REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

"Kahikatea Forest Green Wheel" - developing a tool to assess ecosystem recovery of Kahikatea remnants in the Waikato region

Waikato
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Abstract

The Waikato Regional Council aims to create a "Kahikatea Forest Green Wheel" to help landowners and resource managers measure how similar a given kahikatea forest fragment is to the most healthy and functioning example we could expect in the contemporary ecological and economic setting.

The Green Wheel is a tool designed to assist restoration managers to evaluate the degree to which the ecosystem under treatment is recovering over time. It has been adapted from the Ecosystem Recovery Wheel developed by the Society for Ecological Restoration Australasia (McDonald *et al.* 2016).

It is a conceptual model that allows users to score key abiotic and biotic attributes that measure changes in ecosystem condition along a continuum from degraded to intact (or vice versa). The wheel design allows for variation in the number of attributes and sub-attributes, allowing customisation of the tool for a range of ecosystem types.

Each sub-attribute is accorded a score from a five-star rating system, and visually presented on a wheel graphic, to enable landowners or site managers to quickly identify areas that need improvement, and to track restoration progress towards a higher functioning state or a lower functioning state over time and between sites.

A list of ecosystem attributes (derived from those of McDonald *et al.* 2016) and relevant sub-attributes has been proposed for assessing the health and functioning of kahikatea forest fragments in the Waikato Region. These are grouped under the Pressure, State, Response framework used by the council for monitoring and reporting on the state of the environment.

The attributes and associated scoring system for a Waikato Kahikatea Forest Fragment Green Wheel are presented, along with proposed field datasheets and a completed example for a real-life kahikatea fragment. Recommendations include suggested methods for collecting information to apply each standard, and whether best applied by the landowner/site manager, a specialist contractor, or via GIS analysis conducted by the Waikato Regional Council.

1 Introduction

Kahikatea (*Dacrycarpus dacrydioides*), an ancient podocarp, is New Zealand's tallest native tree species. Kahikatea stands are the characteristic forests of fertile floodplains, lake margins and riverbanks throughout the Waikato Region and elsewhere in New Zealand. They are a classic landscape feature of the contemporary Waikato lowlands.

Before humans arrived in the Waikato, kahikatea-dominant forests grew in the wet areas beside lakes and swamps, and formed extensive areas of the great floodplains of the Waikato, Waipā, Piako and Waihou rivers. It is estimated that some 189,772 hectares of kahikatea-dominant forest was present in the Waikato Region prior to human occupation[1]. Today these forest types occupy 2,760 hectares (1.5 % of their pre-human extent), including some that are so fragmented they are classified as treelands (less than 80% canopy closure). They occur as small fragments, between 0.01 and 35 hectares, over half of the mapped 3,060 patches are less than 5 hectares. Many are secondary forests, grown anew on land previously cleared by early settlers. Most of them grow on the river floodplains of the Waikato Basin, Hauraki Plains and Mōkau River. Kahikatea forest remnants provide core habitat and stepping stones for native lowland fauna, however, introduced pests, edge effects, and intensification of pastoral farming threaten the health and sustainability of these remnants.

The Waikato Regional Council (the council) has taken steps to encourage protection and restoration of these iconic indigenous forest stands, including monitoring, research, financial incentives, education and information. In 2006, the council supported Project Kahikatea, established to document the current condition of kahikatea stands in the Waikato lowlands, and identify options to help landowners protect and enhance the remaining stands. More recently, the council has updated factsheets, case studies and webpages, providing detailed advice to those seeking to restore or replant this forest type.

To encourage and measure restoration efforts at individual sites, the council has sought to develop a tool that ranks any given stand on a 5-star rating basis for a range of attributes relevant to kahikatea forest health and functioning. A ranking system is proposed here for a "Kahikatea Green Wheel" (KGW), based on the Ecosystem Recovery Wheel developed by the Society for Ecological Restoration of Australasia (McDonald *et al*. 2016). This can form the basis of a user-friendly illustrated guide for landowners and land managers.

1.1 SERA Ecosystem Recovery Wheel

The Ecosystem Recovery Wheel (ERW) is a tool designed to assist restoration managers evaluate the degree to which an ecosystem under treatment is recovering over time (McDonald *et al*. 2016). It was developed as part of a package of National Standards for the Practice of Ecological Restoration by the Society for Ecological Restoration of Australia (SERA). The ERW compares a suite of ecosystem-relevant attributes against the state of a reference "healthy" ecosystem.

The ecosystem attributes published by SERA are:

1. Absence of threats
2. Physical conditions
3. Species composition
4. Structural diversity
5. Ecosystem function
6. External exchanges

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[1] Data generated from maps of pre-human vegetation developed by Waikato Regional Council. This is likely to be a slight underestimate as it does not include small patches of kahikatea-dominant forest mapped as a kahikatea forest-wetland mosaic.

Each attribute comprises three sub-attributes, to which are assigned a recovery level score based on a 1-5 star ranking system. Five-star recovery is defined as being "*where the ecosystem is on a self-organising trajectory to full recovery based on an appropriate local indigenous reference ecosystem—is the standard to which all ecological restoration projects aim*" (McDonald *et al*. 2016).

The tool was developed with the intention that a "*practitioner with a high level of familiarity with the goals, objectives and site-specific indicators set for the project and the recovery levels achieved to date can assign the value for each sub-attribute after formal or informal evaluation.*" (McDonald *et al*. 2016).

To assist practitioners assign the appropriate value, a suite of descriptive standards (ideally quantifiable) is developed for each sub-attribute, which define the degree to which the site meets the ideal end state. McDonald *et al.* 2016 provide a generic guide to the 5-star system for each of the high-level attributes (see Table 1) and encourage users to develop specific standards for sub-attributes relevant to their given ecosystem type. Given the very large range of ecosystem types for which ecological restoration is needed, attribute categories are, by necessity, broad and may only be measurable when subdivided into more detailed sub-attributes that are specific enough to inform a given project's goals and objectives needed to achieve the end state target.

The average score of the sub-attributes will return the star rating for that attribute. The average of all attributes will return a single measure of recovery outcome. The results can be graphically portrayed in the form of a wheel (see
Figure 1), with the length of the green "spoke" indicating progress towards the ideal end state (a 5-star rating).

Table 1: Summary of generic standards for 1- to 5-star recovery levels[2].

Number of stars	Recovery outcome (Modelled on an appropriate local indigenous ecological reference)
1	Ongoing deterioration prevented. Substrates remediated (physically and chemically). Some level of indigenous biota present; future recruitment niches not negated by biotic or abiotic characteristics. Future improvements for all attributes planned and future site management secured.
2	Threats from adjacent areas starting to be managed or mitigated. Site has a small subset of characteristic indigenous species and there is little if any internal threat from undesirable species. Improved connectivity arranged with adjacent property holders.
3	Adjacent threats being managed or mitigated. A moderate subset of characteristic indigenous species are established and some evidence of ecosystem functionality commencing. Improved connectivity commencing.
4	A substantial subset of characteristic biota present (representing all species groupings), providing evidence of a developing community structure and commencement of ecosystem processes. Improved connectivity established and surrounding threats being managed or mitigated.
5	Establishment of a characteristic assemblage of biota to a point where structural and trophic complexity is likely to develop without further intervention. Appropriate ecosystem exchanges are enabled and commencing and high levels of resilience is likely with return of appropriate disturbance regimes. Long term management arrangements in place.

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[2] McDonald *et al*. 2016
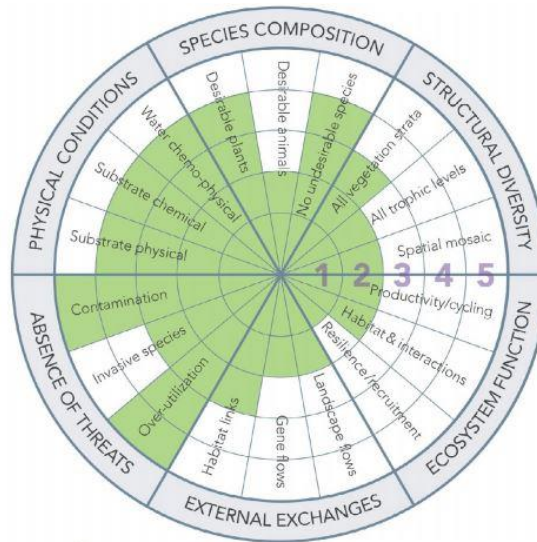
Figure 1: Simulation of a completed ecosystem recovery wheel (McDonald *et al*. 2016)

2   Developing a Kahikatea Green Wheel

Utilising the framework of the SERA Ecosystem Recovery Wheel, a set of attributes and sub-attributes, with specific ranking standards has been developed for kahikatea forest fragments in the Waikato Region. These form the basis of a Kahikatea Green Wheel.

The Kahikatea Green Wheel (KGW) is a tool for landowners or site managers interested in assessing the health of their forest patch. It helps to identify management needs and measure progress towards a best state possible for the patch (within the limitations of the contemporary landscape setting, depleted native flora and fauna, and land use pressures).

The ranking system (1-5 stars) has been designed to follow a trajectory towards a restored state. While the ranks can be used to show deterioration (if a score drops over time), the trajectory from restored to a degraded state can be quicker than the pathway towards restoration. For instance, forest size can be reduced very quickly (hours or days) via fire or felling, while forest establishment takes decades if not centuries.

The KGW was developed by determining sub-attributes most relevant to the health and functioning of lowland Waikato kahikatea forests that can provide timely and measurable information regarding the approximation of a given stand to a healthy "reference" site. They focus on aspects of kahikatea forest health that are within the ability of landowners or site managers to control.

As far as possible, data from published and unpublished sources were used to develop descriptive and, in most cases, quantitative standards for each sub-attribute. A list of reference species (those that most frequently occur in healthy kahikatea forest remnants) has been generated from published species lists, to assist with assessing species composition. A simple spreadsheet with built-in calculations has been developed to allow quick assignment of relevant rank to a number of species-related sub-attributes.

For spatial sub-attributes, the council has used a map of kahikatea-dominant forest types[3] to calculate size, shape, proportion of interior forest and distance to nearest large forest patch metrics for every mapped stand in the region. Regular updating and publishing of this information on line means landowners need only look up the relevant spatial data for their site.

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[3] Created by visual analysis and digitising over 2012 air photographs (WRAPS) supplemented by 2016-17 oblique aerial photographs

Despite the relatively large number of sub-attributes generated for the KGW (31), field testing (Smale 2018) has shown that many are relatively quick and easy to apply, while the council GIS analysis and species assessment spreadsheet also simplify use of the tool. The tool has not yet been tested by non-professionals, and will need further refining and additional visual cues to assist uptake by landowners. Supporting products may include a richly illustrated visual instruction guide and a smartphone application, supported by regular GIS analysis of all kahikatea sites by the council.

2.1 Design considerations and attribute recommendations

The following were considered when determining appropriate sub-attributes and ranking system standards for a kahikatea forest fragment recovery wheel (KGW).

1. A "best-case" scenario for Waikato kahikatea forest fragments was used as a reference state to generate the 5-star scoring system. This was developed by assessing a set of descriptions of sites generally considered to be of good ecological health. A range of factors was assessed, but mainly based on flora lists, being the most consistently reported information in site descriptions. A decision was made to not differentiate between regularly flooded and drained sites for reference descriptions, as too few regularly flooded patches remain to be able to create a representative description, and there is limited scope to restore hydrology of drained stands without significantly affecting surrounding land use and properties. It has therefore been accepted that a "best case" scenario for lowland Waikato kahikatea fragments will unlikely include a return to a regularly flooded state.

2. In the Waikato Region kahikatea-dominant forests originally developed through wet flax and shrublands following flood-induced land clearance. Most contemporary Waikato fragments are relatively young (regenerated in areas of poor drainage since European clearance), small in extent, and now drained as part of landscape-scale drainage systems. It is unrealistic to expect such sites to ever reach (or, if of pre-European age, to be returned to) a fully pre-human state (i.e. extensive in area, regularly flooded, regularly catastrophically damaged and re-established from abundant local seed source). Therefore, the best-case state cannot be based on a pre-human condition because that will not be attainable, rather it will be the best that can be achieved given the current environment and a reasonable degree of effort within a relatively short time frame (20-50 years). The focus therefore should be on managing threats (e.g. stock, animal pests, weeds) and restoration or re-creation through planting. As Burns *et al.* (2011) reported with respect to fencing and pest control, "*Neither treatment... led to the restoration of indigenous species richness to reference forest levels, nor allowed densities of juveniles of shade-tolerant canopy species to establish to levels commensurate with replacement of existing canopy trees.*"

3. The attributes will ideally be framed using the State of the Environment (Pressures, State, Response) framework adopted by the council for environmental monitoring.

4. The selected attributes:

   a. Should be variables that are capable of measurable change over a relatively short time frame (5-10 years), and that are within the capacity of a landowner to change (for instance, a landowner cannot change the soil type, but may be able to change soil condition).

b. Should, as far as possible, be easy enough for landowner to apply, while acknowledging that not all attributes will be, e.g. vegetation attributes may require specialist plant identification skills. The method will indicate those which can be applied by a landowner and those which will require a contractor or which the council can provide (e.g. spatial attributes).

c. Should not require frequent repeat visits. A suitable timeframe is recommended for re-assessment, acknowledging that different attributes may have different time intervals depending on anticipated velocity of change, frequency of necessary data supply (e.g. aerial photos) and expense/ time.

d. Should largely rely on low-tech/ inexpensive equipment that is normally owned by a landowner. Specialist equipment may be used by contractor, or if easy for landowners to access.

e. Should largely be based on field measures, ideally avoiding laboratory analysis or expert (off-site) analysis. For some attributes verification may be required by an off-site expert, e.g. tracking card or chew card mark identification.

f. Ideally should not include measures that require permits (e.g. lizard handling) or involve significant health and safety issues.

g. Should focus on ecological condition, not ecological significance, and as such will not include special features such as cultural values or threatened species. Species threat status is subject to change, and the presence of a threatened species *per se* is not necessarily reflective of a restored kahikatea forest. Rather the focus will be on the presence indicator species for a reference kahikatea stand.

h. Should as far as possible rely on use of quickly gathered hard data to minimise observer bias, however it is accepted that for some attributes, application of a score will be somewhat subjective.

i. Should be relevant to the majority of Waikato kahikatea stands (for instance water quality has not been included as an indicator because many stands do not have constant surface water or streams).

5. For some attributes there may be no published science to justify inclusion at this stage. There was limited scope in the project budget to delve deeply into literature, so some attributes have been treated as "potential attributes" that need further development or investigation. For example, there is currently limited data on soil qualities in kahikatea - most Waikato studies compare soils under pasture with "natural" which could reference any type of native forest - and as such a soil compaction attribute is yet to be developed. Further, there is poor correlation between visual soil characteristics and laboratory-analysed data which limits the ability to create a rapidly applied visual assessment of soil as a proxy to soil health (M. Taylor, the council, pers. comm. 2018). The authors are aware that such information has been collected from many of the Waikato kahikatea fragments and is awaiting analysis (Smale pers. comm. 2018). As these data may in future become available, the sub-attribute has been included but, in the meantime, will not be assessed. The nature of the KGW is such that an unmeasured sub-attribute can simply be excluded from the calculation of the average returned for a given attribute, without affecting the overall score

6. Recovery of a given attribute can take one of several trajectories. It may be rapid then slow (natural log), slow then rapid (exponential), steady (linear) or more-or-less instant (e.g. fencing instantly excludes stock so the pressure is instantly

changed, although the ecosystem recovery – a state indicator – will take longer). The final scoring system should reflect the likely trajectory, for example for an attribute that recovers exponentially, a 5-star score may be twice the value of a 4 star. The ranking system will divide the 5-star scores equally for liner trajectories, finely initially for exponential trajectories, and coarsely at first for natural log trajectories. This is to ensure the landowner/site manager does not lose enthusiasm while waiting for protracted change at the initially slow pace of an exponential trajectory or feel satisfied and cease management following early rapid improvement of a natural log trajectory.

