Impacts of intensive native forest logging in Queensland

A Response to Eco Logical Australia and Department of Agriculture and Fisheries Protection Measures

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About the Australian Rainforest Conservation Society Inc.

The Australian Rainforest Conservation Society (ARCS) is one of Australia's premier nature conservation organisations with a history of delivering science-based conservation outcomes for biodiversity, Australia's forests and our unique World Heritage.

ARCS founders Drs Aila Keto and Keith Scott were commissioned by Federal Governments to write three of Australia's successful World Heritage nominations — the Wet Tropics, K'gari (Fraser Island), and the Gondwanan Rainforests of Australia. Dr Keto, was a foundation member of the Wet Tropics World Heritage Management Board and currently contributes to management of the Gondwana Rainforests of Australia World Heritage Area through its Technical and Scientific Advisory Committees since 2007.

Our expertise includes rainforest restoration in areas needed to protect the core values of the Gondwanan Rainforests World Heritage Area. Our ecological restoration work on the Springbrook Plateau (Springbrook Rescue) beginning in 2005 has been showcased by IUCN as one of 12 global case studies (Keenleyside *et al.* 2012). ARCS operates two commercial businesses to provide reliable, long-term financing that philanthropy or government grants cannot. The foundational and annual reports are on the ARCS website.

ARCS core focus over the past 40 years has been on the unsustainability of native forest logging, the availability of sustainable substitute resources and products, and, significantly increasing the protected area estate.

ARCS was a partner in the international Primary Forest & Climate Change Project led by Professor Brendan Mackey who heads the Griffith University's Griffith Climate Action Beacon. Through outcomes of its research program the project contributes significantly to international policy improvements for primary forests. Our involvement ensures ARCS is up to date on the latest research on the linked biodiversity and climate existential challenges facing life on Earth, and their solutions. Virginia Young (our Director, International Forests and Climate Program) represents ARCS at all important international forums including those of the United Nations Framework Climate Change Convention (UNFCCC) and the Convention on Biological Diversity. A key message is that neither existential crisis can be effectively addressed unless we protect, repair and restore ecosystem and landscape integrity to ensure their stability and resilience.

Fundamentally, ARCS recognises and adopts systems thinking for achieving the necessary transformational systems change across all sectors of society.

This document

Following ARCS persistent questioning regarding intensive logging in greater glider habitat, the Department of Agriculture and Fisheries (DAF) commissioned Eco Logical Australia (ELA) to provide advice and responded with Greater Glider and Yellow-bellied Glider Protection Measures.

This document can be cited as follows: *Keto, A. and Scott, K. (2024). Response to review of intensive logging in Queensland. Working Paper 2024-04.*

This young greater glider was displaced by clearing near Chinchilla on the Darling Downs, Queensland. The young greater glider was lucky to be rescued by a spotter/catcher who was present. Credit: © Briano / WWF-Aus

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1. Summary

- It is clear that selective logging has a significant impact on the Greater Glider. Whereas the Protection Measures proposed by the Department of Agriculture and Fisheries (DAF) may produce a small decrease in the impact, DAF is proposing to continue significantly impacting this endangered species. (General conclusion)
- The application of a policy to balance jobs and the environment is inappropriate for an endangered species. (Section 2.2)
- The overall approach of the risk assessment and DAF's response does not appear to take account of the fact that the Greater Glider is already endangered and in serious decline. (Section 2.5)
- The risk assessment found ongoing selective logging will seriously degrade 31–70% of greater glider foraging habitat resulting in up to 70% decline in population which will be essentially irreversible. (Section 3.1)
- The risk assessment found ongoing selective logging will seriously degrade 31–70% of yellow-bellied glider foraging habitat resulting in up to 100% decline in population which will be essentially irreversible. (Section 3.1)
- The literature review refers to the study by one of the authors of the risk assessment which concluded that 85% of basal area needs to be retained to maintain one Greater Glider per 3 ha in southern Queensland. (Section 3.4)
- Despite the endangered status of the Greater Glider, the proposed Protection Measures will result in the retention of just two extra trees per hectare in southern Queensland. (Section 3.7)
- Logging will remove up to 50% of the canopy cover with all trees harvested being in the >40 cm DBH class, potentially removing close to all of the essential food source for the endangered Greater Glider in the logged area. (Section 3.7)
- Greater gliders will be impacted by climate change and logging impacts will exacerbate the effect. (Section 3.9)
- The Precautionary Principle must be applied in policy and management decisions. (Section 4.3)
- 76% of greater glider habitat and 14% of potential habitat is of major commercial timber value. (ELA 5.1.5)
- 48% of greater glider habitat may be subject to logging (within forestry management planning units). (ELA 6.1)
- 66% of greater glider habitat is highly or very highly disturbed. (ELA 6.2.4)
- 48% of yellow-bellied glider habitat is highly or very highly disturbed. (ELA 6.2.4)

2. General comments

It should be understood at the outset that the *Greater Glider and Yellow-bellied Glider Risk Assessment* is not an independent scientific analysis of the impacts of logging in Queensland. It is a consultancy report commissioned by DAF and prepared in conjunction with DAF staff and involved one workshop and regular meetings to "discuss *feasible* (our emphasis) options for enhancing the protection" of the two glider species. It can be reasonably concluded that there was the underlying assumption that logging would continue in the habitat of the threatened species with possibly reduced impacts.

The ELA Risk Assessment and DAF Protection Measures reports, together with a link to their Code of Practice 2020 (the Code), were released publicly via the DAF website on 28 February 2024: (https://www.daf.qld.gov.au/business-priorities/forestry/environment/glider).

The accompanying website statements by DAF (*How we look after the environment — Gliders*) would grossly mislead the public, especially if the actual reports were not read or critically evaluated. Unsubstantiated claims are made regarding adequacy of The Code and Protection Measures proposed by DAF.

Frequently repeated refrains include: "the more intensive clear-felling practices used in the southern states … are not used in Queensland"[1]; "the Code outlines… *robust safeguards* for trees with hollows, which are a crucial habitat requirement for greater gliders; "The risk assessment confirmed … state forests managed for selective timber harvesting, *crucially conserve* gliders …. *ensuring* the ongoing survival and protection of both glider species' … likely to *protect* foraging and nesting trees" The implication is that there is nothing to worry about. There is!

The greater glider is endangered in northern New South Wales where "selective logging" practices are adopted not unlike those in Queensland. What matters most is whether replacement hollow-bearing trees can form soon enough to maintain current glider populations. They can't, given the logging cycle is about 30 years, hollow formation 100 years or more, the longevity of greater gliders 15 years and their generation length 6-8 years.

Our Response analyses those claims in detail.

[1] McLean, C.M., Kavanagh, R.P., Penman, T. and Bradstock, R.A. (2018). The threatened status of the hollow dependent arboreal marsupial, the Greater Glider (Petauroides volans), can be explained by impacts from wildfire and selective logging. *Forest Ecology and Management 415-416*, 19-25. https://doi.org/10.1016/j.foreco.2018.01.048.

2.1. Recommended Glider Protection Measures NOT "fit for purpose" as claimed.

According to Australian Law, a product or service is considered fit for purpose if it fulfils the specific purpose for which it was intended. What if there's confusion about the specific purpose *intended*?

We note that the phrase "fit for purpose" was used frequently by DAF staff in the briefing provided to us on 1 March 2024. The ELA assessment also notes that the Code of Practice 2020 (the Code) was "found to be *fit for purpose*". Presumably, the purpose is timber harvesting.[2]

The only justiciable cardinal principle of State Forest management in the *Queensland Forestry Act 1959* is permanent reservation for the purpose of *timber production ... in perpetuity* and of *watershed protection*. There is a weaker caveat of only "*having regard to the desirability* of conservation of soil and the environment and protection of water quality.

It is the Department of Environment, Science and Innovation (DESI), as the custodian of the State Forest Estate (State forests and timber reserves) that prescribes operational environmental management standards for timber harvesting via the Code. The Code is based on conflicting principles: on the one hand (a) not undermining any other standard, Code or law;[3] on the other hand (b) it defines *minimum* standards taking account of the need for *efficiency* of timber harvesting operations (Pareto efficiency), optimal community benefit (sustainable timber supplies) whilst allowing for "*acceptable*" environmental impacts (subjective terms); conformity with the National Strategy for Ecologically Sustainable Development 1992,[4] the Intergovernmental Agreement on the Environment 1992 (IGAE) and the Australian Standard for Sustainable Forest Management (AS 4708).

Pareto efficiency assumes the policy intervention involves marginal, predictable (certain) change over short timescales[5] — no change in prices or supply of goods and services (timber) such that no extra resources are required to be allocated, as

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[2] The *Queensland Forestry Act 1959* defines the cardinal principle of management of State Forests as "the permanent reservation of such areas for the *purpose* of producing timber and associated products in perpetuity and of protecting a watershed therein (Part 4, Division 1, Section 33 (1), p. 34; whilst only having *regard* to (b) the *desirability* of conservation of soil and the environment and of protection of water quality.

[3] Including the *Nature Conservation Act 1992, Environmental Protection Act 1994, Environmental Protection and Biodiversity Conservation Act 1999* (Cth) etc.

[4] We address the adequacy of and non-compliance with the concept of *Ecologically Sustainable Management* principles in the Appendix (p. 28)

[5] Sharpe, S., Mercure J-F., Vinuales, J., Ives, M., Grubb, M, Pollitt, H., Knobloch, F. and Nijsse, F. (2020) *Deciding how to decide: Risk-opportunity analysis as a generalisation of cost-benefit analysis.* C-EENRG Working Papers, 2020-3, 1-19. Cambridge Centre for Environment, Energy and Natural Resource Governance, University of Cambridge.

confirmed by DAF at their briefing. The policy fails for complex adaptive systems defined by radical uncertainty, as is the case here.

