuelwood-harvesting. But the areas in question were so few and small that the findings, while strongly suggestive of an impact, lacked statistical power. In any event, 'snapshot' studies like this can only tell you so much when the subject is something as dynamic as dead wood – and so dead-wood dynamics became another major research theme for us.

Dead-wood dynamics? Surely that's an oxymoron: what could be dynamic about dead wood? Humans are ill-equipped to conceive of logs as doing anything other than just sitting there. If you blink, the log doesn't move. Return to your favourite picnic-spot summer after summer, and the logs your kids played on as toddlers will probably still be there when they're teenagers. But logs do change, even if we can't catch them in the act of doing so. As well as slowly decomposing over decades, logs pop into existence when the progenitor trees fall over. In the wet eucalypt forests, the usual reasons for trees doing so are periodic massive disturbance events, typically wildfires or logging. So to find out how long logs last, we used a so-called 'chronosequence' approach. We compared the decay-class composition of logs in forests differing in the number of years that had passed since the last big disturbance event (whether wildfire or logging). Retired FT Huon District Planner Chris Barry knew the recent disturbance history of the southern forests like the back of his hand, and undertook the fieldwork. We were guided by a report on the early timber-getters compiled for FT a few years previously by archaeologist Parry Kostoglou, which helped find sites that had been first logged a century or more ago. Each of the hundreds of logs that Chris assessed became a data-point on a graph that eventually told us how long it takes for *E. obliqua* logs to pass through the five decay-classes. The answer: there's a lot of variation, but decent-sized decay-class three logs tend to have been around for 50 years, while those in decay-class five (well on their way to becoming humus) are likely to have been around for over 150 years. This is much longer than logs in most other parts of the world.

We were fortunate at this stage to host a summer forestry student from Southern Cross University, Lee Stamm. Lee demonstrated an aptitude for deadwoodology that led to him staying on to complete Honours at UTas, and later to his appointment within FT as a Planning Forester. His particular research challenge was to uncover the missing pieces of the dead-wood dynamics puzzle, and build the whole thing into a computer model that would simulate this. This would enable us to play around with disturbance and management scenarios and forecast how these would affect CWD amounts over timescales of many centuries. Lee started by taking a chainsaw to dozens of logs at Warra, to extract 'biscuits', or slices, each comprising a particular decay-class. From these he figured out the component rotten-wood types, and took sub-samples of these back to the lab to work out their density. He used these density values to back-calculate the average density of logs in different decay-classes, and built these values into his computer model. The model started with a mature forest, stocked with a typical array of 'legacy' CWD whose composition accorded with what former FT research technicians Gabriel Warren and Darren McNeil had measured along eleven kilometres (yes, 11 km!) of line-intersect surveys conducted in and around Warra a few years previously. The model also incorporated FT's growth equations for the trees that would generate the CWD. It then simulated periodic wildfires that would kill these trees. The wildfires would simultaneously combust a proportion of the volume of every log, based on some relationships derived from Warra data a few years previously by former FT Fire Management Branch researcher Alen Slijepcevic. What was left would be fed into the next part of the model, comprising the five-stage decomposition process. The model would then spit out CWD volumes and masses for every decay-class and diameter-class combination for every year of the simulation.

The model demonstrated how some of the world's highest volumes of CWD could accumulate in Tasmania's lowland wet *E. obliqua* forests, and confirmed the role that periodic wildfires and slow decomposition rates play in this (Figure 2). These high volumes were in line with our field observations, including those derived from plot-based surveys in the set of 'wildfire chronosequence plots' that Perpetua Turner from UTas had established in and around Warra, in a collaborative project with FT. German forestry diploma students Julia Sohn and Eva Hilbig, alongside FT colleagues, had laboured (I use the term intentionally and with feeling) long and hard to come up with figures for CWD volumes in these plots that range from 351 to 1710 m^3/ha. By building on some of Lee's density analyses, and by incorporating data on the volumes of living stems in the same chronosequence plots from work by Australian National University Honours student Ian Scanlan, Eva's work was additionally able to convert volumes to masses and hence to total carbon. For the record, she estimated that the amount of carbon in trees, roots and CWD in the wildfire chronosequence plots ranged from 97 to 583 t/ha – well above accepted international benchmarks for temperate forests.