7. It is not recommended that age-distribution of kahikatea trees be included as a state attribute. Most contemporary stands are even-aged, and that won't change in a short time frame. Presence of shade-tolerant seedlings/saplings can indicate the scale of regeneration processes, however kahikatea itself will not regenerate in shaded conditions (under its own canopy).

8. As far as possible, field or GIS data from contemporary kahikatea forest stands has been used to generate standards for the 5-star scoring systems, however some assumptions have been made. For instance, planted buffers have been assumed to take probably 5 years to reach heights of 2-3 m (tall and dense enough to dampen forest edge effects), while measures of change in fragment size or shape consider only that portion of a planting zone that can be ecologically classified as kahikatea forest (>3 m tall, >80% canopy closure); a process that could take 15-20 years in a planted buffer or edge vegetation.

9. Habitat diversity has not been included as an attribute in the KGW. Habitat diversity (including vegetation mosaics) contribute to biodiversity and is regularly used as a measure of site ecological value. However, diversity does not necessarily indicate that a site is healthy or functional, as for some ecosystem types this measure is naturally low in (e.g. peatlands). As with threatened species, habitat diversity adds ecological value to a site but is not necessarily a measure of a "restored state". Kahikatea relies on disturbance to regenerate, but the remaining Waikato sites are too few, too scattered and too small to deliberately disturb them to maximise diversity and stimulate kahikatea regeneration. Rather, we should be looking to re-create kahikatea forest in areas already cleared and enlarge the remaining fragments with buffer and linkage planting in areas suitable for kahikatea establishment.

2.2 Proposed KGW attributes

In developing a Green Wheel for Waikato kahikatea fragments, it was quickly determined that limiting sub-attributes to just three broad entities (as described by the SERA system) masked important management actions or required a degree of meaningless "averaging" across very different issues, for instance by limiting assessors to a single score for all invasive plants and animals. Fortunately, the SERA wheel design allows for addition of further attributes, which can be individually scored to provide management level information, but also aggregated to give a composite attribute score.

We retained the full list and structure of the SERA attributes, but we also considered it useful (and important) to include a "response" attribute, indicating management efforts made towards restoration. This helps track progress towards planning and implementation, and provides a reward feedback for attributes that may be very slow to respond, such as re-vegetation.

We also changed the terminology of some attributes in the SERA framework to less technical language to cater for a broader audience, with the expectation that some of the attributes will be measured and assessed by non-experts.

The proposed set of Waikato Kahikatea Green Wheel attributes and anticipated assessors is given in Table 2.

A large number of sub-attributes (31) are included, however:
- many can be quickly applied,
- some can be measured and scored for all kahikatea sites by the council (spatial sub-attributes), and
- several attributes can be scored from a single dataset (such as a vascular plant species list).

Table 2: Waikato Kahikatea Green Wheel attributes and anticipated assessors

PSR framework	Attribute	Sub-attribute		Assessor
Pressure indicators:	Attribute A: Threats	(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11)	stock access feral ungulates browsers mammalian predators canopy weeds shrub layer weeds ground cover weeds pest plant presence nutrient input drainage human footprint	Landowner/ Site manager and contractor
State indicators:	Attribute B: Physical conditions	(12) (13) (14) (15)	size shape forest interior buffering	Waikato RC Landowner (#15)
	Attribute C: Species composition	(16) (17) (18)	dominance of native plants characteristic plant species indicator animal species	Contractor (or landowner for #18)
	Attribute D: Community structure	(19) (20)	vegetation layers canopy condition	Contractor
	Attribute E: Ecosystem function	(21) (22) (23)	winter bird food all season bird food plant recruitment	Contractor
	Attribute F: External exchanges	(24) (25) (26)	landscape matrix (nearby habitat) habitat links - terrestrial habitat links - aquatic	Waikato RC/ Landowner (for #26)
Response indicators	Attribute G: Management regime	(27) (28) (29) (30) (31)	legal protection management plan animal pest control effort invasive plant control effort re-vegetation effort	Landowner/ Site manager/ Waikato RC for #27

2.3   KGW Attribute ranking

Having identified the relevant sub-attributes, the next step is to assign specific ranking standards to distinguish the steps along the restoration journey.

The 5-star ranking system must include a target at the 5-star end of the spectrum that is based on evidence where possible, and takes into account the current landscape structure and processes.

The SERA system starts scoring from a baseline of restoration initiation (see Table 1), such that a score of 1 is "*prevention of further deterioration and plans are in place for restoration*" (McDonald *et al*. 2016). It is based on the presumption that the restoration journey has started for all attributes when the wheel is first applied. In contrast, the KGW places that stage at the 2-star level, to identify actions that are yet to be commenced (1 star). This is in recognition that restoration projects, particularly when funded by private landowners, rarely commence all restorative actions simultaneously. For the Kahikatea Green Wheel, we based our lowest score around the state of a site that is still recognisable as a kahikatea fragment, but in the worst possible state in terms of the relevant ecological criteria.

To generate evidence-based standards and to define a 5-star site within the constraints of the current landscape we compiled available information on Waikato kahikatea fragments.

1. Firstly, we described generic kahikatea forest types in the region, based on the ecosystem classification work of Singers and Rogers (2014) and follow-on work (Singers and Lawrence 2015, and Singers *et al.* 2017). See section 2.3.1.

2. We then used published and grey literature to compile a detailed list of indigenous and exotic species recorded in Waikato kahikatea forests (noting which were very frequently encountered in relatively healthy, ungrazed sites, and therefore highly characteristic of kahikatea forest). Adding annotations to identify which species provided winter or other season bird food assisted with defining the standards for resource provision sub-attributes. We annotated the exotic plant list with those that are regional plant pests, and expanded it to list all Regional Pest Management Strategy[4] (RPMS) species, irrespective of the likelihood of them appearing in a Waikato kahikatea stand – to ensure our judgement calls did not cause an unexpectedly located RMPS species to be missed. See section 2.3.2

3. For GIS-based attributes we analysed the most current map available of Waikato kahikatea forest fragments, summarising size-frequency data, shape, edge:interior ratios and isolation metrics. These were then applied as attributes to every mapped kahikatea fragment in the Region. See section 2.3.3.

4. For indicator fauna, we considered which species would be easy and low cost to measure, sensitive to restorative actions, and relatively immobile (to ensure they represent the patch they occupy rather than the wider landscape). We determined that ground and tree weta species would be a suitable indicator of fauna condition (e.g. Watts *et al.* 2011), and used unpublished data collected from a kahikatea stand within a mammalian pest fence (Rotopiko) to generate a 5-star standard for tracking rates. See section 2.3.4.

5. For threats that are common to many native forests (stock damage, animal pests, weeds, human disturbance), we used expert knowledge and existing assessment standards such as the FORMAK guide (Handford 2002) and developed standards that incorporated anticipated trajectories of improvement. See section 2.3.5.

2.3.1   Kahikatea forest types

Dodd *et al.* 2011 note (albeit with respect to tawa fragments in the Waikato rather than kahikatea) that "a *key issue is that of setting appropriate goals for managing forest fragments, and … the use of large ungrazed and pest-controlled forest systems as a benchmark for restoration is not entirely appropriate*" because the prevailing agricultural land-use matrix within which these fragments lie is unlikely to change in the foreseeable future, and many of the drivers

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[4] Waikato Regional Council 2014. Waikato Regional Pest Management Plan (RPMP) 2014-2024.

of disturbance will remain present in the current landscape context indefinitely. Dodd *et al.* 2011 advise that "*we must seek goals that reflect reasonable targets for fragmented ecosystems*".

In developing the KGW ranking system, it was pertinent to look at the original state of kahikatea as an extreme benchmark of a fully restored state, and temper that with quantitative and qualitative descriptions of a suite of better-quality examples of contemporary kahikatea fragments in the Waikato Region (reference sites).

Singers and Rogers 2014, Singers and Lawrence 2015, and Singers *et al.* 2017 describe three kahikatea forest types in the Waikato Region (compiled excerpts). Some types are mapped as mosaic vegetation with kahikatea forest patches inter-mixed with wetland vegetation types.

MF4: Kahikatea forest
Occurs primarily in sub-humid to semi-arid climatic zones on lowland Holocene flood plains with poor-draining recent (gleyed alluvium), gley soils (moderate to high fertility) and organic soils. Rarer examples occur on lake and lagoon margins. Subject to regular frosts and periodic flooding, resulting in extended spells of water-logged soils that are generally dry in summer. Characterised by abundant kahikatea, capable of forming a very tall, near-monotypic canopy. Along streams and rivers where soils are better drained, mataī is present and can be locally co-dominant with kahikatea. Sub-canopy species include ribbonwood, lacebark, kōwhai, tītoki, māhoe, kaikōmako and divaricating shrubs. Local variation occurs with the presence or absence of sub-canopy species, especially ribbonwood, houhere, tītoki, kōwhai, pōkākā, māhoe and tarata. Pukatea is usually present where frosts are light. Understorey typically comprises divaricating shrubs including tūrepo, swamp māhoe, round-leaved coprosma and poataniwha. This ecosystem often intergrades to either non-forest wetland or, on better-drained soils, alluvial forest types containing abundant tōtara, mataī and, locally, tītoki; and in the northern North Island, puriri. This ecosystem type is very similar to WF8: Kahikatea, pukatea though restricted to cooler and frost prone inland areas that are too inhospitable for pukatea and swamp maire.

WF7-3, Kahikatea, puriri forest
A subset of Puriri forest. Not described in detail in any of the Singer *et al.* reports.

WF8, Kahikatea, pukatea forest
Essentially a swamp forest growing particularly on organic and gley soils with a high water table in warm to mild climates where the distribution of kahikatea and pukatea overlap, and on poor draining soils on flat alluvial terraces, forest-wetland margins. Dominated by podocarp–broadleaved forest, with emergent trees or a canopy of kahikatea and pukatea, and locally, rimu. Swamp maire occurs in areas with a high water table, with tawa, māhoe and locally, tītoki on areas of drier ground. Kiekie, whekī and supplejack are often abundant, creating a dense structure and sub-canopy. Characteristic forest-floor species include mapere, swamp astelia, parataniwha and kiokio.

Threats: European colonisation greatly reduced the extent, as it contained large volumes of valuable timber (e.g. kahikatea), and it occurred on flat land that was highly productive once it was cleared and drained. Virtually all extant examples are small, fragmented and have modified hydrological regimes because of drainage; most are surrounded by intensive agriculture. Major threats are: lowering of the water table; increased fertility, especially of phosphates; and weed invasion. Fragmentation has other consequences, including increasing edge effects and incidental damage from surrounding land uses. Lowering of the water table will likely facilitate invasion by a wider range of plant species (both native and introduced) normally occurring in drier forest types. Despite being long recognised as a highly under-represented ecosystem type, many examples remain legally unprotected and grazed by stock.

Burns *et al.* 1999 state that the Waikato lowland kahikatea fragments "*… are not old growth stands but were formed by kahikatea acting opportunely to colonise large gaps created by anthropogenic disturbance. In these stands, kahikatea may have colonised habitats not normally available to it under natural disturbance regimes or in the presence of then-absent competitors.*" Therefore, assessing these young stands against old-growth stands such as those found in the Paengaroa Scenic Reserve in Taihape would be inappropriate, and reference sites for the Kahikatea Green Wheel should be selected from the suite of younger stands in the Waikato basin and Hauraki plains.

2.3.2   Kahikatea reference sites

To generate evidence-based standards for kahikatea sub-attributes, a literature review was undertaken of site descriptions for Waikato forest fragments. The most commonly reported data are floristic-species lists, almost always of vascular indigenous plants, and more recently also exotic (non-native) plant species.

The star system developed for the KGW is somewhat plant-centric because:
- Most plants are present year-round and easy to encounter.
- They indicate a range of factors (representation, drainage, browsing pressure, bird food resources, natural character).
- Information on kahikatea forests floristic data is more readily available in the literature than other attributes.

From a set of 13 fenced and relatively intact Waikato kahikatea fragments, a set of floristic attributes were derived and used to calculate the "average" condition for a relatively healthy site (see Table 3).

The maximum recorded values for floristic sub-attributes were not used to define the 5-star standard because they may be extreme outlier values for various reasons – e.g. unusually large size, close proximity to seed source, or species lists that include adjacent ecosystems. They could therefore establish unachievable targets. Further, our reference site flora lists may include species that are "vagrants" (outside their normal range) or only present as unestablished seedlings that may not have survived in the site. Slightly higher than the average values were used to define a 5-star score – meaning that a 5-star site is *better than the average of the best set of reference sites we ha*ve. This reflects that even our best remaining sites are degraded, and a 5-star site is among the top 50% of the best sites remaining.

It was considered appropriate to include, in the floristic counts, species that have been planted if they are ecologically appropriate to the site. Active planting is a key restoration technique undertaken to counter the isolation and reduced bird distribution that otherwise limits plant species establishment in a small fragment. As such planted species should be included in the measures when assigning sub-attributes.

To define a representative suite of kahikatea plant species (as a measure of how "typical" the species composition is), we identified plant species that were reported in more than half of our reference stands and called them "characteristic" species. However, these are the *most* representative, and it should not be assumed that less frequently recorded species are ecologically inappropriate. We found 63 vascular plant species that occurred in more than half of our reference sites (Claudelands Bush had 62 of them).

Table 3: Floristic attributes of 13 representative Waikato Kahikatea Fragments

Kahikatea stand	Area (ha)/ Hydrol.	# native vascular plants	# exotic vascular plants (RPMS)	% native	# charact. species[5]	# winter bird food species	# bird food species	Info Source
Awaroa	Wet	120	46 (5)	72	53	18	52	Reeves 2012
Kopuatai	Wet	80	29 (6)	73	38	12	32	Wildlands 2017
Pehitawa	Wet	105	34 (7)	76	50	18	54	Lusk 2015
Rotopiko	1.2 ha / Damp	73	28 (6)	72	40	18	38	Denyer, unpub. list, 2017
Orini	7 ha/ Dry	103	no data	n/a	59	15	47	de Lange 1989

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[5] Those species found in > 50% of our reference sites. Excludes planted non-local native species.

Kahikatea stand	Area (ha)/ Hydrol.	# native vascular plants	# exotic vascular plants (RPMS)	% native	# charact. species[5]	# winter bird food species	# bird food species	Info Source
Burbush	1 ha/ Damp	42	23 (3)	65	37	3	17	de Lange and Champion 1998
Gordonton	2 ha/ Drained	37	28 (2)	57	31	4	15	Smale *et al.* 2005
Claudelands	5.2 ha/ Drained	107	18 (6)	86	62	21	66	Whaley *et al.* 1997, Smale et al. 2005
Marychurch Rd	3.1/ Drained	109	15 (4)	88	59	9	30	Smale *et al.* 2005, de Lange 2014
Whewell's Bush	9.9 ha/ Drained	39	13 (5)	75	56	7	25	Smale *et al.* 2005, de Lange 2014
Yandleys	Drained	67	54 (8)	55	49	8	24	Burns 1998
Arnold's Bush A	3.8 ha/ Drained	53	22 (2)	71	35	8	25	Smale *et al.* 2005
Arnold's Bush B	3.8 ha/ Drained	63	7 (1)	90	44	12	32	Smale *et al.* 2005
MAX		120	(RPMS 8)	90	62	21	66	
MIN		37	(RPMS 1)	55	31	3	15	
Mean		77	(RMPS 4.5)	**73**	**47**	**12**	**35**	

The following five-star standards were applied to floristic sub-attributes:

- **Sub-attribute 16 Dominance of native species:** Over 80% of the species present are native species that are appropriate for kahikatea forest (i.e. from the full list of naturally occurring species found in kahikatea stands, but allowing for qualified botanists to add species not on the reference list that they are confident are naturally occurring/ecologically appropriate). This is broader than the list of "characteristic" species, which are those found in >50% of the best 13 sites for which data were available. This indicator is focussed on the ratio of appropriate native species to exotic and non-local native species.

- **Sub-attribute 17 Characteristic species**: More than 50 of the 63 characteristic species are present (based on an average of 47 rounded up).