The conflicting principles embedded in the Code provide ample wriggle room for compromises and ignore DESI's own statutory obligations regarding e.g. protecting endangered species habitat to avoid extinctions.

However, the IGAE includes principles to be incorporated into Government decision-making processes:

1. *precautionary principle*: where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
2. *intergenerational equity*: the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;
3. *conservation of biological diversity and ecological integrity*: conservation of biological diversity and ecological integrity should be a fundamental consideration.

Nowhere in the Code itself or documentation associated with its development are these principles considered or even defined.

Nowhere in either the ELA and DAF documents is there any suggestion that threats from logging to the endangered Greater Glider will or should be eliminated to prevent local extinctions and further decline in populations. It appears that continuing to impose known threats is accepted.

The overall approach of assessing threats does not appear to take account of the current conservation status of the two species. The Greater Glider, in particular, is already endangered and populations are in decline. That is the starting point when assessing the severity of threats including ongoing logging.

2.2. Government policy of "balance" regarding endangered wildlife is wrong

Underlying this whole issue is the question of Government policy on endangered species. The Greater Glider is listed as endangered under the *Nature Conservation Act 1992* as well as under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC). DAF's stated policy on native timber harvesting is to ensure a long-term sustainable future that *balances* jobs and the environment. That policy appears to be the basis for DAF's response to the risk assessment by Eco Logical Australia and DAF's proposed Protection Measures.

The question is whether a '*balance'* approach is appropriate for an endangered species. There are always innovative, creative alternative solutions, particularly when addressing the multi-sectoral transformational changes required by the rapidly worsening climate-biodiversity crisis. Ceasing native forest logging is not a matter of life and death. Alternative jobs can be found and Queensland native hardwood is not a necessary product. Engineered wood from plantation pine has essentially replaced hardwood in building construction and alternatives are readily available for other products including poles and girders.[6]

DAF's proposed Protection Measures are by no means the best we can do to protect the Greater Glider. Harvests remove up to 50% of the basal area, roughly equivalent to 50% of the canopy cover, and that removal is confined to the larger trees which are the essential food source for the Greater Glider that feeds almost entirely on eucalypt leaves. There can be no doubt that logging will have a significant impact on the endangered species. The Eco Logical Australia risk assessment supports that view. The Queensland Government as a whole needs to decide if the policy of 'balance' is appropriate. Should we knowingly and unnecessarily be adding to the threats already facing an endangered species? Should the Queensland Government prioritise "balance" over its statutory obligations? "Balance" is synonymous with "trade-offs" — in what, or for whom?

2.3. The Queensland Government in breach of its own legislation and ignores the Australian Government's Conservation Advice

The *Nature Conservation (Animals) Regulation 2020* (the Regulation) defines the 'Proposed management intent' for endangered wildlife which includes "to protect the *critical habitat,*[7] or areas of major interest, for the animal".

The *Nature Conservation Act 1992* (s.72) requires that wildlife is to be managed in accordance with the management principles prescribed in the Act and the declared management intent. The declared management intent is the management intent prescribed under the Regulation.

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[6] Keto, A. and Scott, K. (2023). Native Forest Logging: Alternatives to native forest hardwoods. *Briefing Paper 2024-02*

[7] The "Habitat" concept was recently discussed by Martin Taylor, Adjunct Senior Lecturer, Department of Environment, University of Queensland: Taylor, M.E.J. (2024). Queensland DAF Glider Protection Measures: Critique.pdf.; and Ashman, K.R., Watchorn, D.J., Lindenmayer, D.B. and Taylor, M.F. (2021). Is Australia's environmental legislation protecting threatened species? A case study of the national listing of the greater glider. *Pacific Conservation Biology 28*(3), 277-289. https://www.researchgate.net/publication/354108370_Is_Australia's_environmental_legislation_protecting_threatened_species_A_case_study_of_the_national_listing_of_the_greater_glider.

The management principles require that protected wildlife be managed to, *inter alia*, ensure the survival and natural development of the wildlife in the wild, identify, and reduce or remove, the effects of threatening processes, and identify the wildlife's critical habitat and conserve it to the greatest possible extent.

The Conservation Advice for *Petauroides volans*[8] provides a foundation for conservation action and further planning. Included is a requirement for a Recovery Plan. The Advice includes an extensive list of conservation and recovery actions given populations continue to decline and identified threats have not been eliminated. There is no Recovery Plan considered in Queensland nor are any of the comprehensive listed conservation and recovery actions.

We conclude that the Queensland Government may be in breach of its own legislation and ignores the Conservation Advice of the Federal Government. The mitigation actions proposed by DAF fall far short of what was recommended in The Conservation Advice associated with the "Endangered" listing.

2.4. The concept of "habitat" is misapplied

"Habitat" is a foundational concept of ecology.[9,10] Habitat loss is the primary driver of species' population declines and extinctions. Correctly and consistently defining and understanding the concept underpins effective protection, management and restoration strategies. Focusing on single elements such as "habitat or recruit trees" is misleading and likely dangerous for the Greater Glider. "Habitat" correctly used refers to *all* the resources and conditions that allow a specific organism to survive, reproduce, persist, disperse and evolve in the long term. It is a systemic, dynamic concept functionally related to the concepts of ecological and landscape integrity and resilience. All the drivers affecting glider habitat integrity and resilience must be considered.

"Critical habitat" is a legal concept and defined in the *Nature Conservation Act 1992* as "*habitat that is essential for the conservation of a viable population of protected wildlife or community of native wildlife, whether or not special management considerations and protection are required*" or even if "*the area is not presently occupied by the wildlife*". Management principles to "*ensure the survival and natural development of the wildlife*" in question require management to "*identify, and*

[8] Department of Agriculture, Water and the Environment (2021). *Conservation advice for Petauroides volans (greater glider (southern and central))*, Canberra.
[9] Kirk, D.A., Park, A.C., Smith, A.C., Howes, B.J., Prouse, B.K., Kyssa, N.G., Fairhurst, E.N. and Prior, K.A. (2018). Our use, misuse, and abandonment of a concept: Whither habitat? *Ecology and Evolution 8*(8), 4197-4208.
[10] Bamford, M.J. and Calver, M.C. (2014). A precise definition of habitat is needed for effective conservation and communication. *Australian Zoologist, 27*(20), 245-247. https://doi.org/10.7882/AZ.2014.015.

reduce or remove, the effects of threatening processes"; and "*identify the wildlife's critical habitat and conserve it to the greatest possible extent*".

Further, if "critical habitat" is subject to a threatening process that is likely to have significant detrimental effect on the wildlife, habitat or area, the Minister may make an interim conservation order for the conservation, protection or management of the wildlife, habitat or area (Part 6, Section 102). This statutory power has not been exercised by DESI, the *only* custodian of State Forests and Timber Reserves.

Unfortunately, the *Nature Conservation Act 1999* fails to give a more definitive description of "critical habitat". Unless standardised terms and descriptions for "habitat" and "critical habitat" are used, misuse is rife[11] whether unintentional or deliberate with grave consequences for endangered wildlife.

The net effect is that the timber industry currently reliant on native forest logging is effectively "free-riding" (reaping benefits while imposing costs on others).

*2.5. The Greater Glider is **Endangered***

One would think that to stop an endangered species from continuing a trajectory to extinction, one would need to understand the *baseline conditions* (old growth pre-logging state) pertaining when populations were common, abundant, healthy and stable to help quantify its safe living conditions — all the necessary biophysical systems and processes that regulate the glider's functioning, stability, and resilience.[12]

You would also need to know the *current* population trends of this once common and abundant species against the historical pre-disturbance baseline — are they still declining? At what rates? Are there lag effects to consider? Would current and proposed protection measures have any significant impact on current population trends? Are their application too little, too late? How would impact significance/effectiveness be measured?

The management priority should focus on recovery plans as recommended in the Conservation Advice. What adaptive management framework would be robust enough to give high scientific confidence that greater glider levels and their critical habitats are returning to safe levels?

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[11] Krausman, P.R. and Morrison, M.L. (2016). Another plea for standard terminology. *The Journal of Wildlife Management 80*(7): 1143-1144. DOI: 10.1002/jwmg.21121.

[12] Knipler, M.L., Gracanin, A. and Mikac, K.M. (2023). Conservation genomics of an endangered arboreal mammal following the 2019-2020 Australian megafire. *Scientific Reports 13*, 480. https://doi.org/10.1038/s41598-023-27587-3.

As things stand there is a risk of further destabilizing both.

The higher level of statutory responsibilities relates to protecting biodiversity — ecosystems, species, and genetic diversity — all underpin the ability to protect a single species such as the greater glider. All levels of biodiversity are at risk of collapse.

At this stage, as pointed out in the Conservation Advice, we don't even know with certainty whether, on the basis of recent morphological and genetic evidence[13,14] *Petauroides volans* (greater glider (southern and central)) actually comprises two species. If so, the implications for conservation management would be substantial.

Moreover, the lack of knowledge of the genetic structure (e.g. heterozygosity) of the species populations across its range translates into an inability to appropriately manage and protect it from extinction. Protecting genetic diversity is critical to conserving species' resilience and adaptive and evolutionary potential.

Genetic information is vital for assessing population size, quantifying connectivity, delineating range, detecting hybridisation and generally indicating a population's ability to persist.