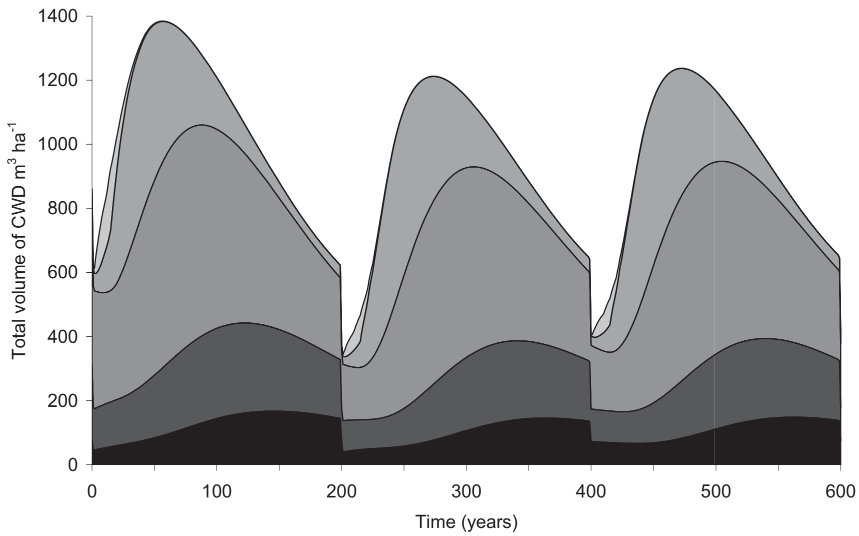

Figure 2. An example of output from Lee Stamm's model of dead-wood dynamics. The graph predicts how volumes of coarse woody debris may vary over time, and by decay-class, following periodic stand-replacing wildfires every 200 years.

I subsequently developed Lee's CWD dynamics model so that it can simulate logging and fuelwood-harvesting as well as wildfires. This has brought us to the point of being able to predict the likely impacts of fuelwood-harvesting on CWD, over and above those of clearfelling. The news is not good. Unconstrained fuelwood-harvesting, practiced at the time of clearfelling, would more-or-less eliminate CWD from affected coupes. The full impact would not be felt for many decades, however, because of the time taken for 'legacy' CWD and unharvested residue to decay away. The model also revealed that the focus on fuelwood-harvesting was to some extent missing the point, because fuelwood-harvesting only brings forward an inevitable loss. Clearfelling on its own is quite capable of producing a similar outcome, but this would only be manifested well into the second silvicultural rotation (i.e. about 150 years hence). This is because it would take that long for the system to respond to the lack of 'legacy' CWD after the second harvest, and to the fact that the new input of harvest residue at this time would comprise smaller-diameter CWD that would not last as long on the forest floor.

Knowing the effects of clearfelling and fuelwood-harvesting on CWD is not quite the same thing as being able to gauge its impacts on dependent biodiversity, which is where my interests really lie. The key missing ingredient is scale. While the model handles the time dimension admirably, it has no concept of space. On the other hand the real world, as we can all readily appreciate, has dimensions of space as well as of time. This calls for a very different research approach – one we are just embarking on. Essentially, we want to find out how much it would matter to the persistence of dead-wood dependent species if parts of our landscape (the bits comprising silvicultural regeneration) ended up lacking sufficient dead wood to sustain them. We know from our surveys that not every part of the forest is capable of supporting every species continuously even in the absence of forestry – there are some areas that naturally have very little CWD, while other areas periodically lack particular decay-classes, or diameter-classes, or combinations of these; some areas appear to have the right habitat, but it remains unoccupied. Species have presumably evolved to cope with this varying capacity of different parts of the landscape to support them. But we don't want to end up with a situation where we have introduced so many obstacles that species can no longer move around the landscape, and consequently become locally extinct. That's where northern Europe has got to, and it's not a good space to be in because it's so difficult to get back out of it.

Enter two further UTas doctoral students and former FT employees, Belinda Yaxley and Lynne Forster. Belinda has spent much of the past couple of years in and around Warra, trying to unravel the ecology of some of the key saproxylic beetle species that previous researchers had identified as potentially vulnerable to forestry activities. These include Mount Mangana stag beetle as well as some inhabitants of the 'mudguts' habitat that I wrote about in this journal in 2007, many of whose close relatives in Europe are on the verge of extinction. One of Belinda's aims is to collect sufficient information about these mostly flightless or otherwise rather immobile species (Plate 2) to be able to model their habitat relationships, and hence their probability of occurrence, across the southern forests landscape, and to relate this to forestry activities and wildfire. Lynne aims to build in a time dimension to Belinda's work, through taking a rather different approach. She will work with a postdoctoral researcher, Christina Schmuki, who has perfected the use of molecular techniques to study how the genetic relatedness among individual beetles varies with physical distance. Lynne and Christina's study also builds on some pilot molecular projects on individual beetle species carried out at Warra a few years back by Latrobe University students Sarah Nash and Simon Watson. Lynne and Christina will explore how the spatial arrangement of dead wood has affected the ability of these beetles to move around the landscape. Parallel to their studies, we will also be sampling saproxylic beetles (and other taxa) widely in the Warra area as part of a new landscape ecology project. The aim of this project is to test the effect that landscape context (i.e. how intensively the landscape is managed) has on the current distribution of species. Together, the findings of these projects should help us to understand at the spatial and temporal scale at which we would need to manage CWD (and the old trees from which CWD is derived) to ensure the long-term persistence of these species in the managed forest landscape.