- **Sub-attribute 21 Winter bird food:** 15 species – note there is variation in the literature (and likely in the field) on fruiting/flowering times for species that provide high energy food to forest passerines, so there may be some debate around whether a given plant species provides winter food.

- **Sub-attribute 22 All season bird food:** 40 species (rounded). We raised the number above the average to account for the likelihood that some qualifying species may be present in very low numbers or as non-fruiting immature plants only. To discourage planting of inappropriate native species only those species characteristic of kahikatea remnants will "count" towards this score. It was also considered to limit this attribute to only those species that are present as mature plants (i.e. capable of producing nectar or fruit), however there is little that managers can do to improve that (it is largely a factor of time rather than management action) and it simplifies the process to just include species that are present whether currently providing food resource or not.

For regional pest plants (RPMS species) we did not limit distribution to within the actual stand, but also within a 50 m radius around the stand to provide early warning of potential infestation of a managed invasive plant species near the stand. For sub-attribute 8 we focused on the number of invasive (RPMS) species, not their abundance. The more species present, the bigger the management task to prevent their spread. A 50 m radius was applied because weeds in the vicinity pose an invasion risk (assuming some shade-tolerance). While plant pests can be dispersed to the site via wind or birds from more than 50 m away, this radius was considered a practical distance for field assessment because it is close enough to be checked easily with a visual assessment and is more likely to be on the same property (under landowner's control). The RPMS includes almost 80 plant pest species, but many are not likely to be found in kahikatea forest (e.g. estuarine, light-demanding, or not yet recorded in the region). An estimated 20-30 species could potentially occupy kahikatea stands, particularly near gardens or abandoned homesteads. In the reference sites 16 RMPS species were recorded in total, with a maximum 8 at one site. It is unlikely that more than 10 RPMS species would be present in one site, but as these are judged to have the greatest potential invasion impact in the region the bar has been set relatively low for this indicator (a total of 6 species is sufficient to trigger the lowest star rating). By contrast, 5 stars reflects the possibility of a zero presence of pest plants.

2.3.3 Spatial analysis

To determine appropriate and realistic contemporary standards for the spatial metrics (size, shape, isolation etc), we again used kahikatea reference sites, based on a recent map of kahikatea forest patches in the Waikato Region[6].

For every kahikatea forest polygon in the current Bioveg 2012 data layer (The council Biovegetation maps 2012), values for each of the sub-attributes listed in
Table 4 were calculated. Bioveg 2012 kahikatea polygons were visually inspected onscreen and classified as either treeland (<80% canopy closure) or forest. Treelands will score poorly for most attributes. The values returned for forest polygons were used to generate standards, being better "reference" sites than areas of kahikatea treeland.

It is proposed that in-house GIS analyses will be performed to produce of the required range of spatial attributes for all kahikatea polygons in the region and the resulting data will be made publicly available on the the council website for landowners to extract; saving them effort and ensuring consistent measurement of the attributes (reducing observer bias). This spatial data is not considered sensitive information as it contains no personal information and can be calculated by anyone using publicly available tools such as Google Earth. Simple "if/then formula" can be used to automatically determine the star-ranking for each sub-attribute based on a site's data. However, it is useful to also present the actual data (e.g. area in hectares) in case ranking standards change, and to show changes within the range of a single star rating.

To be of value for monitoring change, the Bioveg layer will need to be regularly updated with new underlying aerial or satellite images, re-digitised, and the listed spatial attributes updated.

Table 4: Methodology and results for spatial sub-attributes of Waikato kahikatea forest fragments

Sub-attribute	Methodology – based on Bioveg 2012 polygons mapped by the Waikato Regional Council (Waikato RC).	Range for Waikato fragments min-max (mean)
12. Size_ha	Add the polygon size (ha) as an attribute to areas mapped as kahikatea forest.	0.01 -24.3 ha (1.2 ha)

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[6] waikatoregion.govt.nz/vegetation-biodiversity-map

Sub-attribute	Methodology – based on Bioveg 2012 polygons mapped by the Waikato Regional Council (Waikato RC).	Range for Waikato fragments min-max (mean)
13. Shape[7] index	Add the actual perimeter (m) of the kahikatea forest polygon as an attribute. Then calculate (for each polygon) the minimum possible perimeter (m) for its size, and return the ratio of actual to minimum as a Shape Index attribute (e.g. if actual is 200 m and minimum is 100 m. SI =2)	1.0 - 5.2 (1.6)
14. Forest interior_%	Measure the area of the kahikatea stand that is >60 m from an indigenous forest edge (any type of indigenous forest, it may either be solely kahikatea forest, or another forest type contiguous with the kahikatea forest being assessed). The percentage area of the kahikatea forest that is within the forest interior should be entered in the attribute field.	0.0 – 37 % (0.6%)
24. Landscape matrix (amount of nearby habitat)_%	Measure the total (summed) area of indigenous forest or scrub (using Bioveg) within a 1000 m (1 km) "doughnut" of the kahikatea forest boundary. Calculate the % of that 1 km doughnut zone that has indigenous forest or scrub cover. Larger kahikatea forest patches will have a larger 1 km radius around them because it is measured from the forest edge, not from the forest centre, but the sub-attribute is standardised by calculating the % of surrounding landscape in indigenous forest or scrub habitat, rather than the total area.	0.0 – 96 % (12.8%)
25. Habitat links (terrestrial)_m	This is a measure of isolation. Calculate the distance to the nearest area of indigenous forest or scrub (of any type) that is > 25 ha in area (as a measure of proximity to resources such as seeds for native plant establishment or additional food for mobile species such as birds). This involves dissolving internal boundaries of indigenous vegetation maps to calculate areas of forest and or scrub that in total exceed 25 ha (irrespective of vegetation composition).	0.0 – 4991 m (1284 m)

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[7] To calculate shape index for each polygon: 1. Measure area and actual perimeter. 2. Calculate minimum perimeter for a perfect circle of the same size (2*3.14*sqrt of (area/3.14)). Divide actual perimeter by minimum perimeter to calculate the shape index. An index of 2, for example, means the actual perimeter is twice as long as if would be if the polygon was a perfect circle.
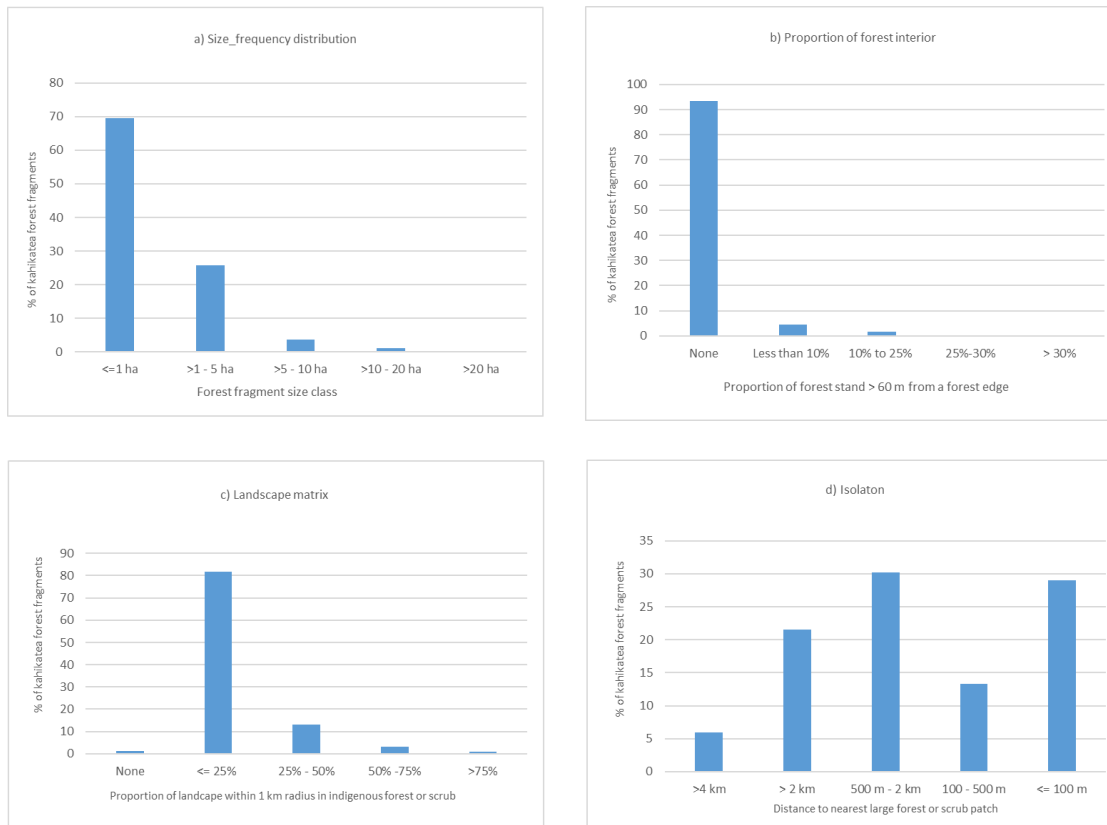
Figure 2: Spatial attributes of kahikatea forest in the Waikato region.

Based on the data calculated from the analyses above we selected the following values as the standard for a 5-star site:

Sub-attribute 12. Size_ha: > 20 hectares, being the largest remaining stand of kahikatea currently (note there are larger patches of kahikatea treeland). While less than 1% of kahikatea fragments currently meet a 5-star standard, the small size of the region's kahikatea fragments is major limitation to their ability to be self-sustaining as kahikatea forest, so an aspirational standard has been set. Increasing size could be achieved without sacrificing large areas of land by planting linkages between neighbouring existing stands. It is acknowledged this attribute will be very slow to improve (20-30 years until the linkage or expansion plants mature to forest).

Sub-attribute 13. Shape index_ratio: 1.5 – being almost circular. Many kahikatea stands are already relatively compact and will score well for this sub-attribute. Shape can be improved by planting between irregular boundaries to "square-up" an existing patch.

Sub-attribute 14. Forest interior_%: > 30% of the forest is "interior". Most kahikatea fragments are extremely small, and only four kahikatea forest fragments in the Region have more than a third of their entire extent more than 60 m from a forest edge (i.e. within the zone that represents forest interior conditions, the original condition for 98% of pre-human Waikato forest)[8]. As with size, this sub-attribute can be most easily improved by linking nearby fragments, or even by planting long-rotation dense native woodlots next to them.

Sub-attribute 24. Landscape matrix_%: >75% of a 1 km radius around the stand is in some form of indigenous forest or scrub. This sub-attribute will be difficult in most cases for landowners to improve, unless they are on a large land-holding and are able to plant areas

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of indigenous vegetation within a 1 km radius of their site. As a restoration action, it is likely a lower priority than expanding the area of their kahikatea forest patch and buffering it. The sub-attribute is included, though, because it also acts as an educational tool (highlighting the importance of neighbouring vegetation for mobile species and seed sources) and an incentive to retain nearby areas of indigenous forest and scrub.

Sub-attribute 25. Habitat links (terrestrial)_m: This sub-attribute relates to proximity to nearby larger areas of indigenous habitat for mobile terrestrial species and seeds. It is similar conceptually to landscape matrix, but total amount of nearby habitat (as measured by landscape matrix) is a more ecologically relevant measure of habitat availability for mobile species than simply distance to the nearest patch. Nevertheless, isolation is easily measured using GIS tools, and provides more nuanced information for stands that have no indigenous vegetation within 1 ha radius, because it returns the actual distance of such isolated stands to the nearest patch. As with landscape matrix, landowners/managers may have limited scope to reduce distance to nearest large (>25 ha) forest or scrub patch.

2.3.4   Indicator animal species

Birds are commonly used as indicators of forest health and functioning. However, for the KGW Sub-attribute 18 "Indicator animal species" they were discounted because the limited resources available in small forest patches means highly mobile forest birds are liable to move between fragments regularly. Therefore, it will be difficult to make assumptions regarding a given patch on the basis of a single bird count.

Weta are a more sedentary indicator species for fauna. They are susceptible to rodents[9] (and likely other predators including possums and hedgehogs) and are easy to monitor. A change in weta abundance is more likely the result of changes within the patch (particularly in terms of rodent control, vegetation recovery and microclimate) than to external factors, and therefore more directly within the control of the landowner or site manager.

There are several commonly used monitoring methods for weta:
1. Tracking tunnels (TT)
2. Artificial cover objects (e.g. foam tree wraps or weta "hotels")
3. Pit-fall traps
4. Spotlighting

Each method has some drawbacks. With tunnels only footprints are visible so there is less certainty regarding identification. With artificial cover objects weta may take up permanent residence, so each year's data would not be independent unless the cover objects were moved and occupants evicted. Pit-fall traps are time-consuming and potentially lethal for animals captured in them (including lizards). Spotlighting is very time-consuming and carries additional health and safety risks.

The National Wetland Trust has been recording weta tracking rates at Rotopiko for several years following mammalian pest eradication. Ten un-baited tracking tunnels deployed in a 1 ha mature kahikatea remnant are checked fortnightly year-round. Their data show weta tracking rates are highest in winter and are almost undetectable in hot summer months.

Landowners could easily do TT monitoring for weta, with some expert assistance to set up the tunnel network and training in print recognition. Weta footprints are readily identified (see Figure 3 and Deng *et al.* 2004), and landowners can store marked tracking cards for a contractor to verify.

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[9] Watts *et al.* 2011
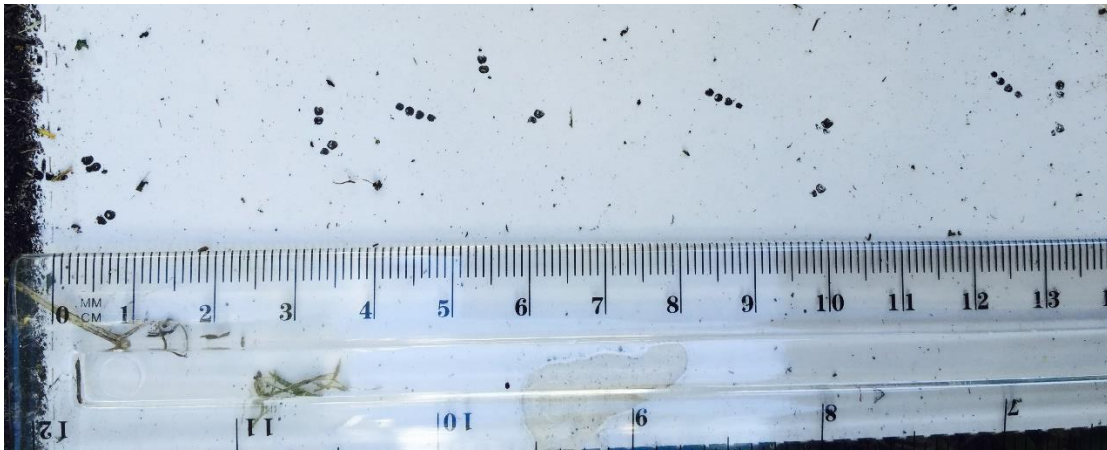
Figure 3: Weta footprints from Rotopiko.

The maximum tracking rate for weta (not identified to species level) recorded at Rotopiko is 60% (i.e. 6 of 10 deployed cards tracked over a 14-day period) [10]. This is in an area that has been rat-free since 2012, and with low mouse numbers (undetectable for most of the year) since 2015. It is feasible that tracking rates may reach much higher numbers over time as numbers continue to climb. If we assume Rotopiko is the 5-star benchmark (there are no other almost entirely pest-free kahikatea stands in the Region), and assuming that weta recovery would initially follow an exponential pattern we can use the Rotopiko data to generate a ranking for unbaited[11] weta tracking rates. It is recommended that indicator animal cards be left out for only one week for the KGW because outside of a rodent-free area such as Rotopiko there is an increased chance of rodents overmarking weta prints when cards are deployed for a longer period. Therefore the expected maximum tracking rate would be half that of the rates recorded over two weeks at Rotopiko. Therefore the following star rankings are recommended: 1* = 0%, 2* = >=1<=10%, 3* = >10<=20%, 4*>20<=30%, 5*>30%. For simplicity[12] it is recommended that the sub-attribute not require identification to species level, rather tracks of any weta species would qualify.