There exist very little baseline and current genetic data without which the conservation strategies proposed amount to little more than "a stab in the dark".

There is nothing in the ELA document nor in DAF's response to indicate that an extraordinary approach is being considered because the species is endangered. One would have expected very significant measures being proposed because of the endangered status. That has not occurred. DAF's response is to retain around two additional trees per hectare while continuing 40 cm+ logging and removing 50% of the basal area.

The Code of Practice was developed 25 years ago when the Greater Glider was not threatened, minimally amended in 2014 when the Greater Glider was not listed as endangered, and amended again in 2020 when the Greater Glider was still not

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[13] McGregor, D.C., Padovan, A., Georges, A., Krockenberger, A., Yoon, H-J. and Youngentob, K.N. (2020). Genetic evidence supports three previously described species of greater glider, *Petauroides volans, P. minor,* and *P. armillatu. Scientific Reports 10:* 1984. https://doi.org/10.1038/s41598-020-76364-z.

[14] Knipler, M.L., Gracanin, A. and Mikac, K.M. (2023). Conservation genomics of an endangered arboreal mammal following the 2019-2020 Australian megafire. *Scientific Reports 13*, 480. https://doi.org/10.1038/s41598-023-27587-3.

listed as endangered.[15] Yet very minor changes are proposed despite the species now being endangered.

Further, references to the literature generally focus on averages, e.g. the average number of hollow-bearing trees occurring over a range of study sites. Basing harvesting practice on such average values is a compromise made in the interest of timber harvest but not appropriate when considering the protection of an endangered species. The conservation advice[16] for listing the Greater Glider as endangered notes "It is likely that only a proportion of forest in potential habitat areas is suitable for the species, as the structural attributes of the forest overstorey and forage quality it relies on vary considerably across the landscape."[17,18]

The greater glider's body may be close to the largest possible for a species to be able to glide yet still survive on typically nutrient-poor and toxin-rich eucalypt foliage. Toxic secondary metabolites (TSMs) require considerable energy to detoxify bringing gliders close to the limit of their energy budget. Thus greater gliders are particularly vulnerable to loss of access to high quality foraging habitat e.g. through fragmentation, depletion by logging and climate change-related elevation of TSMs due to increased atmospheric CO_2 levels.[19]

Thus, areas of high or very high quality will inevitably be degraded. As noted above it represents a misapplication of the concept of "habitat" with grave consequences — particularly when data on population trends are non-existent and monitoring not proposed.

3. Specific comments

3.1 Damning threat assessment summaries ignored

Firstly, we do not accept the process of deriving a summary of the various threats. To take the example of the threat of ongoing logging on both glider species, a reduction in foraging habitat will mean a reduction in the population. The threat will not be compensated by low impact on nesting habitat such that the overall impact is

[15] The Greater Glider was listed as endangered under the *Environmental Protection and Conservation Act 1999* (Cth) on 5 July 2022 and also endangered under the *Nature Conservation (Animals) Regulation 2020* (QLD) in July 2022.

[16] Department of Climate Change, Energy, the Environment and Water (2022). Conservation Advice for *Petauroides volans* (greater glider (southern and central)). 5 July 2022

[17] Eyre, T, (2002). Habitat preferences and management of large gliding possums in southern Queensland. Ph.D. thesis, Southern Cross University. Lismore.

[18] Andrew, R.L., Peakall, R., Wallis, I.R., Wood, J.T., Knight, E.J. and Foley, W.J. (2005). Marker-based quantitative genetics in the wild? The heritability and genetic correlation of chemical defences in Eucalyptus. *Genetics 171*, 1989-1998.

[19] References within Lindenmayer, D.B., Wood, J.T., McBurney, L., MacGregor, C., Youngentob, K. and Banks, S.C. (2011). How to make a common species rare: A case against conservation complacency. *Biological Conservation 144*, 1663-1672.

'medium'. We therefor dispute the statement in DAF's Protection Measures that current selective native timber harvesting practices ranked as medium for both species.

Secondly, the presentation in Tables 6 and 7 of the ELA report tends to obscure the scope, severity and irreversibility of the threats. The tables below summarise the impacts of ongoing logging as presented in Tables 6 and 7.

Impact of selective timber harvesting: Ongoing on foraging habitat	*Scope*	*Severity*	*Irreversibility*
Greater Glider	High	High	High
Yellow-bellied Glider	High	Very high	High
Impact of climate change on foraging habitat			
Greater Glider	High	High	High
Yellow-bellied Glider	High	Medium	High

Meaning of the rankings

Scope	
High	The threat factor is likely to be widespread in its scope, affecting the species/community across much (31–70%) of its occurrence/population.
Severity	
Medium	Within the scope, the threat factor is likely to moderately degrade/reduce the species/community or reduce its population by 11–30% within 10 years or three generations.
High	Within the scope, the threat factor is likely to seriously degrade/reduce the species/community or reduce its population by 31–70% within 10 years or three generations.
Very high	Within the scope, the threat factor is likely to destroy or eliminate the species/community or reduce its population by 71–100% within 10 years or three generations.
Irreversibility	
High	The effects of the threat factor can technically be reversed, and the species/community restored, but it is not practically affordable and/or it would take 21–100 years to achieve.

Summarising the impacts on the Greater Glider, foraging habitat will be seriously degraded over 31–70% of the occurrence of the species by ongoing selective logging such that the population will be reduced by 31–70% within 10 years or three generations and that it will not be practically affordable to reverse the impacts or to restore the community within 21–100 years.

Summarising the impacts on the Yellow-bellied Glider, foraging habitat will be seriously degraded over 31–70% of the occurrence of the species by ongoing selective logging such that the population will be eliminated or reduced by 71–100% within 10 years or three generations and that it will not be practically affordable to reverse the impacts or to restore the community within 21–100 years.

We note that these detailed threat assessments are somewhat obscured, easily overlooked in reading the report and are not discussed at all in either the ELA report or the DAF Protection Measures.

We emphasise that these threat assessments take no account of the fact that both species are already threatened; the Greater Glider (Southern and Central) is endangered throughout its range and populations are in serious ongoing decline.

The obvious conclusion is that logging in the habitat of these species should cease immediately but that is not considered in the report. Such an outcome was presumably considered not to be 'feasible' in meetings between ELA and DAF staff.

We note that the assessment of climate change impact is based on habitat features and does not address the impact on the animal itself (See 3.9.2.).

3.2 Cumulative impacts are not considered in threat assessments

Whereas the Habitat Disturbance Index sums four impact layers, cumulative (additive) impacts are not considered in the threat assessments. As just one example, the impacts of logging and of climate change will be cumulative. Further, the impacts of climate change are very likely to increase exponentially over time for unforeseeable decades. See further comments under Risk Assessment approaches below (Section 4.1 to 4.5).

3.3 Habitat disturbance index application is likely devastating for greater gliders

The purpose of creating a Habitat Disturbance Index is said to be identifying potential areas of low disturbance and therefore of conservation value (p. 6) and for implementation of avoidance or mitigation measures (p. 61).

Figure 21 clearly shows 'very high' disturbance of greater glider habitat throughout most State Forests in South East Queensland and Western Hardwoods areas. This would indicate that 'avoidance' is required throughout these areas but that is not addressed.

The actual application of the Habitat Disturbance Index is not at all clear. DAF's response to the report refers to "application to field operations". It also refers to low disturbance corridor linkages being protected. If the overall intention is to protect low disturbance areas, it would appear to follow that continued logging will be concentrated in areas that are already highly disturbed or very highly disturbed. Given the apparently very small area of low disturbance greater glider habitat in Western Hardwoods and SEQ as shown in Figure 21, continued logging in these areas is likely to be devastating for greater gliders.

We note that there is something wrong with Table 15 in the ELA Report.

3.4 Basal area retention levels are not considered in the risk assessment

Basal area retention after logging is not directly considered in the ELA risk assessment. The authors note that retaining at least 50% of basal area, together with watercourse setbacks and slope limitations, may contribute to the maintenance of structure, function and species mix of the forest for gliders. However, in a study of greater glider habitat selection in southern Queensland, Eyre (2006) concluded that at least 85% of the original tree basal area needs to be retained to maintain at least one glider per 3 ha area in southern Queensland. This finding is included in the ELA literature review but is not considered in the risk assessment. Despite repeated references in the ELA risk assessment, and repeated in the Protection Measures, the Code of Practice does not specify a limit regarding basal area retention, but it does contemplate removal of more than 50% (S6.3.2b). There is a requirement in the Code for retention of 50% of canopy in Visual Resource Protection Areas but in most areas that would be confined to a 20 m buffer strip.

3.5 Hollow-bearing tree identification practices fail gliders

The *Guide to greater glider habitat in Queensland* (Eyre *et al*. 2022)[20] produced by Queensland Herbarium records the unreliability of determining hollow-bearing trees from the ground. This is not considered in the report and the current practice of hollow-bearing tree identification is apparently accepted. Neither the expertise required nor the ongoing costs of comprehensive assessments and compliance monitoring are assessed.

Given the reported unreliability of identifying hollow-bearing trees from the ground, it can be assumed that some hollow-bearing trees will be harvested, potentially with gliders in the hollows at the time, thus contributing to further population declines.

Further, the identification of recruitment hollow-bearing trees is unreliable and requirement for their retention gives false hope. It is unlikely to provide additional nesting resources in the near future or even guarantee their survival long-term. The Protection Measures note that selection of recruitment trees will target those trees "*more likely* to form hollows quickly". Hollows never form quickly. It could take 100 years or more for a recruitment tree to form hollows large enough for greater gliders.

