FINAL REPORT

TECHNICAL REVIEW OF PROPOSED REGENERATION STANDARDS TO APPLY TO COASTAL AND TABLELANDS FORESTS OF NSW OF THE COASTAL INTEGRATED FORESTRY OPERATIONS APPROVAL (IFOA)

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1 Summary of Findings

Report Conclusion	The move towards an "outcomes based" in contrast to a "process based" approach to defining successful regeneration is supported. However specification of successful or threshold outcomes is difficult, given the dynamic nature of the forest, especially in the years immediately after natural or human induced disturbance. The implicit desire for "success" to be measured in terms of the maintenance of the "natural values of the forest" is a global challenge. While there are relatively well established measures of successful regeneration with numbers of trees ha^{-1} relating to commercial wood production, there is limited published or available work on "success" with relationship to ecological values. Ecological success is dependent on factors other than just the number of trees at an arbitrary future point. The regeneration standards proposed in the Forestry Corporation of NSW (FC) position paper are based on Forest Type Grouping (FTG) where each group has similar regeneration habits. The minimum thresholds for regeneration success for all FTGs is proposed to be 250 stems ha^{-1}, which would be assessed 2 – 7 years after a regeneration harvesting event (depending on the FTG). There is little literature or evidence relating to the 250 stems ha^{-1}, except an unsupported assertion by FC that "…most [commercially mature] forest stands have at least c. 250 trees per ha if both canopy and sub-canopy tress are included." The key issues identified in our review include the lack of scientific or management support for the thresholds proposed and a "one dimensional" focus on the number of canopy stems ha^{-1}. The sampling described in the proposal is process-based when it could relatively easily be based on outcomes (e.g. there is a 95% confidence that less than 25% of the harvested area is subject to functional problems like erosion or noxious weed). However these outcome thresholds must also be supported and not simply asserted as being appropriate. We conclude that the regeneration standards and the supplemental information do not provide sufficient information or justification to support the assertion that 250

trees ha^{-1} is an adequate threshold to demonstrate regeneration success. Similarly, there is no justification to use a threshold of less than 95% of one species in the sample plots to conclude that successful species diversity is probable. Success in ecological or biodiversity terms should incorporate more than just numbers of trees to account for functional, structural and species success.

We conclude that, in the absence of current peer reviewed information on regeneration success, there is an urgent need to conduct a collaborative process to develop a biodiversity (or natural values) monitoring and assessment program. This program should support continuous and adaptive improvement in forest operational standards and inventory processes, particularly to insure that regeneration standards are part of effective measures for the achievement of long biodiversity outcomes. Our final section suggests an approach to progress this recommendation.

Introduction and Overview of Methodology

ANUEdge was requested by the EPA to review regeneration standards that are proposed to apply to coastal and tablelands forests of NSW as part of the Coastal Integrated Forestry Operations Approval (IFOA) remake. EPA envisaged that the thresholds provided in the Guidelines will be part of an enforceable protocol in the remade IFOA and be supported by guidance material to support their on-ground implementation. The contract required ANUEdge to review the guidelines for technical appropriateness and adequacy. Given the relatively unsupported documentation provided in the original draft, the reviewers were subsequently requested by the EPA to provide responses to "Scoping Questions" after the draft regeneration guidelines were produced by FC.

Our review process consisted of a careful reading of the draft Standards document, supplemental material provided after a draft report and some of the published reference material. The reviewers worked both alone initially but came together periodically to discuss aspects of the Guidelines and ways to progress.

1.1 Contract specifications

The Consultants were requested "…to assess the appropriateness and adequacy of the proposed regeneration standards upon which the post-harvest and biodiversity monitoring programs will be based. In particular it is proposed that the Expert Assessor/s will provide advice and recommendations on:

- the adequacy of the scope and coverage of the proposed regeneration settings, explicitly considering the outcome that forestry operations should not be a key driver in changing the nature of native forest areas over the long term.
- the appropriateness and adequacy of FCNSW derived regeneration settings that are proposed to be measured against with reference to the supporting information provided by FCNSW.
- addressing the impact of pests and weeds, including Bell Miner Associated Dieback, on the risks that areas may not regenerate to required standards and how these factors could be considered (for example, with forest areas susceptible to "higher risks" triggering time series monitoring.

The Expert Assessor/s will also be required to assess the proposed FCNSW post-harvest assessment methods with a view to determining:

- The adequacy and representativeness of the proposed sampling and measurement to be used, and
- whether the proposed assessment methods have sufficient rigour to determine meaningfully whether regeneration standards are being met at an operational scale and across the landscape.

As a component of the assessment the Expert Assessor/s will:

- make recommendations on any additional regeneration settings that that the IFOA remake should consider setting and measuring against in an operational post-harvest assessment program and broad scale biodiversity monitoring program. Particularly any regeneration settings that should be measured to inform changes to forest management practices and IFOA conditions where necessary.

- propose alternative settings which are based on sound scientific and ecological evidence if FCNSW proposed settings are deemed inadequate.
- Propose alternative sampling and measurement approaches where the FCNSW proposed methods are deemed inadequate.

Additionally the Expert Assessor/s will:

- scope, propose approaches and advise on further work needed to develop a biodiversity monitoring program for regeneration that will at a minimum:
    - assess whether Regeneration Standards are effective measures for the achievement of any longer term biodiversity outcomes and objectives.
    - Determine whether operational practices employed by FCNSW are significantly altering biodiversity objectives and outcomes across the landscape.
- Consider the approach to the regeneration component of a biodiversity monitoring program within the context of developing a broader monitoring framework that will cover threatened species and soil and water issues. Noting that a broader IFOA monitoring framework will be subject to additional body of work at a later stage.