Lizards can also be monitored using tracking tunnels. However, lizards would have to be monitored in summer as they are less active in winter, and detection rates would likely be much lower than weta as they would probably be present at lower baseline numbers, and slower to recover following sustained rodent control. At Rotopiko, within 5 years of rodent eradication skink tracking rates within the kahikatea forest sites is only 7%. There is also a risk of confusing the prints of introduced plague skinks with copper skinks.

By focussing on weta and using tracking tunnels, landowners/site managers can do animal monitoring once per year. By removing grills and replacing the cards for another week, an index of rat tracking rates can also be obtained at the time of year when populations are at a minimum (and therefore less chance of oversaturation of tracking rates). It may be possible to simultaneously monitor rats and weta, but trials will be needed to ensure rat prints don't totally obscure weta prints.

2.3.5   KGW Attribute scoring justification

As described above, for each of the 31 sub-attributes, a set of 5 standards was generated to enable consistent application of a ranking score. The standards divide each sub-attribute into a range from a degraded to highly restored state with three intermediary steps. Real data was used as far as possible to justify the standards for each star ranking. Justification for division of

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[10] Note that much higher weta tracking rates (>80%) have been measured by Watts *et al.* (2011) at Maungatautari (also enclosed in a pest fence), however that is a 2,500 ha tawa-podocarp forest and therefore not a suitable reference site for the KGW.

[11] Peanut butter has been shown to be a very effective lure for weta, however it also attracts rodents. Use of a lure in the presence of rodents may elevate weta predation and rat prints on tracking cards may obscure weta prints.

[12] Footprints of ground, tree and cave weta species can be difficult to distinguish (Watts *et al.* 2011)

the star rankings, along with visual clues and methods for application of the score are summarised in
Table 5.

Table 5: Justification for process of applying ranking standards to 33 kahikatea forest sub-attributes

Sub-attribute	Visual clues/ explanations	Anticipated trajectory from 1 to 5	Scientific basis/ justification/ notes	Method/ frequency/ assessor
1. Stock access	Presence/ state of fencing, presence of stock animals or dung, abundance of unpalatable/ poisonous plants (e.g. Jerusalem cherry, stinking iris) or thorny/spikey (e.g. totara seedlings, barberry, blackberry, thistles).	Instant change from accessible to not accessible if adequately fenced. Rank system will be based on state of stock access/ damage.	Qualitative division into 5-star system based on state of fencing/degree of stock incursion and impacts.	Annual Visual check Landowner
2. Feral ungulates (deer, goats, pigs)	Deer, goats, pigs - ground-based damage. Evidence of browsing - animals seen or pellets present, or browse (above rabbit height) seen.	Instant change in browser numbers once fenced for small fragment. For large sites, natural log to remove the last browser.	None - qualitative division into 5-star system. This attribute is about browser presence, not effect, which is measured using vegetation sub-attributes	Annual Visual check Landowner with contractor at first to train landowner
3. Browsers (rabbits, hares)	Evidence of rabbit/hare presence - animals seen or pellets present. Browse can be difficult to distinguish from sheep browse.	Natural log: easier to drastically reduce initially, slower to eradicate fully.	None - qualitative division into 5-star system	Annual Visual check Landowner
4. Mammalian predators	Possums, rodents, mustelids, hedgehogs, cats. Bite marks and/or footprints on chew cards baited with peanut butter and with jellymeat, or tracking tunnels deployed for 7 days. Chew cards are harder to analyse, but tracking tunnels may not reliably detect possums.	Natural log; - easy to remove 80-90% of the pests, harder to remove the last 10-20%	Standard operating procedure for mammal pest detection, and generally accepted residual trap catch rates. Peter Sweetapple, Graham Nugent 2011 http://www.connovation.co.nz/vdb/document/62	Annual Chew cards/ tracking tunnels Landowner with contractor at first to train landowner. Archive used detection devices for expert verification
5. Canopy weed abundance	Develop illustrated checklist of potential vine or tree weeds in kahikatea forest as a guide, e.g. bindweed, morning glory, ivy or exotic canopy trees. View the site from different sides (inside and outside the stand) and make assessment also based on abundance of vine stems seen on trunks inside the forest.	Natural log: depending on effort, easier to drastically reduce initially, slower to eradicate fully.	This is about assessing potential for canopy collapse to occur. Measured as % of the tier space (planar i.e. birds eye view), not % of the biomass. Use 25% rather than 20% because 1/4 is easier to visualise. It is possible to achieve zero, but allow 5% in 5-star to simplify/ be consistent with ground level standard. Dense area over a continuous 25% of the site is easier to deal with from a management perspective than thinly spread across the whole site but totalling 25% - however it is too difficult to separate the scenarios. Sub-attribute # 8 deals with number of weed species rather than abundance /cover. [The same applies to shrub and ground weeds]	Annual Visual check Landowner with contractor at first to train landowner

Sub-attribute	Visual clues/ explanations	Anticipated trajectory from 1 to 5	Scientific basis/ justification/ notes	Method/ frequency/ assessor
6. Shrub layer weed abundance	Develop illustrated checklist of potential shrub layer weeds in kahikatea forest as a guide e.g. privet, hawthorn, woolly nightshade.	Natural log: depending on effort, easier to drastically reduce initially, slower to eradicate fully	This is about competition for space between exotic and native species. This is as % of the tier space (planar i.e. birds eye view), not % of the vegetation biomass. Use 25% rather than 20% because 1/4 is easier to visualise. It is possible to achieve zero, but allow 5% in 5-star to simplify/ be consistent with ground level standard.	Annual Visual check Landowner with contractor at first to train landowner
7. Groundcover weed abundance (< 30 cm)	Use checklist of potential groundcover weeds in kahikatea forest as a guide, e.g. reed sweetgrass, ginger, wandering dew, ivy.	Natural log: depending on effort, easier to drastically reduce initially, slower to eradicate fully	This is about assessing potential for regeneration to be hampered. This is as % of the tier space (planar i.e. birds eye view), not % of the vegetation biomass - so for instance where there is <50% ground cover of any species you cannot get a 1 or 2 star for ground weeds. This is to reflect the management effort required, rather than the proportion of native to exotic species. Unlikely to ever be able to achieve zero ground cover weeds. Where there is <5% cover of any vegetation type on the forest floor the score will be 5. Ignore minor (non-threatening) herbs e.g. cat's ear, wall lettuce.	Annual Visual check Landowner with contractor at first to train landowner
8. Pest plant presence	Use checklist from the current Regional Plant Pest Plan/Strategy.	Linear: some species will be easy to eradicate, others harder so have "averaged" the trajectory.	This is about the number of invasive species, not their abundance. The more invasive species present, the bigger the management task to prevent their spread. A 50 m radius applies, because invasive weeds in the vicinity pose a more immediate risk (assuming some shade-tolerance). While plant pests can be dispersed to the site via wind or birds from more than 50 m away this radius it is a practical distance for field assessment (visual check of site surrounds), and more likely to be a on the same property (under landowner's control). RPMS includes almost 80 plant pest species, but many are not likely to be found in kahikatea forest (e.g. estuarine, light-demanding, or not yet recorded in the region). Weeds tend to have patchy distribution, and a higher diversity is most likely near gardens or abandoned homesteads. It is unlikely to find more than 10 of the RPMS species in one site, but given these species have the greatest potential invasive impact the bar has been set relatively low for this indicator. It is possible to achieve a zero presence, as indicated by 5 stars.	5-yearly Species list Contractor
9. Nutrient input	Indirect clues may include lush vegetation growth, but there may be other clues such as intense grazing, high bird numbers adding nitrogen. Visual clues from proximity to effluent sources (e.g. dairy shed, grazing upslope etc) and presence of stock/birds/dung/ guano.	Treat as linear. Trajectory depends on source of the pressure, but unlikely to be instant, e.g. if you remove stock or stop effluent spraying from upslope of a stand, there will still be a legacy of nutrient enrichment on and in the soil on the pasture to	None - qualitative division into 5-star Based on the risk (e.g. surrounding land use or any actual effects) – relates to fertiliser application, effluent runoff, stocking rates upslope, whether adjacent land used for effluent irrigation, N-fixing crops etc	Annual Visual check/local knowledge Landowner

Sub-attribute	Visual clues/ explanations	Anticipated trajectory from 1 to 5	Scientific basis/ justification/ notes	Method/ frequency/ assessor
		wash into the stand.		
10. Drainage	Presence of drains, evidence of recent drain clearance (e.g. spoil heaps). Evidence of former high water table (e.g. exposed roots), or of recent flooding (e.g. silt marks on trees).	Linear; ideally hydrology would not be restored so quickly that it could cause plant mortality.	None - qualitative division into 5-star system. It is beyond individual landowners' control to reverse regional groundwater lowering (see soil shrinkage).	Annual Visual check/local knowledge Landowner
11. Human footprint (litter, tracks, vegetation damage etc)	Human-caused damage includes presence or evidence of built structures, litter, graffiti, plant vandalism, vehicle/bicycle use, planting non-native or non-local plants and trampling by people. It does not include indirect effects (such as stock access, covered by a separate indicator). If a track traverses the entire site, consider what % of the site it occupies when applying this attribute.	Linear: trajectory depends on threat – trampling or tree felling involves slower recovery than litter which can be picked up instantly.	None - qualitative division into 5-star system No human presence would preclude traps, monitoring equipment, boardwalks so 5-star rating needs to allow for that. A visual guide/key will be required to assist in determining minor from moderate damage.	Annual Visual check Landowner
12. Size	GIS analysis	Linear: slow, steady recovery of planted areas back to mature kahikatea that will be mappable as kahikatea forest.	Based on analysis of Waikato Regional Council kahikatea maps. Applies only to the area mapped/classified as a kahikatea forest type (does not include extent of recently planted buffers or adjacent/surrounding forest of a different type until they are sufficiently established to be mapped as forest). Base 5-star on the upper size of current patch data. Larger sites have better ability to self-buffer, larger genetic diversity, habitat large enough for fauna survival etc. Limited scope for landowner to increase size though may be able to plant to connect adjacent stands however there will be a significant time lag (decades) until planted areas can be classified as kahikatea forest. Also acts as, an incentive to not reduce size (and worsen their score).	5-yearly GIS analysis Waikato RC – add to web map
13. Shape index	GIS analysis	Linear: slow, steady recovery of planted areas back to mature kahikatea that will be mappable as kahikatea forest	Based on Denyer (2000) shape index, with qualitative (even) division into 5-star system. Shape index is size-independent. More compact sites are less vulnerable to edge effects (harsher microclimate, weed influx, etc).	5-yearly GIS analysis Waikato RC – add to web map
14. Forest interior	GIS analysis.	Linear: slow, steady recovery of planted areas back to mature kahikatea that will be mappable as kahikatea forest	Based on analysis of Waikato Regional Council kahikatea maps. Rank according to the amount of kahikatea forest >60 m away from any forest edge, because surrounding forest (native or exotic) will buffer the kahikatea and support interior-like conditions.	5-yearly GIS analysis Waikato RC – add to web map
15. Buffer	Field visual analysis of the portion of the kahikatea forest perimeter adjacent to areas of tall dense vegetation – any type of forest (other than	Exponential/ S-curve: slow for first few years as new plants establish, faster	Microclimate research (e.g. Denyer et al. 2006). Wide buffers are better than simply a dense edge seal, but it is difficult to separate buffer from edge	5-yearly GIS analysis OR field analysis

Sub-attribute	Visual clues/ explanations	Anticipated trajectory from 1 to 5	Scientific basis/ justification/ notes	Method/ frequency/ assessor
	kahikatea forest as that would form part of the patch being assessed). A secondary sub-attribute incorporated is extent of dense edge understory vegetation forming a seal around the forest edge - how easy is it to see through to the outside.	once foliage density increases, then slower again as plants mature	seal in the same attribute - qualitative division into 5-star system. In the context of the KGW buffering is a measure of the protection a stand has from external pressures, particularly microclimate, which helps to expand the proportion of forest interior. Buffer is defined as 3 m tall and 10 m wide to act as a microclimate seal. A buffer zone is planted or naturally occurring area of dense vegetation (native or exotic) that protects the forest stand from the adverse effects of sunlight and wind. A seal is a dense margin of vegetation under the canopy that seals off the forest margin from edge effects. A buffer will better protect the forest interior than a shield, but even a shield is better than an open edge. To qualify for this indicator, consider only vegetation that is at least 3 m tall and has a closed canopy (>80% canopy cover). A dense buffer cannot be seen through for more than a few metres. Effective buffer zones should be at least 10 m wide to attenuate light, and probably 25 m to reduce edge effects entirely.	Waikato RC – add to web map
16. Dominance of native plants	Based on vascular plant species list (natives and exotics), ratio of the two.	Variable though probably natural log as you can remove the easy exotics and plant many natives to quickly improve the score, but some exotics will be harder to eradicate	Based on flora lists from a set of kahikatea forest stands in reasonable health (fenced). Based on native:exotic ratio for number of species (not abundance, see weeds in Attribute A). 100% indigenous likely no longer possible in lowland kahikatea forest, given the almost ubiquitous occurrence - even well inside intact forest - of some exotic species like wall lettuce. Trajectory also depends on whether site has been grazed (will get initial weed pulse when fenced) or has canopy gaps (light source for weeds), and quality of seed bank and seed sources.	5-yearly Species list Contractor
17. Characteristic plant species	Based on number of pre-defined "characteristic species" that are present – compare site species list with checklist of characteristic species.	Treat as linear. Trajectory depends on degree of human input, proximity to seed source, bird movements etc.	Based on flora lists from a set of reference kahikatea forest stands in reasonable health (fenced). Characteristic species were deemed to be those present in > half of the reference stands. This could be modified and reported as % of characteristic species, rather than an absolute number which would allow for future alterations to the characteristic plant species list. Characteristic species is a more informative measure than species richness, as many native species may not be typical of kahikatea forest, and encouraging planting of a more diverse mix of native species may not be appropriate.	5-yearly Species list Contractor
18. Indicator animal species	Weta tracks on ink cards deployed in winter	Exponential: slow at first following intensive pest control or eradication until numbers of breeding	Deng et al. 2004, Watts et al. 2011. Weta are unlikely to move between fragments so represent the state of fauna in the fragment of interest. Tracking tunnel data collected fortnightly since 2014 from Rotopiko	Annual (winter) Tracking tunnels (20 at 10 m spacing) unbaited, grills on ends to

Sub-attribute	Visual clues/ explanations	Anticipated trajectory from 1 to 5	Scientific basis/ justification/ notes	Method/ frequency/ assessor
		individuals increase. It is likely that most forests will not have sustained rodent control.	(pest fenced) showed peak weta tracking in winter, so best to use that time of year to maximise detection. Maximum detection at Rotopiko 5 years after rodent eradication is 60% for TTs in kahikatea forest. Lizards are likely slower to recover than weta and it is difficult to distinguish footprints of native from invasive skinks, so they have not been selected as an indicator species.	deter larger pests, left out 14 days. Landowner – trained by contractor.
19. Vegetation layers	Visual guides showing examples of intact vs degraded tiers would be helpful and depiction/definition of canopy, shrub, ground layer.	Linear: depends on which tier is missing. Slower to replace upper tiers, faster to regain ground layers if remove browsers/grazers.	Qualitative division into 5-star system Based on the number of tiers that are relatively intact. Will need experienced field workers to distinguish native vegetation from weeds that may make a layer appear intact. In very wet sites ground cover may be naturally sparse, but will likely still be some cover of sedges or aquatic herbs. Should not be surveyed during or after flood as water could obscure ground cover.	5-yearly Visual check Contractor
20. Canopy condition	Die-back/yellowing of canopy foliage, standing dead trunks with no foliage.	Exponential: varies with cause of dieback (e.g. microbial, altered hydrology, microclimate, browsing, herbicide). Recovery likely slow at first, then rapid as canopy recovers if the cause is removed (particularly if plants have been able to survive and re-sprout).	Very little published data is available to generate a star system for this attribute. Ranking has been based on % values spread along exponential trajectory. Baseline mortality seems to be conservatively around 1% (Richardson *et al*. 2009). Measure of tree health, and can also assist in noticing biosecurity risks (e.g. soil borne pathogens or species specific diseases which might affect canopy trees). Based on indigenous species only – does not include weeds that have been sprayed. Landowner may have limited ability to affect this score.	Annual Visual check Contractor
21. Winter bird-food availability	Comparison of site species list with reference list of winter bird food species (pre-determined list of native plant species that naturally occur in kahikatea forest and that provide winter fruit, flowers or nectar for common forest birds).	Exponential: slow for species that are planted by landowner, but fast for recovery of browsed mature plants following pest control.	Presence of bird food is an indicator of the ability of a stand to provide resources for wildlife, and therefore a measure of ecosystem function. Birds have been selected as the indicator because knowledge of bird food preferences is more advanced than for invertebrate and lizard taxa. Further, birds are more effective seed dispersers than other taxa. Ranking is based on reference site species lists and Waikato-relevant flowering/fruiting calendars. Winter is a bottleneck, few native species produce winter fruit or nectar, so a vital attribute for forest birds. Ideally this would be based on a group of mature (reproductive age) plants, however to simplify the attributes application we adjusted the required number per standard upward to account for the likelihood that some species will only be present at immature plants or in low numbers. The reference site list includes 24 winter fruit or nectar providers (some only into early June), with a maximum of 21 and mean of 11. We have set a conservative	5-yearly Species list Contractor