[20] Eyre, T.J., Smith, G.C., Venz, M.F., Mathieson, M.T., Hogan, L.D., Starr, C., Winter, J. and McDonald, K. (2022). Guide to greater glider habitat in Queensland. Report prepared for the Department of Agriculture, Water and the Environment, Canberra. Department of Environment and Science, Queensland Government, Brisbane. CC BY 4.0.

Overall, there remains uncertainty about the effectiveness of proposed measures for protection of hollow-bearing trees and recruits.

3.6 The Species Management Profile for the greater glider has no specific protection measures contrary to claims by Eco Logical Australia

Table 18 of the Risk Assessment includes the statement "*Continue to implement specific protection measures detailed in Species Management Profiles.*" Regarding the Greater Glider, there are no specific protection measures in the profile. It simply refers to the Code of Practice.

There is also the claim in the Species Management Profile for the Greater Glider that the Code requires "*selective harvesting regime that retains structure and species mix*". It is difficult to see how removal of almost all merchantable trees >40 cm DBH can be considered to be maintaining forest structure. Further, Section 7.1 of the Code defines the Objective of a harvesting regime as being "to ensure the forest can, in time (our emphasis), recover its pre-harvesting species composition, structure and function." Recovering *in time* is of no value to arboreal marsupials. Having to resort to smaller and smaller trees over the decades to maintain supply contracts is proof that forest structure is changing radically.

Moreover, regional ecosystems are treated as static entities with boundaries fixed in time. In reality they are dynamic, complex adaptive systems responding to abiotic and biotic drivers and disturbance regimes operating at ecological and evolutionary temporal and spatial scales. They are susceptible to tipping points (ecosystem collapse) depending on the balance between positive and negative feedback mechanisms and individual species functional traits that determine resilience and adaptive capacity. There is increasing evidence of ecosystem collapse already occurring.[21,22] This highlights the need for greater focus to be on predicting / detecting early signs of ecosystem collapse.[23]

The practice of native forest logging is specifically to maintain timber supplies, and not ecological and landscape integrity. DAF provides no credible scientific basis

[21] Lindenmayer, D.B. and Sato, C. (2018). Hidden collapse is driven by fire and logging in a socioecological forest ecosystem. *PNAS 115*(20), 5181-5186.
[22] Bergstrom, D.M., Wienecke, B.C., Hoff, J., Lindenmayer, D.B., Ainsworth, T.D., Baker, C.M., Bland, L., Bowman, D.M.J.S., Brooks, S.T., Canadell, J.G., Constable, A.J., Dafforn, K.A., Depledge, M.H., Dickson, C.R., Duke, N.C., Helmstedt, K.J., Holz, a., Johnson, C.R., McGeoch, M.A., Melbourne-[Thomas, J., Morgain, R., Nicholson, E., Prober, S.M., Raymond, B., Ritchie, E.G., Robinson, S.A., Ruthrof, K.X., Setterfield, S.A., Sgro, C.M., Stark, J.S., Travers, T. Trebilco, R., Ward, D.F.L., Wardle, G.M., Williams, K.J. Zylstra, P.J. and Shaw, J.D. (2021). Combating ecosystem collapse from the tropics to the Antarctic. *Global Change Biology 27*, 1692-1703. https://doi.org/10.1111/gcb.15539.
[23] Willcock, S., Cooper, G.S., Addy, J. and Dearing, J.A. (2023). Earlier collapse of Anthropocene ecosystems driven by multiple faster and noisier drivers. *Nature Sustainability*. https://doi.org/10.1038/s41893-023-01157-x.

relating to maintaining ecological integrity and all levels of biodiversity (genetic, taxonomic, functional and phylogenetic) — all essential for maintaining complex adaptive system characteristics and processes for ecosystem integrity, stability and resilience.

3.7 Intensive (40 cm+) logging greatly reduces greater glider foraging resources

The ELA assessment notes that the implementation of any harvesting regime that increases selection of trees >40 cm DBH will compromise foraging habitat quality for both glider species (p. 55). This relates directly to the 40 cm+ logging currently being practiced. The authors add that retention of additional recruitment hollow-bearing trees could potentially function as suitable foraging trees if the appropriate species are selected. Given DAF's proposal is to retain around two additional trees, the contribution to foraging resources will be minimal.

The ELA literature review notes that greater gliders preferentially select larger trees for foraging, typically >30 cm DBH and particularly in the 60–70 cm DBH range. The 40 cm+ logging regime means all commercially useable trees >40 cm DBH will be harvested, apart from the small number retained as 'habitat-specific' trees. And given that the species selected for harvesting are also commonly the species selected by greater gliders for foraging, this logging regime is specifically focused on the greater glider's food resource and can be expected to greatly deplete it.

DAF's response to the report is to propose retention of 11 habitat-specific trees per hectare which apparently includes hollow-bearing trees and recruitment hollow-bearing trees. Compared with the current Code, that is an increase of 0–3 per hectare depending on the number of hollow-bearing trees available. In southern Queensland, the mean number of hollow-bearing trees has been reported to be 2.2 per hectare.[24] The proposed Protection Measures will therefore result in just two extra trees per hectare being retained in southern Queensland. Under 40 cm+ logging, all commercially useable trees >40 cm DBH will be harvested apart from the proposed 11 habitat-specific trees to be retained. Given the coincidence of harvesting with greater glider foraging resource, logging will result in a major reduction of greater glider foraging resource. Where 50% of the canopy is removed by logging, greater glider foraging resource could be close to eliminated.

[24] Eyre, T.J. (2006). Regional habitat selection of large gliding possums at forest stand and landscape scales in southern Queensland, Australia I. Greater glider (*Petauroides volans*). *Forest Ecology and Management 235*, 270–282.

3.8. Proposed retention of large trees falls far short of glider foraging needs

The ELA report does not directly address the question of how many large trees need to be retained to provide suitable greater glider habitat.

ELA provides data for the proportion of trees used for leaf foraging by greater gliders according to DBH class (Figure 2, p. 15). More than 60% of foraging trees were >50 cm DBH and around 80% were >40 cm DBH. However, ELA does not make specific recommendations regarding retention of large trees but leaves it to DAF to "consider potential thresholds for the number of large trees to be retained following a harvest". DAF's response is to define large trees as having a DBH of 80 cm in dry forests and 100 cm in wet forests. Based on Figure 2 of the ELA report, that would represent less than 10% of the foraging resource and probably far less given trees of that size will be very rare in previously logged forest, especially where 40+ cm logging has been applied.

Further, the entire harvest is focused on the main foraging resource. That is completely unacceptable given the endangered status of the Greater Glider and represents a major compromise in order to continue logging at an economically viable level.

3.9 Climate change impacts are essentially ignored

3.9.1 Impact on greater glider habitat

Climate change impacts are essentially ignored in both reports when it is extremely likely that extensive changes and losses will occur in species and ecosystem diversity and distributions.[25,26,27,28,29] González-Orozoco *et al.* 2016 predicted that within the next 60 years (likely sooner) the vast majority of eucalypt species distributions (91%) across Australia will shrink in size (on average by 51%) and shift south on the basis of projected suitable climate space. Approximately 90% of the current areas with concentrations of paleoendemism, i.e. places with old

[25] González-Orozoco, C.E., Pollock, L.J., Thornhill, A.H., Mishler, B.D., Knerr, N., Laffan, S.W., Miller, J.T., Rossauer, D.F., Faith, D.P., Nipperess, D.A., Kujala, H., Linke, S., Butt, N., Kulheim, C., Crisp, M.D. and Gruber, B. (2016) Phylogenetic approaches reveal biodiversity threats under climate change. *Nature Climate Change 6*(12), 1110-1114.
[26] Nolan, C., Overpeck, J.T. *et al*. (2028). Past and future global transformation of terrestrial ecosystems under climate change. *Science 361*, 920-923.
[27] Lancaster, L.T. and Humphreys, A.M. (2020). Global variation in the thermal tolerances of plants. *PNAS 117*(24), 13580-13587.
[28] Bergstrom, D.M., Wienecke, B.C., Hoff, J., Lindenmayer, D.B., *et al.* (2021). Combating ecosystem collapse from the tropics to the Antarctic. *Global Change Biology 27*, 1692-1703. https://doi.org/10.1111/gcb.15539.
[29] Kemp, L., Xu, C., Depledge, J, Ebi, K., Gibbins, G., Kohler, T.A., Rockstrom, J., Scheffer, M., Schellnhuber, H.J., Steffen, W. and Lenton, T.M. (2022). Climate Endgame: Exploring catastrophic climate change scenarios. *PNAS 119*(34) e2108146119.

evolutionary diversity, are predicted to disappear or shift their location. Climate change threatens whole clades of the phylogenetic tree.

Whereas models based on probabilistic risk assumptions have their limitations, the current pace and scale of climate change gives weight to major likely impacts on biodiversity distributions, abundances and extinctions in the near- and longer-term. One therefore cannot ignore the serious cumulative impacts of climate change.