In the interim, FT is taking a precautionary, yet pragmatic, approach to dead-wood management. The Warra research and modelling results have convinced FT management of the need to endorse a set of prescriptions that would put limits on the extent of fuelwood-harvesting in logging coupes, if and when it eventuates. These prescriptions specify that a third of the harvested area of every clearfelled coupe would be set aside as unavailable for fuelwood-harvesting, with the off-limits areas dispersed across the harvest area (to act as potential stepping-stones). The logic of choosing this particular proportion and spatial arrangement was based on experience that a similar proportion and spatial arrangement of retained forest is the typical outcome of aggregated retention silviculture. Aggregated retention is FT's replacement to clearfelling as the silvicultural system of choice in old-growth wet eucalypt forests. Research on this alternative system began at Warra, using the same coupes used for some of the deadwoodology research reported here. While research has already demonstrated that the retained aggregates continue to function pretty well, an additional prediction is that the regenerating harvested areas will continue to be ecologically influenced by the retained forest– including by the dead wood there. The effects should be scaleable, improving the chances of species' persistence across the landscape. FT researcher Sue Baker is planning on exploring this prediction in the coming three years.

Looking back, the fuelwood-harvesting issue that triggered this frenzy of deadwoodology was but one beneficiary of the research findings, and perhaps not the most important one. The new elephant in the room is carbon. The full implications for forestry of the growing awareness of carbon budgets have yet to play out. Deadwoodology at Warra is sure to play a part in developing our understanding.

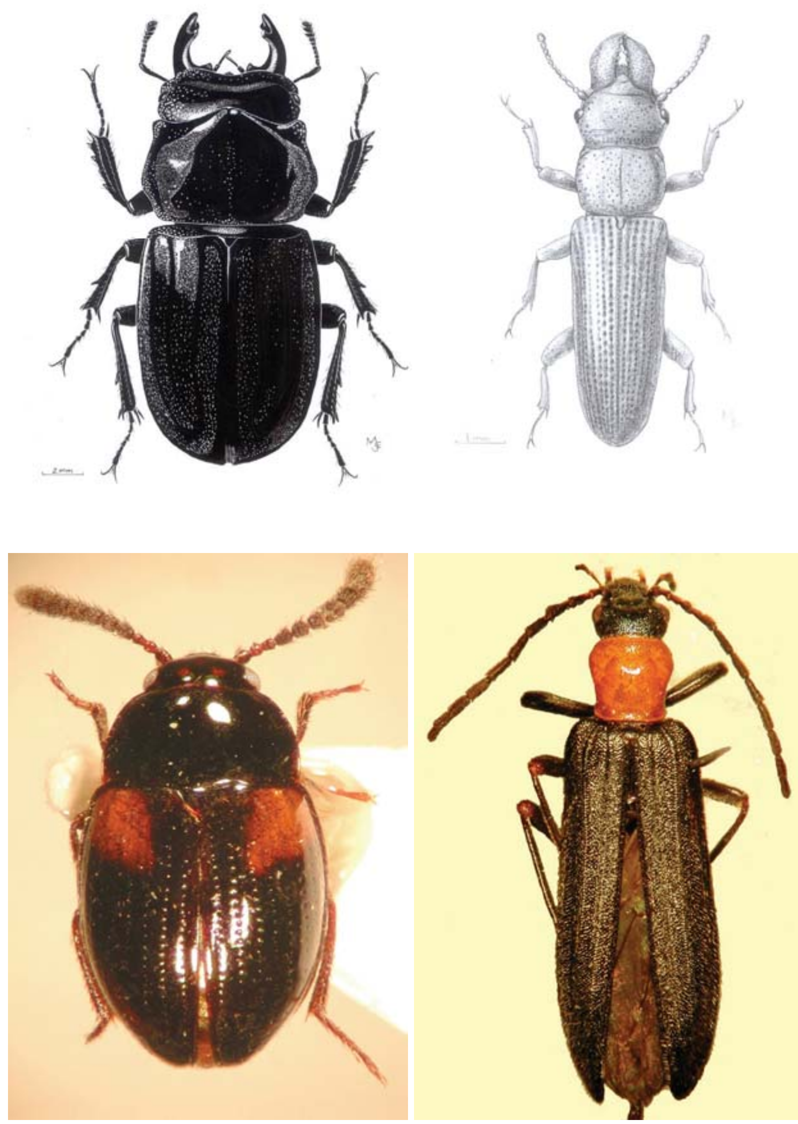

Plate 2. A selection of saproxylic beetle species that are the focus of on-going studies at Warra. (top left) Mount Mangana stag beetle *Lissotes menalcas* and (top right) *Prostomis atkinsoni* (illustrations by Melanie Evans); (bottom left) *Neopelatops* TFIC sp 01 and (bottom right) *Dohrnia simplex* (photos by Lynne Forster).

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To view a list of the 24 Warra research projects conducted under the 'deadwoodology' theme, each hyperlinked to separate project web-pages, see http://www.warra.com/warra/research_projects/research_projects_Carbon_biomass_and_coarse_woody_debris.html. For a hyperlinked listing of the 27 publications arising from this work so far, see http://www.warra.com/warra/pub_html/publications_Carbon__biomass_and_coarse_woody_debris.html.