Sub-attribute	Visual clues/ explanations	Anticipated trajectory from 1 to 5	Scientific basis/ justification/ notes	Method/ frequency/ assessor
			target of 15 species present. The requirement is that qualifying species be those that occur naturally in kahikatea forests, to avoid encourage planting of inappropriate well-known bird food species (e.g., puriri, kohekohe).	
22. All season bird-food availability	Comparison of species list with reference list of bird food species - species naturally occurring in kahikatea forests that provide fruit, flowers or nectar for common forest birds.	Exponential:slow for species that are planted by landowner, but fast for recovery of browsed mature plants following pest control	Reference site species lists and Waikato-relevant flowering/fruiting calendar Native only. Exotics can provide food but threaten natural character so should not be encouraged. The reference list of plant species typical of kahikatea forest that provide bird food is 90. Not all will be present in the same fragment, and in our reference sites the maximum was 66, mean 35. We set a 5-star target as more than 40 (i.e. better than average for good quality sites and greater than 1/3 rd of all possible species likely to be found in kahikatea forest).	5-yearly Species list Contractor
23. Plant recruitment	Determined from species list for the site that notes which are present as established seedlings (> 5 cm < 30 cm). Assess for woody species (trees and shrubs) only.	Linear: averaged to account for high variation in response. Could be natural log or s-curve, e.g. if remove browsing pressure may get mast response, but for some species will also need pollinators (birds/moths). Also confounded by stock presence, and climate (rain at the right time).	Seedling presence is an integrated measure for a range of processes (pollination, germination, growth, dispersal, recruitment). The focus is on woody species (trees and shrubs) only as they are easier to find/ identify, and on self-regeneration - i.e. presence/ abundance of seedlings of those species in the stand. Note that kahikatea themselves rarely regenerate under their own canopy, the recruiting species will mostly be shade-tolerant species present as established seedlings, unless there are large canopy gaps. Also useful to note the presence of species that are *only* present as seedlings - an indication of dispersal into the forest fragment. As that process is largely beyond a landowners' control, this will be supplementary information - not used as an assessment of plant reproduction processes within the stand.	5-yearly Species list/ seedlings noted Contractor
24. Landscape matrix	GIS analysis	Exponential: slow to replant / regrow areas of indigenous vegetation but as plants becomes established, faster for it to succeed into forest.	Based on GIS analysis of kahikatea forest in the Waikato region. A measure of the amount of alternative resource for mobile forest species and source of native seeds to enrich the kahikatea stand. Extent (hectares) of native vegetation/natural habitat within a specified radius of the site's boundary. Note that much of this may be beyond the landowner's control (e.g. if most of that land is not theirs). Surrounding landscape may not be suitable for forest (e.g. may be lake edge).	5-yearly GIS analysis Waikato RC – add to web map

Sub-attribute	Visual clues/ explanations	Anticipated trajectory from 1 to 5	Scientific basis/ justification/ notes	Method/ frequency/ assessor
25. Habitat links - terrestrial	GIS analysis of the distance to the nearest large (>25 ha) patch of indigenous forest and/or scrub.	Exponential: slow to replant / regrow areas of indigenous vegetation but as plants becomes established faster for it to succeed into forest.	Based on GIS analysis of kahikatea forest in the Waikato region. Almost half of remaining stands are relatively close to a larger block (< 500 m). This attribute links to isolation of stands for terrestrial species (including plants dispersed by birds or wind). Scrub is included as large areas of scrub can provide substantial food and other resources for mobile forest species. This attribute may be outside landowner control if they have a small property, so for a 5-star we also allow for the presence of a linking corridor (at least 3 m wide) to a larger area of indigenous forest.	5-yearly GIS analysis Waikato RC – add to web map
26. Habitat links - aquatic	Look for flowing waterways, perched culverts (> than 5 cm above the water level) and other barriers. Look at riparian planting (dense, continuous?). If feasible look up and down stream to property boundary.	Linear over all. Natural log – if remove aquatic link barriers, e.g. install fish-friendly culverts, may get rapid re-establishment of some links (e.g. hardy fish, seed dispersal) with others slower to return. Exponential for riparian cover to become established.	None - qualitative division into 5-star system 5-star will include the non-applicable situation where the site has had no waterway connections since pre-human times, e.g. site is in a basin or well away from a waterway. Unimpeded waterways and riparian cover provide hydrological connectivity, which is important for diadromous fish, seed dispersal (e.g. kowhai), mudfish etc. Culvert checks should be limited to the property (i.e. within the landowner's control). This attribute may be difficult to apply, in which case it can be treated as a not-applicable and excluded from the average score for Attribute F.	5-yearly GIS analysis or visual check Waikato RC – add to web map
27. Legal protection	GIS analysis (for covenants, reserves, scheduled sites).	Instant – not a trajectory (yes/ no)	None - qualitative division into 5-star system Standards are based on permanence of the legal protection and the extent to which it has been put in place. Registered QEII covenants and gazetted reserve score a 5, while Nga Whenua Rahui Kawenta with 25-year reviews score a 4. Council rules that provide some protection (e.g. listed in a schedule) score a 3, willing landowner (e.g. has applied for QEII) a 2, no protection at 1. Note landowners may not be aware of council rules for #3 and those rules may change.	5-yearly Waikato RC – add to web map for QEII, NWRK, reserve, schedule.
28. Management plan	Landowner knowledge	Linear – based on time put in to developing a plan	None - qualitative division into 5-star system At the low end is intent shown by developing a plan, higher scores are allocated as the site becomes subject to active management. Having a plan is an important first step.	5-yearly Landowner records
29. Animal pest control effort	Landowner knowledge/ records	Natural log: fast initial knockdown, but then need sustained effort.	None - qualitative division into 5-star system At 5-star level this may include solely surveillance in areas where pests have been eradicated (e.g. within a pest fence).	5-yearly Landowner knowledge/ records Landowner

Sub-attribute	Visual clues/ explanations	Anticipated trajectory from 1 to 5	Scientific basis/ justification/ notes	Method/ frequency/ assessor
30. Invasive plant control effort	Landowner knowledge/ records, presence/absence of invasive plants (not just RMPS ones).	Natural log: fast initial knockdown, but then need sustained effort.	None - qualitative division into 5-star system For 5-star all invasive plant species identified in the forest are subject to annual control and surveillance measures.	5-yearly Landowner knowledge/ records Landowner
31. Re-vegetation effort	Landowner knowledge/ records, presence of planted species (e.g. indicated by planter stakes).	Exponential: slow to establish then faster growth of plants.	None - qualitative division into 5-star system Indicator incorporates floristic attributes, characteristic species planted, % of absent buffer area planted, or area of future kahikatea forest planted. This attribute measures effort in relation to need of the site (as it may not need much planting).	5-yearly Landowner knowledge/ records Landowner

2.4 KGW Attribute standards

The final proposed standards for the 5-star ranking system are detailed in Appendix 1. These were derived as described above from multiple sources of data from Waikato kahikatea fragments, supplemented with expert knowledge, similar ranking systems for generic issues, and incorporating anticipated recovery trajectories. Some of the standards are subjective, others rely on collection of field data including full species lists.

3 Applying the Kahikatea Green Wheel

The Waikato Regional Council has created a tool using MS Excel that will generate a Kahikatea Green Wheel graph simply by entering the relevant scores into a spreadsheet (see Figure 4). The KGW wheel tool will automatically calculate the average for the broad attributes, and the total site score for the site at the base of the KGW star table.

A vascular plant species list for a site will be required in order to assess several of the sub-attributes. A high threshold is applied to the 5-star standard to account for the potential that some qualifying species may not be established or mature. It was initially proposed to gather information on relative abundance of each plant species to ensure that attributes would not be over-valued. For example, the attribute of presence of winter fruit would not be scored if the species was only present as a single seedling. However, the collection of extra field data (relative abundance) was considered too onerous, and instead, a higher trigger level was applied to the 5-star standard.

The KGW tool also has worksheets with pre-set formulas to automatically calculate the score for botanical sub-attributes # 8, 18, 19, 23, 24 and 25. Users need only indicate by entering a "1" in the blank column if a species on the native or exotic list is present in their site. The spreadsheet automatically calculates the sum of all RPMS species, all exotic species, all native species, all characteristic native species, all winter bird food and all bird food species, and the proportion of vascular plants that are local indigenous species.

A completed example of a Green Wheel Score sheet is presented in Appendix 2.

A full set of field cards is provided in Appendix 3.
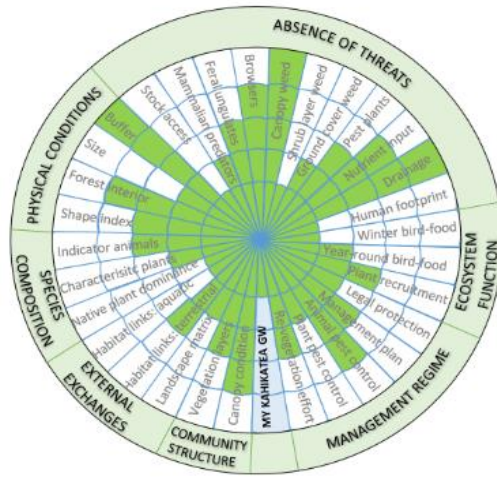
Figure 4: Example of a Kahikatea Green Wheel generated using the KGW tool

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Appendix 1: Ranking standards for Waikato Kahikatea Green Wheel, See Appendix 4 for the rate entry.

ATTRIBUTE CATEGORY	1*	2*	3*	4*	5*	Methods/Who
ATTRIBUTE A. Threats	PRESSURE INDICATORS – main pressures are introduced plants/animals, nutrient input, deliberate human damage					
1. **Stock access**	No fences and heavily grazed throughout - signs include mainly unpalatable plants in ground layer, fresh dung present, livestock may be visible in the stand.	No fences and signs that livestock are frequently in fragment, old signs of dung, many unpalatable plants but site not heavily grazed throughout.	No fences - but access is impeded and livestock access is infrequent or does not penetrate more than 10 m into the site (e.g. blackberry, wet ground, drains or thick exposed roots deter stock).	Fenced but not complete or effective (sometimes breached). Occasional dung or signs of grazing within the past 2 months.	No stock have access, e.g. fully fenced or not in grazing land. No sign of current or recent (<2 months) stock presence.	*Annual* *Visual check* *Landowner*
2. **Feral ungulates** (*deer, goats, pigs*)	Abundant sign of feral ungulates, either more than a few animals are seen, or faecal pellets are scattered across the entire site.	Ungulate dung pellets or sign of shrub browse is scattered across 50-75%.	Faecal pellets or shrub browse are present across 25-49% of the site.	Some evidence of feral ungulates, e.g. some hoof prints or dung but little sign of vegetation damage.	No evidence of feral browsers.	*Annual* *Visual check* *Landowner with contractor at first to train landowner*
3. **Browsers** [13] (*rabbits, hares*)	Abundant sign of rabbits or hares, either more than a few animals are seen, or faecal pellets are scattered across the entire site.	A few rabbits or hares seen, or faecal pellets are scattered across 50-75% of the site.	No rabbits or hares seen, and faecal pellets are present in 25-49% of the site.	Minor sign, no rabbits or hares seen and only very old or just a few piles of pellets seen. No evidence of recent browse.	Fully pest fenced or pest-free island, or no sign rabbits or hares have been recently in the site.	*Annual* *Visual check* *Landowner*
4. **Mammalian predators**	Monitoring indicates very high pest numbers (e.g.	Monitoring indicates moderately high pest numbers (e.g. 50 -75%	Monitoring indicates moderate pest numbers (e.g. 5-50% detection on	Some evidence of predators e.g. fewer than 5 % detection on	Fully pest fenced, or pest-free island and monitoring shows	*Annual* *Chew cards/ tracking tunnels*

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[13] Note that possums can be treated as mammalian predators and measured using detection devices. Kahikatea trees do not show signs of possum browse and possum browse indicator species (e.g. totara) may be infrequent.

ATTRIBUTE CATEGORY	1*	2*	3*	4*	5*	Methods/Who
	>75% detection on chew cards or tracking tunnels[14]).	detection on chew cards or tracking tunnels).	chew cards or tracking tunnels).	chew cards or tracking tunnels, some dung.	pests are absent, or at best recorded only infrequently (incursions).	*Landowner with contractor at first to train landowner. Archive the used detection devices for expert verification*
5. **Canopy weed abundance**	Over 75% of the canopy (where visible or estimated based on vine stem abundance) comprises or is covered in exotic species.	Exotic species cover or comprise >50 and <75% of the canopy.	Exotic species cover or comprise >25 and <50% of the canopy.	Exotic species cover or comprise 5-25% of the canopy.	Exotic species cover or comprise less than 5% of the canopy.	*Annual Visual check* *Landowner with contractor at first to train landowner*
6. **Shrub layer weed abundance**	Exotic species cover more than 75% of the mid-tier zone of the forest stand.	Exotic species cover >50 and < 75% of the mid-tier zone.	Exotic species cover >25 and <50% of the mid-tier zone.	Exotic species cover 5-25% of the mid-tier zone.	Exotic species cover less than 5% of the mid-tier zone.	*Annual Visual check* *Landowner with contractor at first to train landowner*
7. **Ground cover weed abundance** (*<30 cm tall*)	Over 75% of the entire forest floor is covered with exotic species (include vine thickets).	Exotic species comprise >50 and < 75% of the forest floor.	Exotic species cover >25 and <50% of the forest floor.	Exotic species cover 5-25% of the forest floor.	Exotic species cover less than 5% of the forest floor.	*Annual Visual check* *Landowner with contractor at first to train landowner*
8. **Pest plant presence**	More than five regional pest plant species in the site or within 50 m of it within the property.	Four or five regional pest plant species in the site or within 50 m of it within the property.	Two or three regional pest plant species in the site or within 50 m of it within the property.	One regional pest plant species in the site or within 50 m of it within the property.	No regional pest plant species present in the site or within 50 m of it within the property.	*5-yearly Species list Contractor*
9. **Nutrient input**	Site is subject to constant high nutrient enrichment, e.g. septic wastewater pipes or year-round	Site is subject to regular, but not constant, high nutrient enrichment, e.g. grazed on a rotational	Site is regularly subject to small amounts of nutrient enrichment, e.g. slopes above moderately	Site is occasionally subject to small amounts of nutrient enrichment, e.g. never	No obvious human-derived sources of nutrient input on the property (e.g.	*Annual Visual check/local knowledge Landowner*

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[14] When deployed for 7 nights