2 General

Forests are dynamic, especially after major (natural or human induced) disturbance. Disturbance that is sufficiently major to initiate a large scale regeneration event or new stand, will start a forest area along a progression of recovery or change (Figure 1). A large number of parameters, including the number of trees, presence of different species, amount of course and fine deadwood / debris, and faunal habitat will vary during this progression.

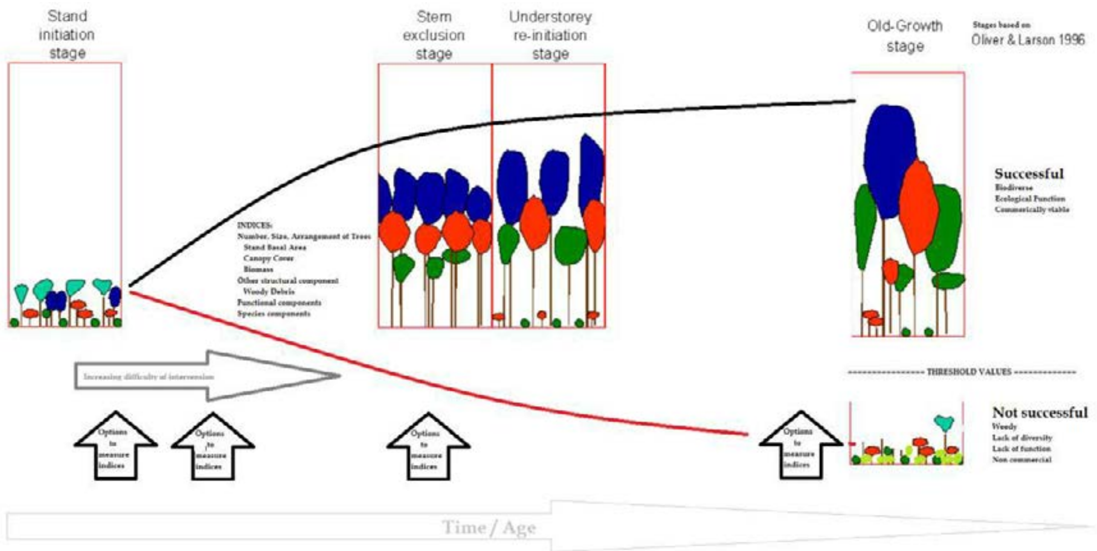

Figure 1. An example of a conceptual model at the stand-level of the progression from regeneration to a mature or reference “end point”. Relevant indices, parameters and thresholds denoting “success” along the trajectory will change with stand age and development stage as will opportunities to measure and react to results. Ideally, index values will clearly distinguish between

“success” (black line) and “not success” (red line) along the trajectory, but it is likely that there will be overlap and imprecision, hence the need for long term monitoring.

At the regeneration stage, the supply of seeds, the receptiveness of the seedbed, competition from ground vegetation, soil surface stability, and the microclimate near the ground will have a profound impact on the development of the future stand. These factors and others have a decisive influence on the stocking and the quality of the new stand, its species composition, and early growth. In early the regeneration phase it is possible for any disturbance to result in understocked or overstocked stands and undesirable species combinations. Undesirable conditions in the forest occurring at the regeneration period are difficult to correct, and subsequent remedial actions taken to improve outcomes often come at high cost. However, when regeneration has been “successful”, the resulting stands are “launched” on a dynamic trajectory of succession and development with consequent changes in species and structural diversity. A successful trajectory should provide varying “natural” and commercial values.

The standards drafted by FC imply that the definition and objectives of successful regeneration is one dimensional (number of canopy species at maturity). An alternate reference suggested by the EPA anticipates that a diversity of values must be considered to ensure that *natural values* are maintained.

A major challenge under the EPA assumption is how to affordably operationalise what ‘natural values’ mean and how they are measured. “Natural Values” could be defined broadly as ecosystem services supported by a forested landscape, but monitoring such services is problematic (expensive) since there is such a diversity of ecosystem services provided by a forest, and at regeneration many exist only as potential future benefits. To allow the potential ‘natural values’ to develop, at regeneration it would be important for:

- A coup not to be eroding (no major soil problems, that is, maintaining its functionality)
- High likelihood that forest structure will likely develop to pre-logging conditions (e.g. canopy, mid story and ground cover; an adequate structure)
- Key species present with adequate densities (dominant overstory and midstory)
- Key species absent: e.g. long lived woody weeds and highly competitive grasses (e.g. Coolatai Grass grass in dry forests).

A fundamental issue in most quantifications of natural values is the question of surrogacy. Ideally, based on quality research, a few indicators would be found that can be rapidly measured and related to the “value” of true interest. Presence of regeneration is likely to be an important surrogate for ‘maintaining natural values’, but it is unlikely to be enough on its own; essential but not sufficient. There is a large literature on biodiversity surrogacy (e.g. McElhinny et al 2006a,b), but relatively little for managed forests at the stage of regeneration.

It can be argued that a protocol for assessing minimal canopy stocking densities is useful and important, **but** as a <u>component</u> of a broader system for monitoring and managing outcomes of silvicultural practises. That is, regeneration monitoring is simply one component of ensuring an outcome of maintaining ‘natural values’. Even when confined to this narrow focus, the current protocol and thresholds for regeneration proposed by FCNSW are inadequate and not justified with references to scientific literature or even common management practice.