3.9.2 Direct impact of climate change on the greater glider itself

The Conservation Advice that led to the endangered listing of the Greater Glider includes climate change as a major threat. The species is sensitive to increase in temperature and increasing aridity can be expected to decrease nutritional and water content of eucalypt leaves. Selective logging has been shown to cause an increase in temperature and decrease in humidity in tropical forests.[30,31] It can be expected that continued logging in greater glider habitat will not only directly remove a major part of the foraging resource but also increase temperatures, adding to the impacts of climate change which include increasing frequency and intensity of heatwaves with temperatures potentially exceeding critical levels (T_{crit}).[32]

Whereas the thermal tolerance of plants is an ongoing crucial research area as the climate warms and extreme weather events become more frequent and intense,[33] we already know the thermal tolerance of the greater glider itself. Its unique physiology and strict *Eucalyptus* diet makes it vulnerable to high temperatures and low water availability. Above 20˚C, its thermoneutral point, the greater glider becomes hyperthermic and heat-stressed.[34,35,36] Wagner *et al.* 2021[37] concluded the

[30] Aggarwal, K. Chanda, R., Rai, S., Rai, M., Pradhan, D.K., Munda, B., Tamang, B., Biswakarma, A. and Srinivasan, U. (2023). The effect of selective logging on microclimates, arthropod abundance and the foraging behaviour of Eastern Himalayan birds. *Forest Ecology and Management 541,* 121076. https://doi.org/10.1016/j.foreco.2023.121076.
[31] Santos, E.G., Svatek, M., Nunes, M.H., Aalto, J., Senior, R.A., Matula, R., Plichta, R. and Maeda, E.J. (2024). Structural changes caused by selective logging undermine the thermal buffering capacity of tropical forests. *Agricultural and Forest Meteorology 348*, 109912.
[32] Doughty, C.E., Keany, J.M., Wiebe, B.C., Rey-Sanchez, C., Carter, K.R., Middleby, K.B., Cheesman, A.W., Goulden, M.L., da Rocha, H.R., Miller, S.D., Malhi, Y., Fauset, S., Gloor, E., Slot, M., Menor, I.O., Crous, K.Y., Goldsmith, G.R. and Fisher, J.B. (2023). Tropical forests are approaching critical temperature thresholds. *Nature 23 August* 2023. https://doi.org/10.1038/s41586-023-06391-z.
[33] Arnold, P.A., Briceño, V.F., Gowland, K.M., Catling, A.A., Bravo, L.A. and Nicotra, A.B. (2021). A high-throughput method for measuring critical thermal limits of leaves by chlorophyll imaging fluorescence. *Functional Plant Biology 48*(6), 634-646. https://doi.org/10.1071/FP20344.
[34] Rübsamen, K., Hume, I.D., Foley, W.J. and Rübsamen, U. (1984). Implications of the large surface area to body mass ratio on the heat balance of the greater glider (*Petauroides volans:* Marsupialia). *J of Comparative Physiology B 154*,105-111.
[35] Wagner, B. (2021). The role of climate and tree nutrition on the occurrence of the southern greater glider (Petauroides volans) and its implications for conservation planning. PhD Thesis, University of Melbourne.
[36] Lindenmayer, D.B., McBurney, L., Blanchard, W., Marsh, K., Bowd, E., Watchorn, D., Taylor, C. and Youngentob, K. (2022). Elevation, disturbance and forest type drive the occurrence of a specialist arboreal foliovore. *PLOS ONE 17*(4): e0265963. https://doi.org/10.1371/journal.pone.0265963.
[37] Wagner, B., Baker, P.J., Stewart, S.B., Lumsden, L.F., Nelson, J.L., Cripps, J.K., *et al.* (2021). Climate change drives habitat contraction of a nocturnal arboreal marsupial at its physiological limits. *Ecosphere 11*:e03262.

number of nights warmer than 20˚C coupled with atmospheric water deficits were highly significant predictors of greater glider occurrence and responsible for major population declines.

They warned identification and protection of climate refugia will be critical for the glider's survival chances. They outline appropriate and feasible methods for their identification. The Australian Government's Conservation Advice also strongly advises the identification and protection of the glider's climate refugia. These are currently being destroyed by ongoing logging as is the overall ecological integrity of the forests on which they depend. Ongoing logging as proposed will therefore aid in the loss of the only known safe refuges for survival of greater glider populations at the peak of predicted climate impacts. By definition, climate refugia provide the glider's only means for ongoing survival and evolution. Their identification and protection are matters of urgency.

Additionally, increasing evaporative demand or vapour pressure deficits (dryness of the atmosphere) associated with climate change are also increasingly responsible for worrying mortalities with largest trees the most vulnerable.[38] These results depended on analysis of Detailed Yield Plots established by the then Department of Forestry over 50 years in North Queensland.

Given greater gliders critically need the largest trees for foraging and denning, comparable analyses could be conducted in southern Queensland as DAF established a similarly large number of Detailed Yield Plots over many decades.

Increased tree mortality and ecosystem collapse risks via climate-change induced increased water stress or temperatures exceeding trait-based thermal tolerances have to be factored into threats to the greater glider's critical habitats.

[38] Bauman, D., Fortunel, C., Delhaye, G., Yadvinder, M., Cernusak, L.A., Bentley, L., Patrick, R., S.W., Aguirre-Gutierrez, J.M. *et al*. (2022). Tropical tree mortality has increased with rising atmospheric water stress. *Nature 608*, 528-533.

4. General comments about Risk Assessment approaches

4.1 Reframing systemic risk

Systemic risk requires conceptual reframing from "probabilistic risk" to "radical uncertainty"[39] necessitating application of the Precautionary Principle.

It is important to recognise the difference between the concepts of risk and uncertainty (radical uncertainty), first articulated by Frank Knight (1921),[40] particularly when dealing with complex adaptive systems such as forests and Earth Systems.

"Risk" or "probabilistic risk" deals with future events to which a mathematical probability can be assigned with confidence. Its use can be appropriate for simple situations (linear dynamics) involving short time scales where all parameters and possible outcomes are sufficiently well-known to be described accurately with quantified probabilities.

It is entirely inappropriate for complex adaptive systems.

"Uncertainty", "radical uncertainty", sometimes referred to as "Knightian uncertainty" (where future outcomes are radically uncertain) deals with the likelihood of future events to which no mathematical probability can be assigned.[41,42] The scientific concept of uncertainty is unrelated to implied lack of information that can be rectified by further research. The implications of systemic "radical uncertainty" are worse than for "risk".[43]

4.2 Uncertainty is an endemic characteristic of complex adaptive systems

Uncertainty is an endemic characteristic of complex adaptive systems, i.e. "unknown unknowns".[44] Ecosystems are dynamic, complex adaptive systems responding to abiotic and biotic drivers and disturbance regimes operating at

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[39] Sillmann, J., Christensen, I., Hochrainer-Stigler, S., Huang-Lachmann, J., Juhola, S., Kornhuber, K., Mahecha, M., Mechler, R., Reichstein, M., Ruane, A.C., Schweizer, P. and Williams, S. (2022). *ISC-UNDRR-RISK KAN Briefing note on systemic risk*, Pairs, France, International Science Council, DOI: 10.24948/2022.01. 35 pp.
[40] Knight, F. (1921). Risk, Uncertainty and Profit [Online]. New York: Schaffner and Marx. Available from: https://doi.org/10.1017/CBO9780511817410.005.
[41] Levy, J. (2020). Radical Uncertainty. *Critical Quarterly 62*(1), 15-28.
[42] Janeway, W.H. (2023). What to do about Radical Uncertainty. *Project Syndicate Longer Reads* 21 July 2023. https://www.project-syndicate.org/onpoint/radical-uncertainty-how-to-thinkabout-market-risk-innovation-and-efficiency-by-william-h-janeway-2023-07.
[43] Wagner, G. (2022). The risky language of climate uncertainty. *OpenMind* 27 October 2022. https://gwagner.com/risky-uncertainty/.
[44] Weitzman, M.L. (2011) Revisiting Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change. *Review of Environmental Economics and Policy 5*(2), 275-292.

ecological and evolutionary temporal and spatial scales. They are susceptible to tipping points (ecosystem collapse) depending on (a) the balance between positive and negative feedback mechanisms associated with multiple interacting systems, and (b) individual species functional traits that determine their adaptive capacity.

When faced with radical systemic uncertainty and essentially irreversible loss of irreplaceable and incommensurable biological values such as from extinction of a species (e.g. the endangered Greater Glider), the only appropriate management policy is based on the Precautionary Principle[45] focused on preventative actions. Then the only ecologically relevant question is "*What is the worst that could happen*" (even if the probability is low) with all management options then directed at avoiding this.[46]

4.3 The Precautionary Principle must be applied when extinction risk is real

The Precautionary Principle is a legal and policy principle to guide managers and decision-makers in responding to uncertainty. Its essence is that where there is scientific uncertainty regarding the nature, likelihood or magnitude of a serious or irreversible environmental threat, this lack of certainty should not be a reason to postpone or fail to implement measures that could prevent that threat materialising.[47]

It in effect shifts the burden of proof from one asserting a threat to the one denying it. The principle is especially relevant where a grave threat of irreversible loss is exacerbated by compounding, cumulative impacts from climate change.[47]

Most importantly, Schuijers (2023)[47] contends that if the legal conditions for application of the principle are met, the principle *must* be applied. It follows that the need to apply and act on the principle cannot be trumped by other considerations or purported to be inconsistent with other objectives.

In the case of impacts of logging on the Greater Glider, we contend the legal conditions of application of the precautionary principle *are* met but ignored, and *are* trumped, but must not be, by other non-essential considerations.

This is vital where the threat of extinction is real and exacerbated by compounding, cumulative impacts of climate change.

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[45] Aldred, J. (2012) Climate change uncertainty, irreversibility and the precautionary principle. *Cambridge Journal of Economics 36*, 1051-1072.
[46] Sharpe, S. (2019) Telling the boiling frog what he needs to know: Why climate change risks should be plotted as probability over time. *Geoscience Communication 2*, 95-100.
[47] Schuijers, L. (2023). 'Responding to Ecological Uncertainty in the Context of Climate Change: Thirty Years of the Precautionary Principle in Australia. *Sydney Law Review 45*(2), 249-277.