ATTRIBUTE CATEGORY	1*	2*	3*	4*	5*	Methods/Who
	effluent disposal, and/or is permanently stocked with grazing animals and dung heaps are abundant, and/or year-round high numbers of roosting birds and guano obvious.	basis, regular fertiliser application or heavy grazing on adjacent paddocks, or periodic / seasonal high number of roosting birds.	grazed, and/or moderate number of birds, and/or lightly grazed (e.g. sheep).	grazed but subject to run-off from lightly grazed slopes above.	fertiliser not applied within 300 m radius, no upslope grazing land, no septic tanks within 300 m, no stock grazed in the stand).	
10. Drainage	Site has been, and still is, subject to severe drainage with evidence of active, regularly maintained drains through, around or near the forest stand.	Drains affecting the stand are present but have not been actively maintained in the past 5 years. Landowner has no plans to restore formerly higher water levels.	Site is subject to a plan to restore water levels.	Drains are in the process of being blocked or filled in, although some drains still remain active.	Site has never been drained and is still subject to regular flooding, or former flooding regime has been completely restored (e.g., all drains filled in). Or site was never subject to flooding.	*Annual* *Visual check/local knowledge* *Landowner*
11. Human footprint (*litter, tracks, huts, clearance, inappropriate plantings of non-local natives or exotic species*)	Human-caused damage is moderate to intense across more than 75% of the site. Or minor damage is evident across the entire site.	Human-caused damage is moderate to intense across 50-75% of the site. Or minor damage is evident across more than 75% of the site.	Human-caused damage is moderate to intense across 20-50 % of the site. Or minor damage is evident across 50-75% of the site.	Human-caused damage is moderate to intense across 5-25 % of the site. Or minor damage is evident across 25-50% of the site.	Minimal or no visual evidence of human presence (e.g. few structures or litter). Minor damage evident in <25% of the stand.	*Annual* *Visual check* *Landowner*
ATTRIBUTE B. Physical conditions	**STATE INDICATORS**					
12. Size	The kahikatea forest area is < 1 ha	The kahikatea forest area is 1 to <5 hectares	The kahikatea forest area is >5 to <10 hectares	The kahikatea forest area is >10 to <20 hectares	The kahikatea forest area is > 20 hectares	*5-yearly* *GIS analysis* Waikato RC – *add to web map*
13. Shape index	Shape index is 3 or more (very convoluted or narrow)	Shape index is 2.5 to 3 (somewhat convoluted)	Shape index is 2 to 2.5 (blocky but stretched out)	Shape index is 1.5 to 2 (oval or round with some slight protrusions)	Shape index is 1.5 or less (very round or square)	*5-yearly* *GIS analysis* Waikato RC – *add to web map*

ATTRIBUTE CATEGORY	1*	2*	3*	4*	5*	Methods/Who
14. **Forest interior**	None of the kahikatea forest vegetation is more than 60 m from a native forest[15] edge.	Less than 10% of the kahikatea forest vegetation is more than 60 m from a native forest edge.	Between 10 and 25% of the kahikatea forest vegetation is more than 60 m from a native forest edge.	Between 25 and 30% of the kahikatea forest vegetation is more than 60 m from a native forest edge.	>30% of the kahikatea forest vegetation is more than 60 m from a native forest edge.	*5-yearly* *GIS analysis* Waikato RC – *add to web map*
15. **Buffer** (>3 m tall, 10 m wide, 80% cover to qualify)	The site has no forested[16] buffer zone >10 m, and less than 25% of the margin is densely vegetated.	Up to 49% of the site has a forested buffer >10 m wide and/or a densely vegetated margin.	Over 50% of the site has a forested buffer >10 m wide and/or dense margin, but there are gaps into the forest edge in places.	Over 50% of the site has a forested buffer >10 m wide, and the unbuffered area has a dense vegetated margin, with no gaps.	The entire site has a buffer of forest >10 m wide.	*5-yearly* *GIS analysis OR field analysis* Waikato RC – *add to web map*
ATTRIBUTE C. Species composition	**STATE INDICATORS**					
16. **Dominance of native plants**	Fewer than 20% of species present are indigenous species that naturally occur in kahikatea forest.	>20 and <50% of the plant species in the forest are indigenous species that naturally occur in kahikatea forest.	>50 and < 70% of the plant species in the forest are indigenous species that naturally occur in kahikatea forest.	70-80 % of the plant species in the forest are indigenous species that naturally occur in kahikatea forest.	Over 80% of the plant species in the forest are indigenous species that naturally occur in kahikatea forest.	*5-yearly* *Species list* *Contractor*
17. **Characteristic plant species**	Fewer than 20 characteristic species are present.	21-30 characteristic species are present.	31-40 characteristic species are present.	41-50 characteristic species are present.	More than 50 characteristic species are present.	*5-yearly* *Species list* *Contractor*
18. **Indicator animal species**	No weta tracks recorded in 7 nights.	<10% weekly tracking rate (weta tracks in 1 or 2 of twenty tunnels).	10 to <20 % weekly tracking rate (weta tracks in 3 or 4 of twenty tunnels).	20 to 30 % weekly tracking rate (weta tracks in 5 or 6 of twenty tunnels).	>30 % weekly tracking rate (weta tracks in 7 or more of twenty tunnels).	*Annual (winter)* *Tracking tunnels (20 at 10 m spacing) unbaited, grills to deter larger*

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[15] This includes any type of indigenous forest type that surrounds or borders the kahikatea. Sixty metres is based on edge effect research conducted in NZ.

[16] We exclude scrub because, being shorter in stature, it provides less buffering capacity than forest. Exotic (plantation) forest can also act as a buffer (Denyer 2000) until it is harvested. Harvest will be picked up when vegetation maps are updated. A 10 m minimum width is applied based on edge effect research (adjacent forest will be buffered from light and wind, though some edge effects will extend for up to 60 m, Denyer 2000). Margin density is a field measure.

ATTRIBUTE CATEGORY	1*	2*	3*	4*	5*	Methods/Who
						pests, left out 14 days. *Landowner –trained by contractor.*
ATTRIBUTE D. **Community structure**	**STATE INDICATORS**					
19. Vegetation layers	No vegetation tier is intact (all layers have <50% cover of indigenous vegetation).	One tier is relatively intact (>50% indigenous cover).	Two tiers are relatively intact (>50% indigenous cover).	All tiers have >50% indigenous cover, and one or two are fully intact (have >75% indigenous cover).	Canopy, shrub and ground cover layers all have >75% cover comprising indigenous species. Emergent trees may or may not be present.	*5-yearly* *Visual check* *Contractor*
20. Canopy condition	Over 75% of the indigenous foliage in the canopy is showing signs of yellowing or defoliation.	50-75% of the indigenous foliage in the canopy is showing signs of yellowing or defoliation.	25-50% of the indigenous foliage in the canopy is showing signs of yellowing or defoliation.	10-25% of the indigenous foliage in the canopy is showing signs of yellowing or defoliation.	Less than 10% of the canopy is showing signs of yellowing or defoliation.	*Annual* *Visual check* *Contractor*
ATTRIBUTE E. **Ecosystem function**	**STATE INDICATORS**					
21. Winter bird-food availability[17]	No winter bird food species are present.	1-5 winter bird food species are present.	6-10 winter bird food species are present.	11-15 winter bird food species are present.	More than 15 winter bird food species are present.	*5-yearly* *Species list* *Contractor*
22. All season bird-food availability[18]	Fewer than 5 bird food species are present.	5-9 bird food species are present.	10-19 bird food species are present.	20 to 40 bird food species are present.	More than 40 bird food species are present.	*5-yearly* *Species list* *Contractor*
23. Plant recruitment	Fewer than 25% of the native trees or shrubs in	25-50% of native trees or shrubs in the stand are	50 -75% of native trees or shrubs in the stand are	75-90% of native trees or shrubs in the stand	Over 90% of native trees or shrubs in the	*5-yearly* *Species list/ seedlings noted*

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[17] Applies only to indigenous plant species that naturally occur in kahikatea forest – a list is available in Appendix 3.
[18] Applies only to indigenous plant species that naturally occur in kahikatea forest – a list is available in Appendix 3.

ATTRIBUTE CATEGORY	1*	2*	3*	4*	5*	Methods/Who
	the stand are present as established seedlings.	present as established seedlings.	present as established seedlings.	are present as established seedlings.	stand are present as established seedlings.	*Contractor*
ATTRIBUTE F. External exchanges	**STATE INDICATORS**					
24. **Landscape matrix** (*within 1 km radius*)[19]	There is no indigenous forest or indigenous scrub within a 1 km radius of the site.	Less than 25% of the land within a 1 km radius of the site is in indigenous forest or indigenous scrub.	Between 25 and 50% of the land within a 1 km radius of the site is in indigenous forest or indigenous scrub.	Between 50 and 75% of the land within a 1 km radius of the site is in indigenous forest or indigenous scrub.	Over 75% of the land within a 1 km radius of the site is in indigenous forest or indigenous scrub.	*5-yearly GIS analysis* Waikato RC – *add to web map*
25. **Habitat links - terrestrial**[20]	Site is further than 4 km from another patch of indigenous forest and/or scrub[21] > 25 hectares.	Site is within 2 to 4 km of another patch of indigenous forest and/or scrub > 25 hectares.	Site is within 500 m to 2 km from another patch of indigenous forest and/or scrub > 25 hectares.	Site is within 100-500 m of another patch of indigenous forest and/or scrub > 25 hectares.	Site is < 100 m from another patch of indigenous forest > 25 hectares. Or (field assessment) if > 100 m away is connected to the nearest area of indigenous forest and/or scrub > 25 ha by a continuous vegetated corridor at least 10 m wide.	*5-yearly GIS analysis or visual check* Waikato RC – *add to web map*
26. **Habitat links - aquatic**	No natural links remain, site no longer inundated.	Partial links to nearby stream or wetland via extreme flood events.	Streams or drains flow through or beside the stand, but most of them are un-vegetated, and/or have perched culverts on the property. Partial links via moderate to extreme flood events.	All waterways are connected up and down stream (with no perched culverts) but some have breaks in riparian cover on the property. Partial inundation via surface flows/flood events.	All waterways in the stand (if any) fully connected with continuous riparian buffers and no perched culverts or other fish barriers between the site and property boundary.	*5-yearly Visual check Contractor*

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[19] This measures the amount of indigenous habitat within a fixed distance from the kahikatea stand (providing additional resources for mobile species and seed/gene transfer).

[20] This measures how isolated (distant) the stand is from a decent sized area of indigenous vegetation for species of limited mobility (including plants for pollen/seed/ spore dispersal).

[21] Scrub included because indigenous scrub can provide substantial food and other resources for mobile native species. Exotic plantation forest is excluded as it is a temporary feature by design. It is acknowledged that exotic forest/scrub can provide food resources but are also a significant source of weed seeds.

ATTRIBUTE CATEGORY	1*	2*	3*	4*	5*	Methods/Who
					Regular inundation via flooding or surface flows. Or was likely never connected to a waterway.	
ATTRIBUTE G. **Management regime**	RESPONSE INDICATORS					
27. **Legal protection**	No formal legal protection or plans for such.	Legal protection is being pursued (e.g. application lodged with QEII National Trust).	Site is listed on a district or regional council schedule of significant areas.	Legally protected for a fixed term via a kawenata or management agreement.	Legally protected in perpetuity as a gazetted reserve or private covenant.	*5-yearly* *Landowner knowledge/ records* *Landowner*
28. **Management plan**	No management plan exists or intended.	Informal (unwritten) plan exists for the site.	Site is subject to a wider farm or reserve plan, but with minimal specific reference to the site.	Site is subject to a wider farm or reserve plan with specific reference and action points.	Professionally prepared management plan exists specifically for the fragment.	*5-yearly* *Landowner knowledge/ records* *Landowner*
29. **Animal pest control effort**	No animal pest control is conducted, and no plans are in place to implement animal pest control.	No animal pest control is conducted but professional pest control plans are being or have been developed though not yet implemented.	Animal pest control has been implemented but is irregular, or does not target all major animal pest species present, or not professionally guided.	Site is subject to an ongoing programme of predator monitoring and control for all major pest species likely to be present, under the guidance of a professional pest control practioner.	Site is fully pest-fenced or on a pest-free island and monitoring shows animal pests are absent (or are managed in the event of an incursion).	*Annual* *Landowner knowledge/ records* *Landowner*
30. **Invasive plant control effort**	Site is highly or moderately degraded (scoring fewer than 4 stars for most of the sub-attributes #5, 6, 7, 8, 18) and no invasive plant /weed control has been planned.	Site is highly or moderately degraded (scoring fewer than 4 stars for most of the sub-attributes #5, 6, 7, 8, 18) and no invasive plant control is conducted, but	Site is moderately degraded (scoring mostly 3 or 4 stars for sub-attributes #5, 6, 7, 8, 18) but invasive plant control has been implemented, although it is irregular or	Site is moderately degraded for attributes #5, 6, 7, 8, 18, but subject to an ongoing programme of plant pest control, under the guidance of a	Site is under intensive, comprehensive, regular and sustained invasive plant control, as evidenced by weed control	*Annual* *Landowner knowledge/ records* *Landowner*

ATTRIBUTE CATEGORY	1*	2*	3*	4*	5*	Methods/Who
		professional control plans are being or have been developed though not yet implemented, or control has not yet been effective.	not professionally guided.	professional. Not all invasive plant species are targeted.	records and/or relatively low levels of invasive plant presence (e.g. scores of 4-5 for sub-attributes #5, 6, 7, 8, 18).	
31. Re-vegetation effort	Site is highly or moderately degraded (scoring 2 or 3 stars for sub-attributes #18, 19, 21, 23, 24, 25) and no re-vegetation has been planned.	Site is highly or moderately degraded (scoring 2 or 3 stars for sub-attributes #18, 19, 21, 23, 24, 25) but a re-vegetation plan is being developed or complete, though not yet implemented.	Site is highly or moderately degraded (scoring 2 or 3 stars for sub-attributes #18, 19, 21, 23, 24, 25) but re-planting is underway.	Very little re-vegetation is required (site ranks a 4 or 5 for sub-attributes #18, 19, 21, 23, 24, 25), OR (if site ranks 3 or lower for those attributes) extensive revegetation has been undertaken, including buffer zone, gaps and understory.	No re-vegetation is required- site ranks a 5 star for all of sub-attributes #18, 19, 21, 23, 24, 25, and site has a dense edge buffer (sub-attribute 15).	*Annual Landowner knowledge/ records Landowner*

Appendix 2: Completed example of a KGW

Evaluation of Kahikatea Forest Recovery[22]

Site name: *Rotopiko/Turney Bush*   Date: *5 Aug 2018*

Assessor: *Karen Denyer*   Date of last assessment: *n/a*

Stable attributes[23]:

Location (district): *Waipa*

Location (NZTM): E 1803749   N 5796849

Soil type: Peat ☒   Gleyed Silt Loam ☐   Pumice ☐   Other(state): ....

Landform: Flat ☒   Gentle slope ☐ Basin ☐   Steep slope ☐
(tick all that apply and circle the predominant one)

Original forest type[24]: *Not mapped in Waikato RC pre-human but nearest examples are WF8: Kahikatea-pukatea forest*

Birds noted during visit: *Tui, fantail, grey warbler, morepork, falcon and exotic passerines*

Special features (e.g. threatened species): *Planted swamp maire, swamp astelia*

Tree/shrub species present only as seedlings: *Pokaka, Melicytus micranthus, white maire (planted)*

Site sketch/location[25]

20-30 year old planted kahikatea stands

Turneys' Bush (mature kahikatea/pukatea forest)

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[22]   Adapted from: "Society for Ecological Restoration Australia (SERA-evaluation-wheel, 2016)" tool http://www.seraustralasia.com/standards/NationalRestorationStandards-RestorationEcologyWithCaseStudies.pdf
[23] Waikato RC to provide this top page information on a per fragment basis on a web-accessed GIS, as well as size, buffer, shape etc
[24] Provided by Waikato RC via Singers and Rogers original vegetation type map. Use to assess representative plant species
[25] Draw a sketch map to show kahikatea fragment distribution at the site, if more than one name them as Unit 1, Unit 2 etc. Mark and label each unit on an aerial photograph.