3 Scoping Questions

To provide a structure to our report, EPA requested that we answer some specific "scoping questions".

3.1 The applicability of Regeneration Standards

> *FCNSW advise that not all silvicultural treatments will have the principal aim of achieving regeneration therefore standards should not necessarily apply to all logging operations. Given the NSW Government is looking to have a clear and enforceable framework, not necessarily linked to silvicultural objectives and settings, are there any meaningful, measurable and preferably simple field based triggers and thresholds that can be used to determine when regeneration in NSW coastal and tablelands forests should be reasonably expected ? For example stocking, basal area removal/retention rates, canopy coverage, disturbance levels?*

Silviculture is defined as the manipulation of forest stand structure and dynamics to achieve specific forest management objectives. These forest management objectives usually include the production of wood and non-timber products (e.g. water, honey) and maintenance of environmental and conservation values such as soil quality and wildlife habitat. Thus, silvicultural practices encompass many activities that may be employed over the entire life of the forest to manipulate forest stands or stand structure. However, silvicultural systems are generally named after the harvesting or regeneration method used including: single tree selection, group selection, shelterwood, seed tree system, and clear-felling. These silvicultural interventions create disturbance, which may be defined as an event or series of events that removes plants or parts of plants, and makes growing space available. That growing space can be used or re-colonised by surviving or newly establishing plants.

Any silvicultural operation then will impact on available growing space and may result in regeneration by newly established plants. However, the potential for regeneration will depend, not only on an available seed source, but also on the disturbance regime, which can be characterised by:

- ***Magnitude***: e.g. the amount of overstorey removed, or whether the disturbance was stand-replacing or minor.
- ***Frequency:*** e.g. very frequently through to very infrequent.
- ***Spatial patterning:*** e.g. only affecting only certain components of forest stands through to entire stands or landscapes.
- ***Randomness:*** e.g. systematic or non-systematic returns
- ***Seasonality:*** e.g. winter vs summer disturbances

Thus, there are a number of treatments which are unlikely to result in significant establishment of new plants, or at least of nominated types of plants (e.g. shade intolerant eucalypts). A lack of significant regeneration is not an issue when the specific management objective may be to (1) redirect growing space to the residual trees to maximise their growth; and (2) produce a commercial product prior to final harvest. If a silvicultural intervention is not anticipated to produce sufficient regeneration of new plants to fully occupy a site then it would be important that the remaining overstorey is of sufficient magnitude and patterning to occupy the released growing space in a reasonable time.

Site occupancy indices in forests are related to the number, size and distribution of the trees. Fifty young and small trees, for example are unlikely to fully occupy 1 ha of land, while 50 mature and large trees well distributed over the area may. The most common index of occupancy is stand basal area which incorporates both number and average size, with an assumption that the trees are relatively well distributed. In Australian forests, stand basal area of fully stocked stands frequently lies in the range 20-50 m^2 ha^{-1} but on exceptionally productive sites, may reach 150 m^2 ha^{-1}. Heavily thinned stands that reduce stand basal areas to 10-20 m^2 ha^{-1}, without any expectation of significant regeneration, are common. An alternative measure of occupancy is canopy cover – when the canopies touch or the projected coverage of the canopies is 100%, then the site is fully occupied. Given a strong correlation between tree basal area and tree canopy, a 50% reduction in canopy cover may be correlated to a 50% reduction in stand basal area.

Single Tree Selection (STS light) for example is restricted to removing no more than 50% of the pre-thinning standing basal area with residual trees well-spaced under the assumption that these residual trees will grow to fully occupy the site. Australian Group Selection (AGS) on the other hand, allows the removal of all the basal area within a nominated maximum area to allow for the regeneration of shade intolerant eucalypt species. The minimum/maximum size for AGS is a compromise between the shading effect of the group boundary inhibiting regeneration and the distance for seed dispersal and other biodiversity requirements.

Conclusion: It is possible to classify silvicultural practices into those that are designed to promote regeneration of new trees and those that redistribute site resources to existing trees. There are quantifiable parameters which may be used in such classifications. These parameters usually include some index of the amount of biomass removed or reduction in site occupancy, specifically the reduction in stand basal area or canopy area within a minimum specified size.

Recommendation: Review existing permanent growth plot data to confirm thresholds that determine whether remaining trees fully occupy the site, and thus negate the need for regeneration of canopy species. Potential parameters include the percentage residual basal area, canopy cover or crown cover separation (mean gap between crowns divided by mean crown diameter). Such thresholds may be species group and age dependent and can be determined in situ or from appropriately scaled remotely sensed images.

3.2 Stratification and regeneration settings proposed by FCNSW

Is the proposed stratification approach and regeneration thresholds set by FCNSW adequate, appropriate and meaningful given the overall objectives and outcomes proposed by the EPA for regeneration? If not what recommendations would you make for improvement?

Stratification into the *Forest Type Groupings* (FTG) is largely adequate and appropriate for the commercial forests as they do provide a logical grouping into ecological types and commercial interest. There is also a long history of use of these FTGs in NSW. However, the proposed further grouping into silviculture, stocking, and moist/dry/grassy appears to be either redundant (e.g. moist coastal hardwood classified as moist) or irrelevant as each FTG only appears once. The Dry Blackbutt Group, for example, only occurs under the classification of “dry” and “High initial stocking” after a “Regeneration Harvesting”. Presumably there is no other type of Dry Blackbutt and so the other classifications add no discriminating value or information.