The Precautionary Principle is embedded in Australia, e.g. in the IGAE, the EPBC (s 291), the *Environmental Protection Act 1994* (Qld) and in international legal instruments and domestic laws of many other countries.

4.4 The Precautionary Principle was not considered in the ELA Risk Assessment and DAF Protection Measures.

The models or approaches adopted in the ELA Risk Assessment Report have profound implications for biodiversity[48] and the future of the native forest timber industry. The inherent assumption in their "risk assessment" is that one *can* assign a mathematical probability to future events/crises. As noted in 4.1-4.3, probabilistic risk assessment is only relevant in cases of simple linear dynamics over short timescales.

Thus it is critically important we understand the limitations, assumptions and uncertainties of any risk assessment approach /method adopted. Failure to recognise systemic risk/uncertainty grossly underestimates impacts on biodiversity, ecosystems, and Earth Systems generally and introduces optimistic bias in proposed management prescriptions.

Optimistic bias camouflages the risk even to so called common species.[49] These should not be overlooked as they can be as likely to decline over time as rare or even currently endangered species such as the greater glider.

Systemic risks deal with four to five core properties of systems behaviour: 1. Extreme complexity; 2. high nonlinearity; 3. transboundary causality (multiple interacting systems); 4. deep (radical) uncertainty; and 5. the probability of tipping points leading to system collapse.[50]

In summary, the approach adopted by Eco Logical Australia largely ignores the already recorded and likely future impacts of extreme climate and weather events and the potential for multiple cascading, compounding, cumulative and escalating risks leading to ecosystem and population collapses.

[48] Trust, S., Joshi, S., Lenton, T. and Oliver, J. (2023). The Emperor's New Climate Scenarios: Limitations and assumptions of commonly used climate-change scenarios in financial services. Institute and Faculty of Actuaries and the University of Exeter. www.actuaries.org.uk.

[49] Daskalova, G.N., Myers-Smith, I.H. and Godlee, J.L. (2020). Rare and common vertebrates span a wide spectrum of population trends. *Nature Communications 11*: 4394. https://doi.org/10.1038/s41467-020-17779-0.

[50] Janzwood, S. and Homer-Dixon, T. (2022). *'What is a Global Polycrisis?'* Discussion Paper 2022-4. Cascade Institute. https:// cascadeinstitute.org/technical-paper/what-is-a-global-polycrisis/.

Because of inherent lags associated with ecosystem and population dynamics, such collapses can be hidden (ecosystems appear superficially intact but never-the-less the trajectory of collapse already committed and irreversible).[51] Underestimation of impacts of extreme climate and weather events in complex impact and climate models is common.[52]

Tropical forests are already approaching critical temperature thresholds beyond which it is too hot for trees to photosynthesize resulting in widespread deaths.[53] Increases in atmospheric evaporative demand (drying) are already causing significant (up to doubling) mortality of large tree cohorts.[54] Whilst comparable studies have not been undertaken for subtropical forests it is highly likely similar impacts will be recorded.

The existing and extensive "detailed inventory and yield plots" established by DAF over many decades provide the ideal opportunity for evaluating climate-change induced mortalities in subtropical forests.

The predicted and observed preferential loss of large trees during heatwaves and elevated climate-change induced temperatures (means and anomalies) will impact the denning resource of the greater glider.

The scientific literature is now awash with evidence that Earth System risks are indeed systemic, rapidly increasing and unprecedented, precipitating humanity and the rest of the biosphere into totally unchartered territory not experienced by any past civilizations or other biota.[55,56,57,58,59,60,61]

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[51] Lindenmayer, D.B. and Sato, C. (2018). Hidden collapse is driven by fire and logging in a socioecological forest ecosystem. *PNAS 115*(20), 5181-5186.
[52] Schewe, J. *et al*. (2019). State-of-the-art global models underestimate impacts from climate extremes. *Nature Communications 10*:1055. https://doi.org/10.1038/s41167-019-08745-6.
[53] Doughty, C.E., Keany, J.M., Wiebe, B.C., Rey-Sanchez, C., Carter, K.R., Middleby, K.B., Cheesman, A.W., Goulden, M.L., da Rocha, H.R., Miller, S.D., Malhi, Y., Fauset, S., Gloor, E., Slot, M., Menor, I.O., Crous, K.Y., Goldsmith, G.R. and Fisher, J.B. (2023). Tropical forests are approaching critical temperature thresholds. *Nature 23 August* 2023. https://doi.org/10.1038/s41586-023-06391-z.
[54] Bauman, D., Fortunel, C., Cernusak, L.A., Bentley, L.P., McMahon, Rifai, S.W., Aguirre-Gutierrez, J., Oliveras, I., Bradford, M., Laurance, S.G.W., Delhaye, G., Hutchinson, M.F., Dempsey, R., McNellis, B.E., Santos-Andrade, P.E., Ninantay-Rivera, H.R., Chambi Paucar, J.R., Phillips, O.L. and Malhi, Y. (2021). Tropical tree growth sensitivity to climate is driven by species intrinsic growth rate and leaf traits. *Global Change Biology 28*, 1414-1432.
[55] Hansen, J.E., Sato, M., Simons, L., Nazarenko, L.S., Sangha, I., Kharecha, P., Zachos, J.C., von Schuckmann, K., Loeb, N.G., Osman, M.B., Jin, Q., Tselioudis, G., Jeong, E., Lacis, A., Ruedy, R., Russell, G., Cao, J. and Li, J. (2023). Global warming in the Pipeline. *Oxford Open Climate Change 3*(1), kgad008.
[56] Hansen, J. Kharecha, P. and Sato, M. (2023). "A Miracle Will Occur" Is not sensible climate policy. http://www.columbia.edu/~jeh1/mailings/2023/Miracle.2023.12.07.pdf.
[57] Boers, N. (2021) Observation-based early-warning signals for a collapse of the Atlantic Meridional Overturning Circulation. *Nature Climate Change 11*, 680-688.
[58] Ditlevsen, P. and Ditlevsen, S. (2023). Warning of a forthcoming collapse of the Atlantic meridional overturning circulation. *Nature Communications 14*: 4254. 12 pp.
[59] WMO (2024). State of the Global Climate 2023. WMO No. 1447.

The danger is, as pointed out by Bradshaw *et al.* (2021),[62] that future environmental conditions will be far more dangerous than currently believed. The scale of threats to the biosphere and all its life forms — including humanity — is in fact so great that it is difficult to grasp for even well-informed experts.

The authors pose the relevant question: "what political or economic system, or leadership, is prepared to handle the predicted disasters, or even capable of such action"?

Moreover, they conclude this dire situation places an extraordinary responsibility on scientists to speak (write) candidly and accurately when engaging with government and the public.

We have the technological means and advances in 'tipping' science to do better than the minimalist and potentially ineffective strategies proposed in the ELA Risk Assessment report and the DAF Protection Measures response. Priority should be given to detecting early warning signals of impending ecosystem tipping phenomena before it's too late.[63,64]

Prioritising evidence-based remedial actions to restore ecosystem and landscape integrity to prevent extinctions[65] would be more prudent than guesswork in the absence of hard data from long-term monitoring.

Norman and Mackey (2023)[66] recently used satellite remote sensing to spatially identify the most mature forest cover still remaining as a proxy for critical limiting resources of the greater glider in Queensland. It thus provides the basis for on-going monitoring of legacy and future climate change-related impacts on the greater glider.

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[60] Carrington, Damian (2023). "Gobsmackingly bananas': scientists stunned by planet's record September heat. *The Guardian* 5 October 2023. https://www.theguardian.com/environment/2023/oct/05/gobsmackinglybananas-scientists-stunned-by-planets-record-septemberheat?
[61] Schmidt, G. (2024). Why 2023's heat anomaly is worrying scientists. *Nature 627*, 467.
[62] Bradshaw, C.J.A., Ehrlich, P.R., Beattie, A., Ceballos, G., Crist, E., Diamond, J., Dirzo, R., Ehrlich, A.H., Harge, J., Harte, M.E., Pyke, G., Raven, P.H., Ripple, W.J., Saltré, F., Turnbull, C., Wackernagel, M. and Blumstein, D.T. (2021) Underestimating the Challenges of Avoiding a Ghastly Future. *Frontiers in Conservation Science 1*(Article 615319).
[63] Lenton, T.M., Abrams, J.F., Bartsch, A., Bathiany, S., Boulton, C.A., Buxton, J.E., Conversi, A., Cunliffe, A.M., Hebden, S., Lavergne, T., Poulter, B., Shepherd, A., Smith, T., Swingedouw, D., Winkelmann, R. and Boers, N. (2024). Remotely sensing potential climate change tipping points across scales. *Nature Communications 15*(343), 1-15.
[64] van Westen, R.M., Kliphuis, M. and Dijkstra, H.A. (2024). Physics-based early warning signal shows that AMOC is on tipping course. *Science Advances 10*(5), 11pp. https://www.science.org/doi/epdf/10.1126/sciadv.adk1189.
[65] Rogers, B.M., Mackey, B., Shestakova, T.A., Keith, H., Young, V., Kormos, C.F., DellaSala, D.A., Dean, J., Birdsey, R., Bush, G., Houghton, R.A. and Moomaw, W.R. (2022). Using ecosystem integrity to maximize climate mitigation and minimize risk in international forest policy. *Frontiers in Forests and Global Change 5*:929281. doi:103389/ffgc.2022.929281.
[66] Norman, P. and Mackey, B. (2023). Priority areas for conserving Greater Gliders in Queensland, Australia. *Pacific Conservation Biology.* doi:10.1071/PC23018.