ATTRIBUTE CATEGORY	RECOVERY LEVEL (1-5 or n/a)[26]	EVIDENCE FOR RECOVERY LEVEL	Method
ATTRIBUTE A.		**Absence of threats**	
1. Stock access	5	*No stock – securely fenced since 2008*	Visual check
2. Feral ungulates (deer, goats, pigs)	5	*Fully pest-proof fenced since 2011, unlikely to have had feral browsers – too isolated and small*	Visual check
3. Browsers (rabbits, hares)	5	*All ground browsers eradicated in 2011*	Visual check
4. Mammalian predators	5	*Fully pest-proof fenced since 2011*	Tracking tunnels, chew cards
5. Canopy weed abundance	5	*No canopy weeds present*	Visual check
6. Shrub layer weed abundance	5	*Virtually no shrub layer weeds present, occasional tree privet seedling*	Visual check
7. Ground cover weed abundance (<30 cm)	4	*Adventives in light-gaps (Yorkshire fog, cock's foot) and sparsely under full canopy (some blackberry, Jerusalem cherry, stinking iris, arum) – all subject to regular control*	Visual check
8. Pest plant presence	2	*Five species: Hedychium species (not flowering) – one specimen has been found and dug out, tutsan, Taiwanese cherry (seedlings only) several large-leaved and Chinese privet trees/seedlings have been found and will be progressively removed.*	Species list
9. Nutrient input	2	*Subject to run-off from grazed slopes above and high numbers of roosting birds following mammalian pest exclusion – though mostly only at the edge.*	Visual check
10. Drainage	2	*Subject to past drainage which has lowered soil surface up to 1 m, no plans to re-flood (would require pumps)*	Visual check/ local knowledge
11. Human footprint	4	*Tracks and activity stations installed for visitors*	Visual check/ local knowledge
AVERAGED SCORE	4	**KEY ISSUES:** *Excessive nutrient input from large bird roost and limited ability to repair past drainage, also RPMS weeds*	
ATTRIBUTE B.		**Physical conditions**	
12. Size	2	*1.3 ha (Waikato RC)*	GIS analysis
13. Shape index	5	*1.3 (Waikato RC) – relatively compact*	GIS analysis
14. Forest interior	1	*None of the kahikatea forest is more than 60 m from the native forest edge*	GIS analysis
15. Buffer	3	*About 40 % of the stand has a dense planted buffer and most of the remaining edge has dense vegetated margin planting.*	Visual check
AVERAGED SCORE	2.8	**KEY ISSUES:** *This stand is very small and has no interior forest, with time as adjacent planted forest matures and planted this will*	

[26] n/a = not applicable or not able to be assessed

ATTRIBUTE CATEGORY	RECOVERY LEVEL (1-5 or n/a)[26]	EVIDENCE FOR RECOVERY LEVEL	Method
		improve to some extent. At this stage there are few management options other than time.	
ATTRIBUTE C.		Species composition	
16. Dominance of native plants	4	*73% of species present are indigenous species that naturally occur in kahikatea forest (74 of 102 species)*	Species list with relative abundance
17. Characteristic plant species	4	*42 species of highly representative kahikatea forest plants are present in the stand.*	Species list with relative abundance
18. Indicator animal species	4	*Weta in 3 of 10 tunnels (equivalent rate as 6 out of 20) deployed 8 July to - 20 July 2018*	Tracking tunnels
AVERAGED SCORE	4	KEY ISSUES: *The site is scoring relatively highly, there is scope to improve attribute 18 through eradication of the 5 RMPS species, and of #19 through further planting.*	
ATTRIBUTE D.		Community structure	
19. Vegetation layers	4	*Relatively dense canopy and shrub layer, but ground layer bare under dense mahoe, some canopy gaps in exotic grass*	Visual check
20. Canopy condition	5	*Little evidence of dieback when viewed externally or using aerial images*	Visual check
AVERAGED SCORE	4.5	KEY ISSUES: *Ground layer depauperate or exotic-dominant in places*	
ATTRIBUTE E.		Ecosystem function	
21. Winter bird-food availability	5	*17 winter bird-food species are present, most of them as established individuals*	Species list with relative abundance
22. All season bird-food availability	5	*46 bird food plant species are present, some are only as young planted specimens*	Species list with relative abundance
23. Plant recruitment	3	*39 shrub/tree species are present, of which 21 (54%) have established seedlings. Many native shrub/tree species have been recently planted and not yet reproducing.*	Plot data
AVERAGED SCORE	4.3	KEY ISSUES: *Just needs time for planted species to mature*	
ATTRIBUTE F.		External exchanges	
24. Landscape matrix	2	*5.8 % - Less than or equal to 25% of the land within a 1 km radius of the site is in indigenous forest or indigenous scrub.*	GIS analysis
25. Habitat links - terrestrial	2	*4160 m from nearest patch of indigenous forest and/or scrub > 25 hectares*	GIS analysis
26. Habitat links - aquatic	5	*A drain runs along the edge of the stand, it is fully planted and connected with the peat lake downstream. However there are minimal links between the stand and the incised drain.*	Field analysis
AVERAGED SCORE	3	KEY ISSUES: *Distant from large stands of native vegetation and in a pastoral catchment – limited ability to improve this score as relies on actions by other landowners.*	
ATTRIBUTE G.		Management regime	
27. Legal protection	5	*District council reserve*	Landowner knowledge

ATTRIBUTE CATEGORY	RECOVERY LEVEL (1-5 or n/a)[26]	EVIDENCE FOR RECOVERY LEVEL	Method
28. Management plan	4	*Part of a plan for the East Lake complex within the pest fence.*	Landowner knowledge/ records
29. Animal pest control effort	5	*Within predator fence, all mammalian predators excluded, no mice recorded here since 2012*	Landowner knowledge/ records
30. Plant pest control effort	5	*Regular annual control of exotics*	Landowner knowledge/ records
31. Re-vegetation effort	4	*Some understory and buffer planting to improve structure and diversity*	Landowner knowledge
AVERAGED SCORE	4.6	KEY ISSUES: *Weeds*	
TOTAL SCORE[27] score/max	27 /35		

Key positive features / changes since last visit:

n/a – first assessment

Key issues that could be addressed to improve the health of this forest:

Increase weed control and focus efforts on reducing exotic bird roost.

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[27] Total score is the sum of the averaged scores A-G.

Appendix 3: KGW field sheet templates

Recommended field methods

1. In the field – outside the forest stand	Relevant sub-attribute[28]
Note any RPMS species within 50 m of the site (but within the property boundary)	8
Look at the state of culverts on the property for any waterways that pass through the kahikatea stand	10, 26
Assess the condition of the buffer (height, density) and vegetation in dripline (vegetation margin)	15
Assess the condition of stock fences if relevant	1
Look for signs of human-derived sources of nutrient input (e.g. fertiliser applied within 300 m radius, upslope grazing land, septic tanks within 100 m, stock grazing in the stand, high numbers of birds, e.g. geese/ paradise ducks).	9
Take photos to record the items above – establish at least one permanently marked photopoint. Record details on PHOTOPOINT RECORD SHEET (Field card A).	General record

2. In the field – inside the forest stand	
Generate full species list as per tables (separate native and exotic) for the stand. Record details on INDIGENOUS VASCULAR PLANTS DATA SHEET (Field card B), and EXOTIC VASCULAR PLANTS (Field card B)	
Tick which vegetation tier each species occurs in	
For exotics, give a total % cover class for all exotics combined per vegetation tier	5, 6, 7
Look for signs of stock, animal pests, human damage, nutrient enrichment, drainage	# 2, 3, 4, 10, 11,
Assess the condition of the canopy and intactness of each vegetation layer (canopy, shrub, ground <30 cm)	19, 20
Take photos to record the items above – establish at least one permanently marked photopoint. Record details on PHOTOPOINT RECORD SHEET (Field card A).	General record
Place 20 tracking tunnels out for weta and rodent analysis (weta for 14 days unbaited, grills on tunnels, rodents for 14 days) – this requires return visit.	2, 18

3. In the office	
Tick characteristic kahikatea forest species and bird food species (or use the automated Spreadsheet for this).	
Count indicator and bird food species, number of native and number of exotic plant species, percent of woody species present also as seedlings	16, 17, 21, 22, 23
Complete the ranking card – including management actions Sub-attributes 27-31 either applied by, or in discussion with, landowner/manager	All non-spatial

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[28] Sub-attributes 12, 13, 14, 26 and 27 calculated by Waikato RC using maps of kahikatea and GIS tools

A: KAHIKATEA FOREST GREEN WHEEL: PHOTOPOINT RECORD SHEET

Mark the photopoint location in the field with a permanent cattle tag or similar on a fixed structure (e.g. fence post, established tree). Where possible, also mark photo points on map with a cross. Indicate direction of photographs taken with arrow.

Use a high-quality camera/high resolution phone camera to capture clear images – check they are in focus before moving on.

Photo No[29]	General description (e.g. "photo of forest buffer for sub attribute 15")	Date/time	Compass bearing (direction photo taken)	Location of photographer NZTM Easting: NZTM Northing:

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[29] Use the unique photo number given to the photo file by the camera as that won't change if you delete any photos in the camera.

B: KAHIKATEA FOREST GREEN WHEEL: INDIGENOUS VASCULAR PLANTS

List all native vascular species, tick if present as seedlings (tree and shrub species only) indicate relative abundance (optional). Complete shaded boxes in the office - tick species that are kahikatea forest characteristic species and for species that are abundant or established, indicate which provide bird food by writing the relevant season codes.

Site name ……..……..……..……..   NZTM …….……..……..……..……..

Date………………………..…………..   Assessor……..……..……..……..

Summary data

# of characteristic species (Attrib. 17)	
# of winter bird food species (Attrib. 21)	
# of all bird food species (Attrib. 22)	
# of tree/shrub species present that occur as seedlings (Attrib. 23)	
# of tree/shrub species that occur <u>only</u> as seedlings (notes for proforma header)	

% cover indigenous vegetation per tier (Attrib. 19)	
Canopy (< 50, 50-75 or >75)	
Mid-tier (< 50, 50-75 or >75)	
Ground (< 50, 50-75 or >75)	

	Native Species	Seedlings (tree/shrubs 15-135 cm) ✓ X n/a	Rel. Abundance [30]	Charact[31]. species ✓	Bird food[32] W or O
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					

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[30] OPTIONAL EXTRA INFORMATION A = abundant established plants, C = common established plants, F = few established plants (<10 individuals or < 1 m² cover), S = present as unestablished seedlings only (< 15 cm tall) for shrub/tree species
[31] Tick species present that are on the characteristic species list
[32] Indicate whether Winter (W) food or other seasons (O)

INDIGENOUS VASCULAR PLANTS (2) Site name: Date:

	Native Species	Seedlings ✓	Rel. Abndce[33]	Charact. species ✓	Bird food[34] W or O
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
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41					
42					
43					
44					
45					
46					
47					
48					
49					
50					
51					
52					

[33] OPTIONAL EXTRA INFORMATION   A = abundant established plants, C = common established plants, F = few established plants
   (<10 individuals or < 1 m² cover), S = present as unestablished seedlings only (< 5 cm tall) for shrub/tree species
[34] For species present as A or C, indicate whether Winter (W) food or other seasons (O)

	Native Species	Seedlings ✓	Rel. Abndce	Charact. species ✓	Bird food W or O
53					
54					
55					
56					
57					
58					
59					
60					
61					
62					
63					
64					
65					
66					
67					
68					
69					
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84					
85					
86					
87					

C. KAHIKATEA FOREST GREEN WHEEL: EXOTIC VASCULAR PLANTS

List exotic vascular species. Indicate which tier each occurs in and (optional) its relative abundance. Indicate cover class per tier for all exotics combined (estimate as birds eye view). In the office tick which are RPMS species.

Site name ……………………….…….   NZTM ……………………..…………….

Date…………………………………..   Assessor……..……..……..………..

Exotic species ……..   # Native……….   # All vascular ……….

% native [#Native/#All vascular*100] (Sub-attribute 16)	
% Total exotic cover in canopy (Sub-attribute 5)	
% Total exotic cover in mid-tier/shrub layer (Sub-attribute 6)	
% Total exotic cover in ground layer (Sub-attribute 7)	

	Exotic Species in forest patch	Canopy ✓	Mid ✓	Gnd ✓	Rel Abndce[35]	√ if RPMS plant
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
	Total % Cover[36] per C, M, Gnd					
	Number RPMS species					

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[35] OPTIONAL A = abundant established plants, C = common established plants, F = few established plants (<10 individuals or < 1 m² cover), S = present as unestablished seedlings only (< 5 cm tall) for shrub/tree species

[36] Use this to assist in applying sub-attributes 5, 6, and 7

D. KAHIKATEA FOREST GREEN WHEEL: REGIONAL PLANT PEST SPECIES

List any RPMS species within 50 m of the site (on the same property). Higher probability species listed below, add any others encountered. Record RPMS species located <u>inside</u> the kahikatea stand on the Exotic species datasheet.

	Regional Pest Management Species		Regional Pest Management Species	
1	*Actinidia deliciosa*		*Hedychium gardnerianum*	
2	*Ageratina adenophora*		*Hypericum androsaemum*	
3	*Alternanthera philoxeroides*		*Iris pseudacorus*	
4	*Anredera cordifolia*		*Juglans ailantifolia*	
5	*Araujia hortorum (syn. A. sericifera)*		*Lantana camara*	
6	*Asparagus aethiopicus*		*Ligustrum lucidum*	
7	*Asparagus setaceus*		*Ligustrum sinense*	
8	*Carduus acanthoides*		*Osmunda regalis*	
9	*Carduus nutans*		*Passiflora tripartita (syn P. mixta)*	
10	*Clematis vitalba*		*Prunus serrulata*	
11	*Cortaderia jubata*		*Salix cinerea*	
12	*Cortaderia selloana*		*Salix fragilis*	
13	*Glyceria maxima*		*Solanum mauritianum*	
14	*Gunnera tinctoria or G. manicata*		*Ulex europaeus*	
15	*Hedychium flavescens*			
			Total number RPMS species	

E. KAHIKATEA FOREST GREEN WHEEL: CHARACTERISTIC NATIVE SPECIES

Tick the first column if this species is in the kahikatea stand you are assessing, to apply sub-attribute 17.