Similarly, the regeneration targets and percentages of stocked plots are also the same for all the FTGs which implies there are no significant commercial or ecological differences between the groups. It is difficult to agree that 250 stems ha^{-1} at the time of measurement is an adequate minimum threshold for both high and low Initial Stocking groups – competition between trees in the high initial stocking group is often vital to ensure the trees grow into forest as opposed to woodland forms (straight stems and "self pruned" branching), as well as resulting in mortality of some stems which provides the coarse woody debris used by other components of the ecosystem. There are likely to be other structural elements important for ecological resilience that are not developed in the "high initial" stocking stands if the regeneration were as low as 250 stems ha^{-1}.

There is no scientific justification of the threshold of 250 stems ha^{-1} for any of the FTGs, and only an unsupported comment that, presumably at maturity "…most forest stands have at least c. 250 trees per ha if both canopy and sub-canopy trees are included." There is a comparison with mature plantation grown "for maximum diameter increment have c. 70 trees per ha at rotation age", but no comment that that plantations generally begin with establishment rates in excess of 1000 stems ha^{-1} before being thinned down to their final stocking rates, often during a series of operations. There is an implied suggestion that with a regeneration density as low as 250 trees ha^{-1}, there would be no self-thinning and therefore this low regeneration threshold would be close to the final tree density and thus within the range reported.

There is no comment on whether this 250 trees ha^{-1} value is related to economic viability or ecological functionality, although we note it is substantially less that the threshold we understand is used to denote success in commercially orientated forests (600 – 800 trees ha^{-1}). Fagg et al (2013) define the concept of "ecological stocking" to help classify successful regeneration after wildfire in non-commercial forests of Victoria. The ecological stocking level proposed by Fagg et al (2013) is less than for commercial forests, but the forests where it is applicable is generated by fire with the consequent production of significant quantities of standing dead trees and coarse wood debris. Fagg et al note that the removal of coarse woody debris after the fire, say to improve regeneration numbers, may have a detrimental effect on other aspects of biodiversity and so a compromise between lower stocking but increased structural diversity is made. Thus, the ecological stocking level appropriate after fire in Victorian native Ash forests may not be relevant to the stocking level after commercial harvest.

Conclusion: Stratification into the broad FTGs is appropriate.

However, there is no scientific, appropriate commercial or ecological justification for the threshold of 250 stems ha^{-1} for any of the FTGs.

Recommendation: Review the permanent growth plots and inventory data to determine the range of values observed in regeneration for each of the FTGs and whether these levels led to subsequent commercially viable and ecologically functional forests (see section 4 for further details).

3.3 Scale of assessment

The current EPA outcome for regeneration (attached) proposes to maintain flora coverage and floristic diversity at both the operational scale and landscape scale over the short and long term. To meet this proposed outcome, the EPA has been considering the incorporation of enforceable thresholds for tree species diversity into a post-harvest assessment program for regeneration.

Is it meaningful, achievable and appropriate to incorporate thresholds for tree species diversity or richness or more broadly floristic diversity or richness into an operational scale – short term (say 2-10 year) regeneration assessment program? If so are there examples where this has been done elsewhere, particularly within an enforceable regulatory setting? Are there other indicators and thresholds that may be more appropriate to measure in a post-harvest assessment program that would meet the overall outcome? Given a process of ecological succession will occur post logging and burning, will the inclusion of these thresholds in the short term have meaningful links longer term landscape scale outcomes being achieved?

Species diversity or biodiversity is a difficult parameter to define, let alone quantify. The species diversity of a given region is strongly influenced by the interplay among (Perry and Amaranthus 1997):

- **Disturbance**, which destroys more modifies habitats and creates new ones,
- **Recovery** (in the form of regeneration and succession), which reverses the effects of disturbance and is dynamic through time, and
- **Biological legacies** such as stags, which maintain some habitat continuity following disturbance.

Ecosystem resilience is the ability of an ecosystem to recover from disturbance and to return to the general pre-disturbance state. The greater the resilience the faster the rate of recovery. The recovery of an ecosystem following disturbance is influenced by the organisms and structures that survive the event; e.g. surviving trees may provide propagules for re-colonisation of the site. This legacy can determine the speed and direction of subsequent succession. Succession is a well-known process of resilience and by definition describes the dynamic nature of the ecosystem. Recovery and recolonisation will also be highly dependent on climate (and micro-climate) and may be significantly influenced by larger scale weather patterns like *La Nina* and *El Nino* rainfall cycles. Landscape patterns also contribute significantly to resilience by providing refugia for populations to recolonise disturbed sites.

Additionally, many species cannot be identified until fruiting bodies or other vital characteristics are observable – well beyond the 2 – 5 year timeframe proposed by FC for sampling. Consequently, there is often a concentration on the measurement of structures that support biodiversity (McElhinny et al, 2006a,b).

It is thus difficult to set thresholds for species diversity and the FC documentation that concludes biodiversity indices "…are not sufficiently developed, and are unlikely to be sufficiently developed in the near future, that they could be used to set operational regulatory thresholds" is partially justified.