4.5 The Precautionary Principle also applies to social-ecological systems which include resource-based communities

Resource-based communities including those based on native forests *are* social-ecological systems equally subject to radical uncertainty and collapse.[67] Therefore the precautionary principle applies.

There is a vast literature on the vulnerability of such communities, both present and future, to economic downturns, degradations of the resource base, power and equity imbalances, poverty traps, lower access to education and loss of social mobility.

Resilience of resource-based communities is commonly but inappropriately defined differently from that for ecological systems as the ability of a system to *transform and adapt* (i.e. a transformative capacity) rather than to persist.

This enables trade-offs between short-term resilience that benefits the powerful and long-term intergenerational resilience and wellbeing of resource-based communities. The power imbalance is exacerbated by potential corporate capture of the state.

Whereas DAF's legal role may relate primarily to timber production, it is DESI that has the overriding responsibility for ensuring that all statutory obligations to maintain ecological integrity and prevent extinctions are met.

In summary, the only appropriate approach under these circumstances of radical uncertainty, collapse of systems resilience (detected by loss of variance in selected parameters) and the irreplaceable losses of biological diversity and social cohesion is an essentially precautionary approach to management policy and strategies.[68]

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[67] Molla, N., Delonno, J. and Herman, J. (2021). Dynamics of resilience-equity interactions in resource-based communities. *Communications Earth & Environment 2*(27). https://doi.org/10.1038/s43247-021-00093-y.
[68] Chenet, H., Kedward, K., Ryan-Collins, J. and van Lerven, F. (2022). Developing a Precautionary Approach to financial Policy — From climate to Biodiversity. *Policy Briefing Paper 02*. INSPIRE Sustainable Central Banking Toolbox.

APPENDIX

The following is a relevant extract from our Submission in October 2022 to the Federal Government's Consultation Paper on "Native Forest Wood Waste in the Renewable Energy Target".

ESFM principles are not adhered to in Queensland

Whereas the Code of Practice for State Forests in Queensland supposedly requires consistency with ESFM principles, there is little or no evidence to confirm this.

A short-list of deficiencies follows:

(a) longitudinal studies of ecosystem structure, composition and function are not done:

(b) baseline or reference pre-disturbance conditions do not exist;

(c) comprehensive biodiversity assessments are not carried out;

(d) long-term monitoring of threatened species (including endangered) is non-existent;

(e) no trend studies of ecosystem stability (detection of thresholds for ecosystem collapse);

(f) no assessment, protection or recovery of carbon sink health;

(f) repeated logging of endangered species habitats is routine;

(g) impact of native forest logging and associated land uses on soil organic carbon is ignored.

(a) The time series needs to span ≥10 years, preferably longer. Adequacy of any empirical, quantitative evidence must detail both the pre-logging baseline and subsequent states. The scale of any detected changes must reveal whether recovery to the base state is likely. That evidence must include population size and distribution of characteristic and keystone species, ecosystem biomass, and be capable of revealing loss of ecosystem function.[69] Other predictors of potential forest recovery include proximity to intact species propagules, pollinator and

[69] Bergstrom, D.M., Wienecke, B.C., van den Hoff, J., Hughes, L., Lindenmayer, D.B. *et al*. (2020). Combating ecosystem collapse from the tropics to the Antarctic. *Global Change Biology 27* (9): 1692–1703.

dispersal agent pools, roads, slope and aspect, soil health and condition, and the frequency and intensity of all relevant disturbance regimes.

As far as we know, despite Queensland's native forest having been subject to mainly selective logging for well over a hundred years and other well-documented threatening processes (fires, grazing, weeds, feral animals, landscape fragmentation) no assessments have been made of how close ecosystems are to collapse as defined by the IUCN Red List of Ecosystems — a globally recognized, scientific, evidence-based framework already being used elsewhere in Australia.[70,71,72,73]

For "*structure*" in (a) the *purpose* of the studies matters. Regional ecosystem mapping, primarily at a scale of 1:100,000 is inadequate as it would not measure changes in habitat quality for species important for ecosystem stability and resilience.[74] There would be no capacity for detecting the extinction, for example, of hollow-dependent, endangered arboreal gliders.

(c) Biodiversity provides natural resistance, resilience and adaptive capacity to ecosystems and enables larger and long-lived ecosystem carbon stocks. The multiple levels of biodiversity must be considered. These include genetic, taxonomic, functional and phylogenetic — all are relevant to maintaining complex adaptive system characteristics and processes for ecosystem integrity, stability and resilience. They are not considered. Taxonomic diversity alone or Regional Ecosystems are not adequate surrogates, nor is species richness.

(e) Gobally, collapse of ecosystems — potentially irreversible change to ecosystem structure, composition, and functions — is becoming a major and escalating problem.[72] Pressures from climate change and other regional human impacts, including native forest logging, drive extinctions and ecosystem collapse, or loss of ecological integrity.

Definitions of ecological integrity are based on *complex systems science* and include the capacity to maintain stability within the natural range of variability of the

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[70] Lindenmayer, D., Messier, C and Sato, C. (2016) Avoiding ecosystem collapse in managed forest ecosystems. *Frontiers in Ecology and the Environment 14* (10), 561-568.
[71] Harris, R.M.B., Beaumont, L.J. *et al.* (2018) Biological responses to the press and pulse of climate trends and extreme events. *Nature Climate Change 8*, 579-587.
[72] Lindenmayer, D.B. and Sato, C. (2018) Hidden collapse is driven by fire and logging in a socioecological forest ecosystem. *PNAS 115*(20), 5181-5186.
[73] Bergstrom, D.M., Hoff, J. *et al*. (2021) Combating ecosystem collapse from the tropics to the Antarctic. *Global Change Biology 27*, 1692-1703. https://doi.org/10.1111/gcb.15539.
[74] Eyre T.J., Butler, D.W., Kelly, A.L. and Wang, J. (2010). Effects of forest management on structural features important for biodiversity in mixed-age hardwood forests in Australia's subtropics. *Forest Ecology and Management 259*, 534–546.

original condition over its distributional range. To measure loss of ecological integrity, a reference pre-disturbance condition is essential.

> *"Loss of ecological integrity must be determined against a pre-disturbance condition"*

This becomes vitally important for proof of "ecological sustainability" claims for native forest logging, for verification and credibility of national carbon accounts[75] that are part of Australia's reporting of Nationally Determined Commitments[76], and identifying, mapping and protecting irrecoverable carbon stocks in our forest ecosystems[77,78,79]. These irrecoverable carbon stocks in forest ecosystems are very vulnerable to disturbance including from logging. Retaining maximum carbon sequestration capacity is a vital part of mitigating climate change. It is clearly important to have credible, transparent statistics. We do not.[80]

Altitudinally restricted mountain ecosystems predominate in the eastern seaboard from western Victoria north to Cape York Peninsula. They are inherently vulnerable to ecosystem collapse because of their narrow environmental envelopes, geographically restricted distribution and are already near their climatic thresholds or ecosystem tipping points.[81]

The South East Queensland area was captured in an amendment to the EPBC Act by defining it as an RFA region. So actions in that area are exempt from the EPBC. DAF is currently applying a 40cm+ logging regime which means all merchantable trees >40cm diameter are harvested in State Forests. In the Western Hardwoods area 30cm+ logging was applied from 3007 to 2013. The Western Hardwoods area essentially equates with the Brigalow Belt South Bioregion which with Brigalow Belt North is one of Australia's 15 Biodiversity Hotspots. Brigalow Country - QLD is included as one of 20 Priority Places in the Threatened Species Action Plan 2022-2032.

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[75] Keith, H., Czucz, B., Jackson, B., Driver, A., Nicholson, E. and Maes, J. (2020). A conceptual framework and practical structure for implementing ecosystem condition accounts. *One Ecosystem 5*: e58216. Doi: 10.3897/oneeco.5.e58216.
[76] Nationally Determined Commitments (NDCs) are the only way of taking progressive stock of the world's collective progress towards achieving the purpose of the Paris Agreement and its short- and long-term goals. It is clearly important to have credible, transparent statistics.
[77] Goldstein, A., Turner, W.R., Rockstrom, J *et al*. (2020). Protecting irrecoverable carbon in Earth's ecosystems. *Nature Climate Change 10*, 287-295.
[78] Noon, M.L., Goldstein, A., Ledezma, J.C. *et al*. (2022). Mapping the irrecoverable carbon in Earth's ecosystems. *Nature Sustainability 5*, 37-46.
[79] Rockstrom, J., Beringer, T., Hole, D., Griscom, B., Mascia, M.B., Folke, C. and Creutzig, F. (2021). We need biosphere stewardship that protects carbon sinks and builds resilience. *PNAS 118* (38), 22115218118.
[80] Mackey, B., Moomaw, W., Lindenmayer, D. and Keith, H. (2022). Net carbon accounting and reporting are a barrier to understanding the mitigation value of forest protection in developed countries. *Environmental Research Letters 17*, 054028.
[81] Laurance, W.F., Dell, B., Turton, S.M. *et al*. (2011). The 10 Australian ecosystems most vulnerable to topping points. *Biological Conservation 144*, 1472-1480.