	Alectryon excelsus subsp. excelsus	Titoki
	Aristotelia serrata	Wineberry
	Asplenium bulbiferum	Hen and chicken fern
	Asplenium flaccidum	Hanging spleenwort
	Asplenium oblongifolium	Shining spleenwort
	Asplenium polyodon	Sickle spleenwort
	Astelia hastata (syn Collospermum hastatum)	Tank lily
	Austroblechnum lanceolatum (syn Blechnum chambersii)	Lance fern
	Beilschmiedia tawa	Tawa
	Calystegia sepium subsp. roseata	Bindweed
	Carex dissita	Sedge
	Carex lambertiana	Sedge
	Carex virgata	Purei
	Carpodetus serratus	Putaputaweta
	Coprosma areolata	Thin-leaved coprosma
	Coprosma tenuicaulis	Swamp coprosma
	Cordyline australis	Ti, cabbage tree
	Cranfillia fluviatilis (syn Blechnum fluviatile)	Thread fern
	Cyathea dealbata	Ponga, silver fern
	Cyathea medullaris	Mamaku, black fern
	Dacrycarpus dacrydioides	Kahikatea
	Dacrydium cupressinum	Rimu
	Deparia petersenii subsp. congrua (incl. D. tenuifolia)	Fern
	Dicksonia fibrosa	Wheki-ponga
	Dicksonia squarrosa	Wheki
	Diplazium australe	Fern
	Doodia australis (syn D. media, Blechnum parrisiae)	Rasp fern
	Freycinetia banksii	Kiekie
	Geniostoma ligustrifolium var. ligustrifolium	Hangehange
	Hedycarya arborea	Pigeonwood
	Histiopteris incisa	Waterfern
	Icarus filiformis (syn Blechnum filiforme)	Thread fern
	Knightia excelsa	Rewarewa
	Lastreopsis glabella	Fern
	Laurelia novae-zelandiae	Pukatea
	Melicytus micranthus	Swamp mahoe
	Melicytus ramiflorus subsp. ramiflorus	Mahoe
	Metrosideros diffusa	White rata
	Metrosideros perforata	White rata
	Microlaena avenacea (syn Ehrhata diplax)	Bush rice grass
	Microlaena stipoides	Bush rice grass
	Microsorum pustulatum subsp. pustulatum	Hounds tonge fern
	Microsorum scandens	Hounds tonge fern
	Muehlenbeckia australis	Pohuehue
	Myrsine australis	Mapou
	Nestegis lanceolata	White maire
	Oplismenus hirtellus subsp. imbecillis	Panic grass
	Parablechnum novae-zelandiae (syn Blechnum novae-zelandiae)	Kiokio
	Parapolystichum microsora subsp. pentangularis (syn Lastreopsis)	Fern
	Parsonsia heterophylla	New Zealand jasmine
	Passiflora tetrandra	Native passionfruit
	Pellaea rotundifolia	Fern
	Pneumatopteris pennigera	Fern
	Podocarpus totara var. totara	Lowland totara
	Prumnopitys taxifolia	Matai
	Pseudopanax crassifolius	Lancewood
	Pteridium esculentum	Bracken
	Pteris macilenta	Fern
	Pteris tremula	Fern
	Pyrrosia eleagnifolia	Fern
	Ripogonum scandens	Supplejack
	Streblus heterophyllus	Turepo
	Uncinia uncinata (now Carex uncinata)	Hooksedge
	TOTAL NUMBER	

F. KAHIKATEA FOREST GREEN WHEEL: BIRD FOOD SPECIES

Use this list of species that naturally occur in kahikatea forests and provide high energy food resources for native forest fruit or nectar eating birds to score sub-attributes 21 and 22. Derived from species lists of reference sites and various sources to apply seasonal fruiting attributes.

SCIENTIFIC NAME	COMMON NAME	WINTER	W or O if present
Alectryon excelsus subsp. *excelsus*	Titoki		
Alseuosmia macrophylla	Toropapa		
Alseuosmia x quercifolia	Toropapa		
Aristotelia serrata	Wineberry		
Astelia fragrans	Kakaha		
Astelia grandis	Swamp astelia		
Astelia hastata (syn *Collospermum hastatum*)	Tank lily	y	
Astelia microsperma (syn *Collospermum microspermum*)	Kakaha	y	
Astelia solandri	Kaiwharawhara	y	
Beilschmiedia tawa	Tawa		
Brachyglottis repanda	Rangiora		
Carpodetus serratus	Putaputaweta	y	
Coprosma arborea	Mamangi	y	
Coprosma areolata	Thin-leaved coprosma	y	
Coprosma grandifolia	Kanono	y	
Coprosma lucida	Shining karamu	y	
Coprosma propinqua	Mingimingi	y	
Coprosma propinqua x C. robusta	Mingimingi	y	
Coprosma rhamnoides	Coprosma		
Coprosma rigida	Coprosma	y	
Coprosma robusta	Karamu	y	
Coprosma rotundifolia	Round leaved coprosma		
Coprosma tenuicaulis	Swamp coprosma	y	
Cordyline australis	Ti, cabbage tree		
Corynocarpus laevigatus	Karaka		
Dacrycarpus dacrydioides	Kahikatea		
Dacrydium cupressinum	Rimu		
Dianella haematica	Swamp blueberry		
Dianella nigra	Turutu, native blueberry		
Dysoxylum spectabile	Kohekohe	y	
Elaeocarpus dentatus	Hinau		
Elaeocarpus hookerianus	Pokaka		
Freycinetia banksii	Kiekie		
Fuchsia excorticata	Tree fuchsia		
Fuchsia perscandens	Scrambling fuchsia		
Geniostoma ligustrifolium var. *ligustrifolium*	Hangehange		
Hedycarya arborea	Pigeonwood	y	
Hoheria populnea	Houhere		
Hoheria sexstylosa	Houhere		
Knightia excelsa	Rewarewa		
Leucopogon fasciculatus	Mingimingi		
Litsea calicaris	Mangeao		
Lophomyrtus bullata	Ramarama		
Melicope simplex	Poataniwha		
Melicytus lanceolatus	Narrow-leaved mahoe	y	
Melicytus micranthus	Swamp mahoe		
Melicytus ramiflorus subsp. *ramiflorus*	Mahoe		
Metrosideros colensoi	Rata		
Metrosideros diffusa	White rata		
Metrosideros fulgens	Rata	y	
Metrosideros perforata	White rata		
Metrosideros robusta	Northern rata		
Muehlenbeckia australis	Pohuehue		
Muehlenbeckia axillaris	Pohuehue		
Muehlenbeckia complexa	Pohuehue		
Myrsine australis	Mapou	y	
Neomyrtus pedunculata	Rohutu		
Nertera dichondrifolia	Nertera		
Nertera scapanoides	Nertera		
Nestegis cunninghamii	Black maire		
Nestegis lanceolata	White maire		
Nestegis montana	Narrow-leaved maire		
Nestegis montana	Narrow-leaved maire		
Olearia rani	Houpara		
Parsonsia capsularis	New Zealand jasmine		
Parsonsia heterophylla	New Zealand jasmine	y	

Passiflora tetrandra	Native passionfruit		
Pennantia corymbosa	Kaikomako		
Phormium tenax	Flax, harakeke	y	
Piper excelsum (syn Macropiper excelsum var. *excelsum)*	Kawakawa		
Pittosporum cornifolium	Tawhirikaro	y	
Pittosporum eugenioides	Tarata		
Pittosporum tenuifolium	Kohuhu	y	
Podocarpus totara var. *totara*	Lowland totara	y	
Prumnopitys ferruginea	Miro		
Prumnopitys taxifolia	Matai		
Pseudopanax anomalus (syn Raukaua)	Raukawa	y	
Pseudopanax arboreus	Five-finger	y	
Pseudopanax crassifolius	Lancewood		
Rhopalostylis sapida	Nikau	y	
Ripogonum scandens	Supplejack		
Rubus australis	Bush lawyer		
Rubus cissoides	Bush lawyer		
Rubus schmidelioides	Bush lawyer	y	
Schefflera digitata	Pate		
Solanum aviculare var. *aviculare*	Poroporo		
Solanum nodiflorum (syn S. americanum)	Small-flowered nightshade		
Sophora microphylla	Kowhai		
Streblus heterophyllus	Turepo	y	
Syzygium maire	Swamp maire		
Veronica stricta var *stricta (syn Hebe stricta* var *stricta)*	Koromiko		
TOTAL NUMBER (W only)			
TOTAL NUMBER (all bird food species present)			

Appendix 4: Example of Green Wheel Excel spreadsheet and produced graphs*

Below are examples of the Excel tables filled out with varying recovery levels for all attributes, and the associated green wheels produced by these.

An ecosystem with values of zero for all attributes.

| ATTRIBUTE CATEGORY	RECOVERY LEVEL (1-5)	EVIDENCE FOR RECOVERY LEVEL
ATTRIBUTE 1. Absence of threats		
Stock Access	0	
Mammalian Predators	0	
Feral ungulates (deer, goats, pig)	0	
Browsers (rabbits, hares)	0	
Canopy weed abundance	0	
Shrub layer weed abundance	0	
Ground cover weed abundance (<30 cm)	0	
Pest plant presence	0	
Nutrient input	0	
Drainage	0	
Human footprint	0	
ATTRIBUTE 2. Physical conditions		
Size	0	
Shape index	0	
Forest interior	0	
Buffer	0	
ATTRIBUTE 3. Species composition		
Dominance of native plants	0	
Characterisitic plant species	0	
Indicator animal species	0	
ATTRIBUTE 4. Community structure		
Vegetation layers	0	
Canopy condition	0	
ECOSYSTEM TYPE	0	
ATTRIBUTE 5. Ecosystem function		
Winter bird-food availability	0	
All season bird-food availability	0	
Plant recruitment	0	
ATTRIBUTE 6. External exchanges		
Landscape matrix	0	
Habitat links - terrestrial	0	
Habitat links - aquatic	0	
ATTRIBUTE 7. Management regime		
Legal Protection	0	
Management plan	0	
Animal pest control effort	0	
Plant pest control effort	0	
Re-vegetation effort	0	

An ecosystem with a mixture of recovery levels for all attributes

| ATTRIBUTE CATEGORY	RECOVERY LEVEL (1-5)	EVIDENCE FOR RECOVERY LEVEL
ATTRIBUTE 1. Absence of threats		
Stock Access	1	
Mammalian Predators	3	
Feral ungulates (deer, goats, pig)	2	
Browsers (rabbits, hares)	4	
Canopy weed abundance	3	
Shrub layer weed abundance	1	
Ground cover weed abundance (<30 cm)	2	
Pest plant presence	3	
Nutrient input	3	
Drainage	2	
Human footprint	4	
ATTRIBUTE 2. Physical conditions		
Size	5	
Shape index	3	
Forest interior	2	
Buffer	4	
ATTRIBUTE 3. Species composition		
Dominance of native plants	2	
Characterisitic plant species	2	
Indicator animal species	3	
ATTRIBUTE 4. Community structure		
Vegetation layers	3	
Canopy condition	3	
ECOSYSTEM TYPE	2	
ATTRIBUTE 5. Ecosystem function		
Winter bird-food availability	2	
All season bird-food availability	4	
Plant recruitment	3	
ATTRIBUTE 6. External exchanges		
Landscape matrix	4	
Habitat links - terrestrial	2	
Habitat links - aquatic	3	
ATTRIBUTE 7. Management regime		
Legal Protection	4	
Management plan	3	
Animal pest control effort	3	
Plant pest control effort	4	
Re-vegetation effort	4	

An ecosystem with values of five for all attributes

| ATTRIBUTE CATEGORY	RECOVERY LEVEL (1-5)	EVIDENCE FOR RECOVERY LEVEL
ATTRIBUTE 1. Absence of threats		
Stock Access	5	
Mammalian Predators	5	
Feral ungulates (deer, goats, pig)	5	
Browsers (rabbits, hares)	5	
Canopy weed abundance	5	
Shrub layer weed abundance	5	
Ground cover weed abundance (<30 cm)	5	
Pest plant presence	5	
Nutrient input	5	
Drainage	5	
Human footprint	5	
ATTRIBUTE 2. Physical conditions		
Size	5	
Shape index	5	
Forest interior	5	
Buffer	5	
ATTRIBUTE 3. Species composition		
Dominance of native plants	5	
Characterisitic plant species	5	
Indicator animal species	5	
ATTRIBUTE 4. Community structure		
Vegetation layers	5	
Canopy condition	5	
ECOSYSTEM TYPE	5	
ATTRIBUTE 5. Ecosystem function		
Winter bird-food availability	5	
All season bird-food availability	5	
Plant recruitment	5	
ATTRIBUTE 6. External exchanges		
Landscape matrix	5	
Habitat links - terrestrial	5	
Habitat links - aquatic	5	
ATTRIBUTE 7. Management regime		
Legal Protection	5	
Management plan	5	
Animal pest control effort	5	
Plant pest control effort	5	
Re-vegetation effort	5	

The produced green wheels from the above tables.
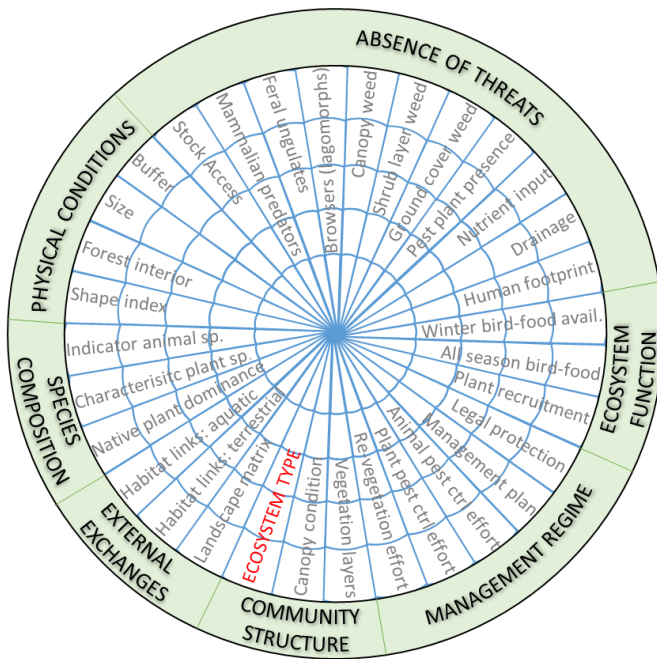
Update recovery wheel
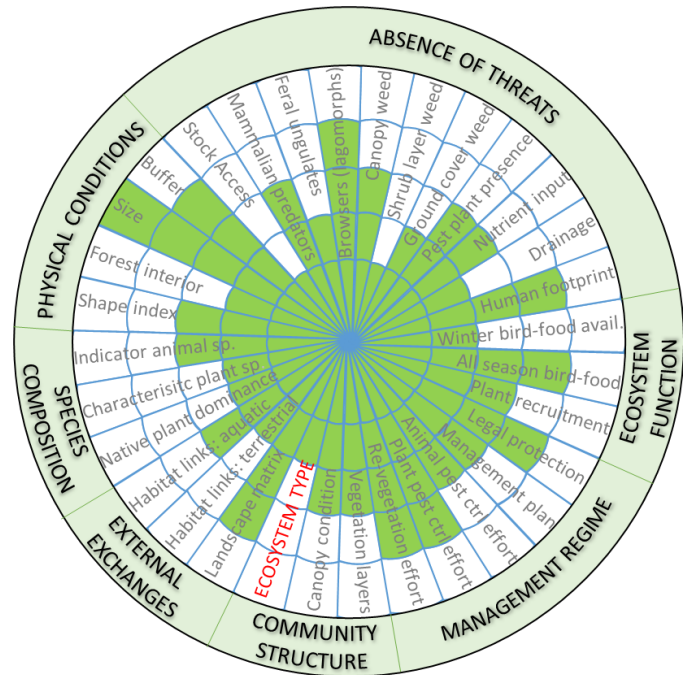
Update recovery wheel
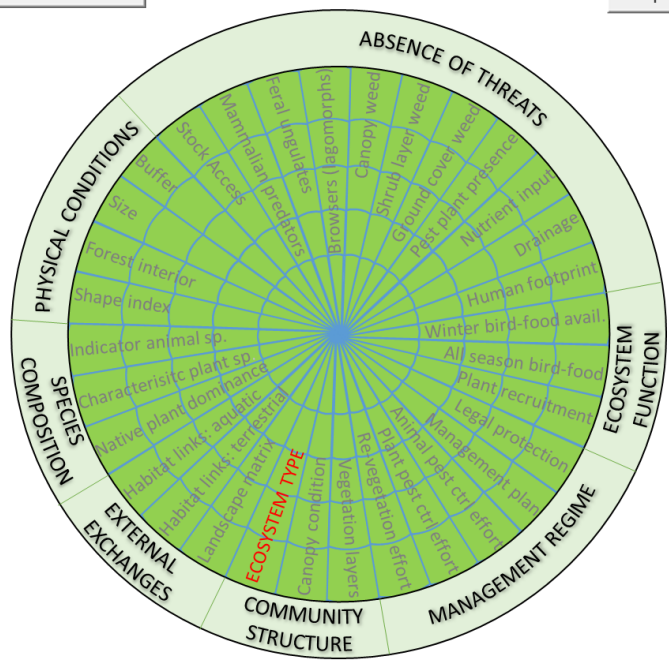
Update recovery wheel

How to use the Green Wheel spreadsheet:

1. Assess the ecosystem and determine the recovery level for each attribute.
2. Fill out the recovery level column by entering the determined score alongside its associated attribute.
3. Click 'Update recovery wheel' underneath the wheel figure.
4. The wheel will be filled with green bars corresponding to the entered recovery levels, overall evaluating the ecosystem recovery.

*Adapted from: http://seraustralasia.com/wheel/wheel.html