However, the FC draft does propose a biodiversity threshold "no species occupying >95% of stocking…", i.e. no pure monoculture. We do not consider this threshold particularly useful or practical. There is no peer reviewed literature referenced as to the value of this threshold of less than 95% of one species at regeneration leading to a usefully biodiversity outcome. Further, an equal probability sampling approach, as proposed, with small plots and a simple "binary" of presence or absence is relatively inefficient in quantifying the proportion of rare species. Even 50 plots – the minimum suggested in the supplementary material – without any other species being observed leads to a conclusion that the one species observed occupies 93 – 100% of the population at p=0.05, i.e. still within the threshold of a non-monoculture.

As an alternative to simply counting species, Noss (1990) proposed a monitoring framework which is based on three broad system components: forest function, structure and composition. Function should focus on soil health (e.g. soil surface stability), structure on regeneration of overstory, mid story and understory at appropriate densities (or cover), and composition on key desirable over story and mid story species, acknowledging that understory species are likely highly dynamic through time. However given the difficulties in identifying species at an early age, the framework could be adapted into two stages. In the first stage, indices that confirm no loss of function and the general presence of non-weedy vegetation could be carried out in the 2 – 5 year period. There could be an explicit assumptions that if seed producing trees and shrubs were present before the harvest (as confirmed during pre-harvest inspections), then a variety of habitats should result in a variety of species. Such assumptions could be confirmed during longer-term monitoring programs.

Measurements relating to the maintenance of function in regenerating forests could include soil stability (including cryptogram cover and lack of evidence of erosion); nutrient and carbon cycling (including woody debris volume and diversity). McElhinny et al (2006a) documents the range of these values in healthy forests and woodlands which may be used as initial reference values

Conclusion: Measuring tree or shrub species diversity within the first few years after a regeneration event is impractical and may not provide any useful data. However, setting a threshold of "no species occupying >95% of stocking" is also of little value.

Is it not meaningful, achievable or appropriate to incorporate thresholds for tree species diversity (or richness or more broadly floristic diversity or richness) into operational scale inventory.

There are indicators and thresholds that may be appropriate to measure in a post-harvest assessment program that would indicate the likelihood of a successful biodiverse outcome given the original presence of diverse regeneration sources.

Recommendation: Consider a framework that is based on freedom of the loss of function (e.g. soil surface stability is not impaired); percentage cover of overstorey and other vegetative storeys; low density of exotic weeds (especially woody weeds) and presence of key structures related to biodiversity.

3.4 Timeframes for regeneration

A key component of the threatened species licence is to set meaningful time and space conditions. This includes the setting of logging return times for areas previously harvested and areas adjacent to previously harvested areas. The EPA believes there may be an opportunity to consider setting logging return times based on the "likelihood" that a certain regeneration state has been achieved. The FPA report has provided some initial suggestions on linking return times to regeneration state (based around a 5 year timeframe). Given proposed threatened species habitat and floristic diversity objectives, do the expert assessors have any suggestions on meaningful return times associated with logging events?

Timing in the draft Standards appears to be limited to when adequate regeneration (i.e. above threshold levels) has been met and does not consider timing of operations in adjacent areas. The timing of operations in adjacent areas would need to consider the risk of damaging regeneration (harvesting operations or fire) as well as the landscape pattern and disturbance regime. To minimise risks, trees that could provide seed into a regenerating area may need to be retained until the regenerating area is of sufficient age or developmental stage to recover naturally from fires that escape from nearby operations. Brookhouse et al (2003) suggest one of a series of metrics that quantify landscape patterns of regeneration or forest structure to help ensure there is an appropriate spatial mixture.

Requirements that regeneration thresholds be met within 2 – 3 years may result in a number of "false positive issues" given the longer term cycles of seeding, rainfall, etc. La Nina / El Nino cycles are of the order of 5 – 7 years, and many eucalypts do not have annual seed setting cycles. Successful regeneration may therefore be a function of exiting seed sources (possibly confirmed during pre-harvest inspections) and subsequent rainfall, frost, and temperature patterns. Even highly successful regeneration events can be negated by subsequent frosts or periods of below average rainfall. Alternatively, apparent failures to regenerate may resolve themselves given appropriate rainfall in the third year or onwards.

Conclusion: A return to inspect the status of regeneration within 2 – 3 years (in say high initial stocking) or 5 – 7 years (low initial stocking) FTGs is reasonable for many cases but may lead to false positives and false negatives as the early stages of succession are highly dynamic and may be influenced by rainfall variation and extreme temperature patterns.

Recommendation: Include risk and the need for site occupation by damage resistant trees (e.g. minimum size and bark thickness to reduce chance of losses due to fire or abrasion) when returning to adjacent areas for logging. Consider alternatives to returning in 2 years to minimise false positives and negatives. For example, returning after a minimum cumulative rainfall threshold (calculated as part of the routine drought indices).

3.5 Assessment of regeneration 'survivability'

3.5.1 Other regeneration parameters

Other jurisdictions such as Victoria and Tasmania measure against indicators for regeneration survivability, such as "acceptable seedlings" in Victoria and regeneration height in Tasmania. Are there any meaningful, simple and clearly enforceable measures that could be set for NSW coastal and tablelands forests which have explicit linkages to the likelihood of long term survival of regeneration? Would incorporation of these requirements into a short term/operational scale post-harvest assessment program be worthwhile ?