State Forests in South East Queensland and, particularly, in the Western Hardwoods area include large areas of habitat for the endangered Greater Glider. The intensive logging in these areas can be expected to have a very significant impact on this species, including their extinction.[82,.83,84]

The integrally linked Climate and Biodiversity crises are now so dire that use of market mechanisms that provided a façade for continued GHG emissions is over.

(g) Impact on soil organic carbon is ignored. It is the planet's largest terrestrial carbon pool far exceeding those in above ground vegetation and the atmosphere. It is second only to that in the oceans.[85] Seventy nine per-cent of countries worldwide are affected by net declines of soil organic carbon since 2001. It is a critical indicator of ecosystem health and stability (**ecological sustainability**) and failure to monitor this parameter risks failure to limit global temperature increases to 1.5˚C or even higher.

4. Native forest logging is seriously in conflict with the latest IPCC advice and most recent scientific literature.

For more than three decades regular IPCC reports have chronicled ongoing acceleration of global warming due to unmitigated greenhouse gas emissions and the potentially irreversible impacts on, even collapse of, ecological, social and economic systems.

The native forest timber industry justifies ongoing logging as "carbon neutral" referencing an old 2007 IPCC report.

This is just cherry-picking. The science has moved on significantly since 2007.

The IPCC 6th Assessment Report (2022), Mitigation of Climate Change, Chapter 7, Agriculture, Forestry and Other land Uses (AFOLU) reached really important conclusions for synergistic climate and biodiversity action:

> "*actions that* ***protect*** *offer the highest total and per area mitigation*

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[82] Eyre, T.J. (2006). Regional habitat selection of large gliding possums at forest stand and landscape scales in southern Queensland, Australia I. Greater glider (*Petauroides volans*). *Forest Ecology and Management 235*, 270-282.

[83] Eyre TJ, Smith GC, Venz MF, Mathieson MT, Hogan LD, Starr, C, Winter, J and McDonald, K. (2022). *Guide to greater glider habitat in Queensland*, report prepared for the Department of Agriculture, Water and the Environment, Canberra. Department of Environment and Science, Queensland Government, Brisbane. CC BY 4.0.

[84] Eyre T.J., Butler, D.W., Kelly, A.L. and Wang, J. (2010). Effects of forest management on structural features important for biodiversity in mixed-age hardwood forests in Australia's subtropics. *Forest Ecology and Management 259*, 534–546.

[85] Prăvălie, R., Nita, I-A., Psatriche, C., Niculiță, M., Birsan, M.V., Roşca, B. and Bandoc, G. (2021). Global changes in soil organic carbon and implications for land degradation neutrality and climate stability. *Environmental Research 201*, 1-10.

> *value of any action in the AFOLU sector*";
>
> "*the* ***protection*** *of high biodiversity ecosystems such as primary forests delivers high synergies with Greenhouse Gas abatemen*t";
>
> "*most mitigation options are available and ready to deploy and emissions reductions can be unlocked relatively quickly* (through) *the* ***protection*** *of natural ecosystems*".

Protecting and restoring native forests is a critical mitigation action if Australia is to meet its net zero emissions targets with the critical decade.[86]

Not only does burning native forest biomass contribute to emissions but also native forest harvesting which is a condition of eligibility itself contributes to emissions.

In Queensland, it is likely that only around 50% of the wood harvested in a native forest operation finds its way to a sawmill.[87] In the harvesting process, only around 40% of the log is recovered as sawn timber.[88] Therefore, no more than 20% of the carbon removed from the forest in a native forest logging operation ends up in anything that could be called long-term storage. Up to 80% of the harvested carbon will contribute to GHG emissions and will not be recovered through future growth for many decades. Added to that are the emissions produced by harvesting machinery, transport and sawmilling.

5. Legal risk is increasing for both the government and industry

Corporate law firms are recently playing a greater role aimed at reducing the impact of climate change by "nudging" governments and companies to act or live up to their climate pledges.[89] The number of climate litigation cases has doubled globally since 2015.[90] There have been more than 70 "framework cases" that challenge governments' responses to climate change. Collaborations amongst law firms have proliferated since the Paris Agreement (2015), for example, the Net Zero Lawyers Alliance and the UK-based Legal Sustainability Alliance.

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[86] Lindenmayer, D., Mackey, B. and Keith, H. (2022). The only way we can meet our zero targets. Canberra times, 14 October 2022.

[87] Ngugi, M.R., Neldner, V.J., Ryan, S., Lewis, T., Li, J., Norman, P. and Mogilski, M. (2018). Estimating potential harvestable biomass for bioenergy from sustainably managed private native forests in Southeast Queensland, Australia. *Forest Ecosystems* (2018) 5–6. DOI 10.1186/s40663-018-0129-z

[88] Downham, R, Gavran, M and Frakes, I. (2019). *ABARES National Wood Processing Survey: 2016–17*, ABARES technical report 19.3, Canberra, June. CC BY 4.0. https://doi.org/10.25814/5cf8ebadb377f.

[89] Bryan, K. (2022). Law firms hold leaders to account on green claims. *Financial Times,* 14 October 2022.

[90] Setzer, J. and Higham, C. (2022). *Global Trends in Climate Change Litigation: 2022 Snapshot*. London: Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, London School of Economics and Political Science.

Not-for-Profit organisations, particularly in Europe, are increasingly running strategic litigation cases against company boards and individual directors for failure to consider climate risks, or for 'greenwashing'.

Prominent amongst these is the US-based Partnership for Policy Integrity (headed by Dr Mary Booth) which provides scientific and legal support especially for cases aimed at **ending use of forest biomass as a renewable energy source.**[91]

The number of court cases fought in Australia is also rising.

It would be prudent for governments and industry bodies to factor in legal risk in their policy decisions.

6. Only cross-sectoral, integrated transformational change will suffice

The world is facing combined climate and biodiversity crises as pointed out repeatedly in this submission. Achieving a balance between environmental matters and impacts on the native forest timber industry is no longer appropriate or tenable. 'Business as Usual' is not acceptable. Urgent and unprecedented transformational change is required across *all* sectors of society including governance.[92,93,94] It has to be "all hands on deck" if we are to avoid cascading collapse of life support systems.

That applies to the native forest timber industry including the native forest-dependent biofuels sector.

As also detailed previously, a key feature of complex adaptive systems is uncertainty and the potential for hard-to-predict, likely irreversible, phase shifts or "tipping points". Populations of common species, even whole ecosystem, can suddenly collapse if positive reinforcing feedback mechanisms become dominant[95,96] including through management interventions such as intensified logging.

It is inappropriate and unfair to regional industry workers to be giving false hope of

[91] Nuttall Jones, P. (2021). Everything but the (forest) sink. *Energy Monitor*, 16 June, 2021. https://energymonitor.ai/tech/renewables/everything-but-the-forest-sink.
[92] King, D., Schrag, D., Dadi, Z., Ye, Q. and Ghosh, A. (2021). Climate Change: A risk assessment. London: UK Foreign & Commonwealth Office.
[93] Pörtner et al. 2021. Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change: IPBES secretariat, Bonn, Germany, DOI:10.5281/zenodo.4659158.
[94] Stoddard *et al*. (2021). Three decades of climate mitigation: Why haven't we bent the global emissions curve. *Annual Review of Environment and Resources 46*, 653–689.
[95] Lindenmayer, D.B., Wood, J.T., McBurney, L., MacGregor, C., Youngentob, K and Banks, S.C. (2011). How to mak a common species rare: A case against conservation complacency. *Biological conservation 144*, 1663-1672.
[96] Ceballos, G., Ehrlich, P.R. and Dirzo, R. (2017). Biological annihilation via the ongoing sixth mass exinction signaled by vertebrate population losses and declines. *PNAS E6089-E6096*. 10 July, 2017

security by promoting long-term sustainability of the industry bolstered by new products such as forest biomass as an alternative energy source to replace fossil fuels.

A long-overdue economic and governance paradigm shift is emerging.[97] Instead of current piecemeal market-based measures by siloed governance structures, we need interlinked, aligned social, economic, political and environmental governance structures appropriate for dealing with the multiple, escalating crises worldwide. Many research organisations are now grappling with these issues riddled with complexity and uncertainty.[98,99,100] There is no “normal”, no “new normal” because the baseline is now ever-changing. That needs a new approach more than ever. Governments need to be smart, strategic and able to solve the unprecedented, linked climate and biodiversity crises. That means the goals need to be specific, measurable, broken down into specific milestones, monitored, and adapted rapidly in responses to new evidence. Our future depends on it.

[97] Mazzucato, M. (2021). *A New Global Economic Consensus*. Project Syndicate, 13 October 2021. https://www.project-syndicate.org/commentary/cornwall-consensus-rebuilding-global-governance-by-mariana-mazzucato-2021-10
[98] King, D., Schrag, D., Dadi, Z., Ye, Q. and Ghosh, A. (2021). Climate Change: A risk assessment. London: UK Foreign & Commonwealth Office.
[99] Mazzucato, M. (2021) The right institutions for the Climate Transition. *Project Syndicate*. 16 November 2021.
[99] Sharpe, S., Mercure, J.-F., Vinuales, J., Ives, M., Grubb, M., Pollitt, H., Knobloch, F. and Nijse, F.J.M.M. (2020) Deciding how to decide: Risk-opportunity analysis as a generalization of cost-benefit analysis. C-EENRG Working Papers, 2020-3. Pp. 1-19. Cambridge Centre for Environment, Energy and Natural Resource Governance, University of Cambridge.
[100] Mazzucato, M. (2022) Directing Economic Growth: A Mission-Oriented Approach. 2022 Philip Gamble Memorial Lecture. https://www.youtube.com/watch?v=s_FTwka1n-A.