Acceptable seedlings could include those of an acceptable species that are in a location relatively free from critical competition (over-shadowing by edge trees, weeds, etc). This type of classification would include a qualitative judgement. Literature that focuses on eucalypt species does tend to suggest that spacing – distance to a competitor and distance to the edge of the gap (where mature trees still stand) are likely to be the most important factors in survival and growth rates (e.g. Kinny et al, 2011). For light demanding species in particular, significant competition may occur when woody weeds (or others) are taller than the regeneration.

There is some unpublished research from the NSW Forestry Commission (Horne, unpub) which suggests a correlation between the mean height of *Pinus radiata* plantation seedlings at age 3 years with the stand basal area at age 10 years. However, this is the only piece of research that we are aware of that relates parameters of seedling size at such an early age with subsequent survival at a stand level.

3.5.2 Bell Miner Associated Dieback

> *Also how can risk/threat/competition factors to regeneration, such as Bell Miner Associated Dieback, weed infestation etc, be considered in a post-harvest regeneration assessment program ? Are there any meaningful indicators/thresholds of competition that may be assessed post-harvest to ascertain whether there is an elevated risk of regeneration failure?*

The FC proposed guidelines provide for 50% of coupes likely to be affected by Bell Minor Associated Dieback BMAD are inspected at 2 – 3 years to provide an early warning of regeneration failure. Such a condition does not seem to be applied to stands at risk from weed invasion or other significant factors.

BMAD is likely to be associated with limited seed set or reduced seed banks. Such limitations may have a negative impact on the numbers of regenerating seedlings, but this may not be significant if sufficient seeds still manage to germinate and occupy the site. Determination of the risk of reduced numbers of viable seedling due to BMAD is probably best carried out pre-harvest during an assessment of abundance of mature tree seed capsules.

Conclusion: The draft standards do not consider any plant size or related parameters when determining likelihood of survivability. For very young regeneration, this is probably appropriate, however over-shadowing by weeds or other non-desirable plants may be a significant predictor of survivability.

Recommendation: Revise the classification of a plot as stocked, or seedlings as likely to survive, to include freedom from overtopping by woody weeds or other non-desirable plants. Distance thresholds for overtopping may be as simple as the distance to a woody weed must be greater than height which that weed exceeds the seedling height (i.e. there is a clear zone of 45^{o} around the seedling). Some FTG may have less restrictive thresholds if the seedlings are shade tolerant.

3.6 Regeneration Assessment approach and rigour

> *Given cost constraints, FCNSW have proposed to implement a field based regeneration survey program at a broad scale and if these broad assessments find that thresholds are not met a more rigorous field assessment will occur to determine the extent of regeneration failure within the operational area. The EPA needs to be confident that the broadscale assessment approach is adequately designed and of sufficient rigour to identify areas of regeneration success or failure in the first instance. For example is the risk based sampling approach adequate? Will the sampling approach be adequate to identify substantial regeneration failures or "voids" within operational area?*

Are there other, more cost effective approaches that can be used to determine regeneration standards have been met at the operational and landscape scales?

The FC draft guidelines propose to sample a sub-set of coupes harvested using 16 m^2 plot systematically located with an average of 1 plot per 10 ha (subject to a minimum of 50 plots). The 16 m^2 plot size is used in other jurisdictions as well for regeneration surveys (e.g. Fagg et al 2013).

The number of coupes sampled varies from 10% - 50% of the total number of coupes in each FTG, with the percentage increasing as the perceived risk of failure to regenerate increases. There is no justification for the range from 10% – 50% of coupes sampled nor why a binary (stocked / not-stocked) classification is necessary. If every plot contained one healthy seedling likely to survive to maturity (stocked), there would be an average of 625 healthy and well-spaced trees ha^{-1} in the selected coupe. However, the threshold targeted number of stocked plots in each FTG is 50% which means that on average there must be at least 312 trees ha^{-1}. However the proposed sampling approach does not distinguish between the stocked plots being randomly spaced over the entire FTG or concentrated in say, one large void.

The proposed sampling technique to determine if the threshold has been succeeded is based on a systematic grid of 16 m^2 plots established in a sub-sample of harvested areas (10 – 50% of harvested coupes, depending on assumed risk of failure). If at least 50% of the 16 m^2 plots include at 1 or more “canopy species consistent with the FTG”, and no one species occurs in more than 95% of the plots then regeneration is considered successful. With an average of one plot / 10 ha (and minimum of 50 plots) a 50% success rate would equate to an average of 312 tress ha^{-1}, or a lower confidence boundary of about 230 at p=0.05. Note also that if only 95% of successful plots had one species, the confidence range for that species coverage would be 89 – 98% (p=0.05). If just 1 plot in 50 contained a different species, the coverage would be 90 – 99% (p=0.05), while statistically 0 plots in 50 still has a range of 93 – 100%.

In any nominated year, sampling only 1 coupe in 10 for the low risk FTG may easily miss coupes that have failed due to localised conditions. If a failed coupe is randomly selected and noted as a failure, the Guidelines would presumably require the other coupes also be examined to determine if the failure were more widespread. However, if a successful coupe were initially selected, there would be no follow up and any failed coupes may be missed. A low intensity, remotely sensed census of all coupes, followed by in situ measurements of questionable coupes may be a more sensible approach. Infra-red imagery from satellite, aircraft or even Unmanned Aerial Vehicles (UAVs) could be used to determine if vegetation was growing or extensive areas remained bare. Multi-spectral scanners may be used to estimate the probability of eucalypt species being present. Any coupe where the estimated percentage cover times the probability of eucalypt presence is less than a threshold value should be subject to in situ observation.

There are alternatives to the binary distribution of stocked/unstocked plots for in situ observations. Plotless samples (e.g. point to plant or plant to plant) for example may be more efficient for determining regeneration numbers and distribution. Plots of the frequency of point-to-plant or plant-to-plant distances can provide useful information of spatial patterns, voids and numbers of stems ha^{-1} ,although corrections for voids must be remembered to avoid bias in the average stocking numbers.

Conclusion: The proposed sampling is relatively simplistic and describes a process rather than an outcome. The process itself (percentage of stocked plots) is not directly related to the earlier definition of a successfully regenerated coupe (more than 250 trees ha^{-1}).

Recommendation: Multi-scale assessments of regeneration success over all coupes harvested should be considered. Given that regeneration success can be influenced by very broad (e.g. weather in a given year) or spatially explicit (e.g. topographic variation or harvesting practice) factors sampling a fraction of coupes can easily miss significant problems. Broad scale classification of likely problem areas using remote sensing should be considered to focus in situ observations. The in situ observations should be more comprehensive than just stocked/unstocked plots to maximise value of information gain. Maximum distances between trees (size and number of voids) should be part of the decision tree of regeneration success.

3.7 Use of intervention triggers

The EPA model for regeneration standards provided for the setting of management intervention triggers into the regeneration assessment program. The purpose of these triggers is for to act as an early warning for regeneration failure, so that the land manager and regulator do not need to wait a number of years to determine whether thresholds are likely to be met. FCNSW have not proposed to incorporate intervention triggers in their current settings. Is this a reasonable approach by FCNSW given the longest assessment period proposed by FCNSW is between 5- 7 years after logging?, Are there any simple measurable triggers that could be adopted by as early warning triggers for regeneration failure? Could threats to regeneration success such as Bell Miner Associated Dieback be addressed through these intervention triggers, if so how?

The stem ha^{-1} thresholds in the current draft appear unlikely to trigger a conclusion of inadequate regeneration except in extremely circumstances. As above, we believe that rapid assessment of forest function, structure and composition using remote sensing supported by in situ observation of at risk areas, after a regeneration event could produce timely warnings of the potential failure of regeneration and need for remedial action. Even the intensity of this rapid assessment could vary depending on any pre-logging assessment of mature seed source quality and quantity.

Crown closure (full occupation of the site by overstorey species) will normally occur around 5 - 10 years after disturbance. Such closure may be checked by currently available remote sensing approaches which could provide more certainty about successful regeneration of a fully functional forest.

Note however, that the idea of the new IFOA approach is outcomes based rather than procedurally based and therefore the setting of an intervention process may appear contra-indicated. The process would therefore need to be specified in terms of "alternative" quantified outcomes, like:

- There is high confidence ($p>0.05$) that at least 65% of the area is not limited by forest function, structure and composition by age 5 years; OR the distribution of distance between overstorey plants (point-to-plant) has at least 75% of healthy trees between x and y metres.
- There is high confidence ($p>0.05$) that at least 65% of the area has achieved canopy closure by overstorey trees indigenous to the area by age 10 years.

If the outputs fail to meet the standard, either remedial treatment would be required, or a case made to wait for the “next” output (delaying action but risking more expensive action and increasing liability). FC, as a commercial corporation thus retains the power to make commercial decisions based on costs and liability.

> **Conclusion**: The draft standard does not formally propose intervention triggers, but as a commercial entity, FC will need to balance its costs and liabilities.
>
> **Recommendation:** Alternative standards of outputs relevant to different ages and FTGs should be considered to allow improved confidence of success/failure of regeneration at different ages.

4 Further work

Section 3 concluded that the Regeneration Standards proposed by FC were inadequate due to limited scientific justifications and a one-dimensional focus on stocking of canopy tree species. This section outlines a recommended process to address these inadequacies.

The following is a recommended process to develop post-harvest inventory procedures integrated with a biodiversity monitoring program that continuously informs and adapts regulatory Regeneration Standards.

The consensus from an international conference on the subject of biodiversity monitoring (Klenner et al. 2009) argued that current monitoring programs and practices for managed forests are inconsistent, inadequate, and do not provide forest managers with the necessary information to make informed decisions. These authors provide a convincing argument for large scale, systematic biodiversity monitoring that is statistically robust and considers a wide range of forest attributes. The authors postulate that if forest management agencies are sincere in their desire to manage biodiversity, they need to devote the same effort and scientific rigor used to monitor tree growth and harvest rates to develop standardized protocols and rigorous sampling designs for biodiversity monitoring. However, collecting detailed information on a wide range of forest attributes is expensive and may include redundant data. There is a significant body of work to develop indices which more effectively capture information about biodiversity (e.g. McElhinney et al. 2006ab).

We agree with Klenner et al. (2009) that governments land management agencies, as well as the scientific community, need to cooperate with and support forest managers in this endeavour. Hence this proposal is based on a collaborative process to develop a practical, cost effective and scientifically robust monitoring program. A monitoring program to inform adaptive forestry management is needed because the trajectories of managed forests are inherently uncertain. This uncertainty is particularly high during the first 5-10 years post-harvesting. There is a long standing need for a robust and practical monitoring program to underpin efficient and informative inventory measurements of forest conditions at the operation scale (e.g. coups).

4.1 Recommended objectives

1. Conduct a collaborative process to develop a biodiversity (or natural values) monitoring and assessment program that supports continuous and adaptive improvement in forest operational standards and inventory processes, particularly to insure that regeneration standards (thresholds) are effective measures for the achievement of longer term biodiversity outcomes.

2. Recommend, through a collaborator process, Regeneration Standards and Thresholds that are based on the best available data and informed by a monitoring and assessment program.

4.2 Recommended Methodology

4.2.1 Literature review

There is a large body of scientific literature on principles, frameworks and indicators for monitoring biodiversity, and more broadly natural values in managed forests. The reference section below lists a few introductory papers to this long standing subject. There is a need to synthesise this literature in the context of developing a biodiversity monitoring program for harvested forests in NSW. The literature review will include a scan of the NSW agency reports relevant to monitoring the impact of forest practices.

4.2.2 Existing Monitoring

The literature review should be complemented by describing and assessing the use and suitability of past and present monitoring data available within NRM agencies in NSW relevant to commercial forest management.

4.2.3 Workshops

Schulte et al (2006) recommend that constructive bridges be built between science and practitioners to realize the goal of effective and efficient monitoring design and implementation. Hence, we recommend two collaborative workshops to develop a biodiversity monitoring program that underpins the settings (e.g. regeneration thresholds) for commercially managed forests. Similarly Lindenmayer (1999) advocates stronger links among researchers and between researchers and managers to improve the quality and validity of monitoring studies and to ensure that the results of such programs are incorporated into management practices.

It is recommended that a monitoring program be based on the principles of Lindenmayer and Likens (2010):

(1) **A conceptual model of an ecosystem or population**: A draft conceptual model of the impact of forest practices and on biodiversity and forest dynamics (trajectories) at multiple scales should be presented at the first workshop for discussion and modification. A draft conceptual model at the patch (coup) scale is shown below (Figure 1).

(2) **Good questions**: Prior to the workshops a draft set of questions should be developed for discussion at the first workshop. These questions should be informed by the literature review described above. A key broad question that needs to be addressed early in the process is; what are the long term biodiversity (natural values) outcomes for managed forests in NSW? Assuming there is consensus on this question, the next logical question will likely be; what are practical indicators of desired biodiversity outcomes for managed forests?

(3) **Strong partnerships between scientists, policy-makers and managers**: Such partnerships will likely be fostered through a workshop process that involves key agencies and expertise as suggested below.

(4) **Frequent use of data collected**: As recommended above, past and present monitoring programs and data should be assessed for utility in supporting adaptive management of harvested forests in NSW. In addition, an outcome of this process will likely be an

assessment framework (e.g. decision tree) on how operational inventory data should be used to trigger management interventions (e.g. the application of thresholds like regeneration standards).

Two workshops are recommended:

1. A broad stakeholder workshop to:
    a. Discuss and refine a conceptual model of possible trajectories of forest dynamics starting with a model similar to Figure 1.
    b. Then scope "good questions" for management and monitoring of forests. Draft questions should be prepared prior to this workshop for consideration by participants including questions about regeneration standards.
    c. Work towards a consensus of priority questions.

2. A technical working group to:
    a. Comment on the broad outcomes of the literature review.
    b. Comment on the review of past and existing forestry monitoring activities.
    c. Scope a monitoring and assessment program that is consistent with the conceptual model(s) and priority questions that come out of the first workshop. It is likely that a question around regeneration thresholds will be amongst the priority questions.
    d. Propose efficient and effective measurement (inventory) and sampling procedures to determine whether thresholds have been exceeded in the field. These procedures and techniques may include modern sampling tools provided they are commercially available.
    e. Propose regeneration standards that are continuously informed and modified by the recommended inventory and biodiversity monitoring program.

4.2.4 Workshop participants

Stakeholder participants for the first workshop should include:

- Groups active in forest conservation
- Senior EPA regulators
- Senior Forestry managers
- Forest ecologists

Participants for the second workshop (technical working group) should include:

- EPA regulators with experience in the forestry sector
- Forestry ecologists from NSW Agencies and research institutions with expertise in forest ecosystem monitoring
- Operational foresters with experience in forest inventory

4.2.5 Peer review

Independent peer review should be sought for each step of the monitoring program development including:

- The literature review
- Workshop design
- Draft monitoring framework
- Project recommendations

Review will include assessing draft designs against the common mistakes in monitoring design described by Failing and Gregory (2003).

4.3 Recommended deliverables

- Literature review of principles, frameworks and methodologies for assessing the impact of forestry practices on biodiversity and other natural values
- Initial monitoring questions, objectives and conceptual model to be presented to the first workshop
- Report on the outcomes of the first workshop for informing by the second workshop
- Report describing the recommended design of an adaptive monitoring program that:
    - assesses the impact of forestry operations on biodiversity and other natural values
    - provides insight for continuous and adaptive improvements in sustainable forestry practices
    - Specifically underpins regeneration standards and operational monitoring (inventory)
    - provides an indicative cost of implementing the recommended monitoring program that underpin sustainable forestry practices.
- Recommended Regeneration Standards and thresholds

4.4 Expected outcomes

1. Recommended Regeneration Standards, including thresholds, based on the best available data and expertise.
2. A monitoring program design that is:
    - implementable
    - scientifically rigorous and refined by peer review processes
    - broadly costed
    - that will effectively and efficiently underpin adaptive forestry standards (e.g. regeneration) and practices in NSW

4.5 Indicative timeline

- Review of relevant literature and existing data: 4 weeks
- Workshops: 2 weeks
- Final report preparation, review and revisions: 4 weeks

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