

A preliminary assessment of the environmental impacts of Cyclone Larry on the forest landscapes of northeast Queensland, with reference to responses to natural resource management issues in the aftermath

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Introduction

Disturbances, both natural and anthropogenic, shape forest ecosystems by controlling their species composition, structure and functional processes. The tropical forests of the Wet Tropics of northeast Australia have been moulded by their natural disturbance and land-use history and over many millennia but particularly over the past 100 years. Forests of the region are subjected to a range of natural disturbances, including bush fires, droughts, floods, occasional landslides and tropical cyclones. All these natural disturbances interact in complex ways with anthropogenic disturbances across the landscape, such as land-use change resulting from forest conversion to agricultural systems, indigenous fire management regimes, earlier logging practices, urban and peri-urban development and infrastructure projects, such as major roads, powerline corridors and dams.

Tropical cyclones are significant natural disturbance phenomena for forest ecosystems in the Wet Tropics of northeast Australia, especially for forests near the coast. For this reason, even continuous forests in the region have been described as hyper-disturbed ecosystems with patches of damaged forest constantly recovering from previous cyclonic events, often in concert with floods, droughts and fires. Cyclones are part of the ecosystem dynamics of these forested landscapes and recovery of canopy cover following such events is often remarkably rapid, although forest structure and composition may take many decades to recover. The same cannot be said for fragmented forests in the Wet Tropics, located within either an agricultural, urban, linear infrastructure or grassland matrix. These forest fragments are particularly vulnerable to impacts of tropical cyclones and their associated strong winds, largely due to their high forest edge to area ratios.

Severe cyclones cause widespread defoliation of rainforest canopy trees, removal of vines and epiphytes, along with the breakage of crown stems and associated tree falls. These catastrophic impacts typically result in significant changes in forest microclimates in the understorey and canopy, and complex vegetation and faunal responses to newly created light, temperature and humidity regimes. Cyclonic disturbance has also been shown to accelerate invasion by exotic tree, vine and grass species leading to a decline in biodiversity of native plant species in some forest regions.

Given the relatively high frequency of tropical cyclones, there is a general consensus that they contribute to the structure and function of tropical rainforests in cyclone-prone areas, with ecosystem impacts and recovery processes occurring at several spatial and temporal scales. Impacts of tropical cyclones on forests at the landscape-scale (>10km) are the result of the complex interaction of anthropogenic, meteorological, topographical and biotic factors. Three main factors control forest damage at this scale: 1) wind velocity gradients resulting from cyclone size, speed of forward movement, cyclone intensity and proximity to the storm track, complicated by local convective-scale effects; 2) variations in site exposure and other effects of local topography (e.g. severe lee waves or leeward acceleration, windward exposure, topographic shading); and 3) differential response of individual ecosystems to wind disturbance as a function of species composition and forest structure.

Severe Tropical Cyclone Larry, with maximum wind gusts were near 280 km h⁻¹, crossed the coast near Innisfail (Fig. 1) as a borderline Category 4/5 storm on 20 March 2006 causing extensive damage to human communities, primary industries, infrastructure and ecosystems across a 100 km strip of coastal lowlands and adjacent uplands. The system was moving at 25 km h⁻¹ when it crossed the coast and was still Category 3 status when it crossed over the Atherton Tablelands some 60 km from the coast (Fig. 1). Cyclone Larry produced numerous tornado-type features within the system's eyewall and feeder bands that have been linked to patches of catastrophic forest damage. Larry was a very 'compact' system with its radius of maximum winds extending only 20-30 km from the centre (BOM, this report).

We examine the landscape-scale impacts of Cyclone “Larry” on the ecosystems of far north Queensland and provide a comparison with previous cyclones that have impacted along the wet tropical coast of Queensland over the period 1858-2006. We also discuss responses to the natural resource management issues facing the affected region in the aftermath.

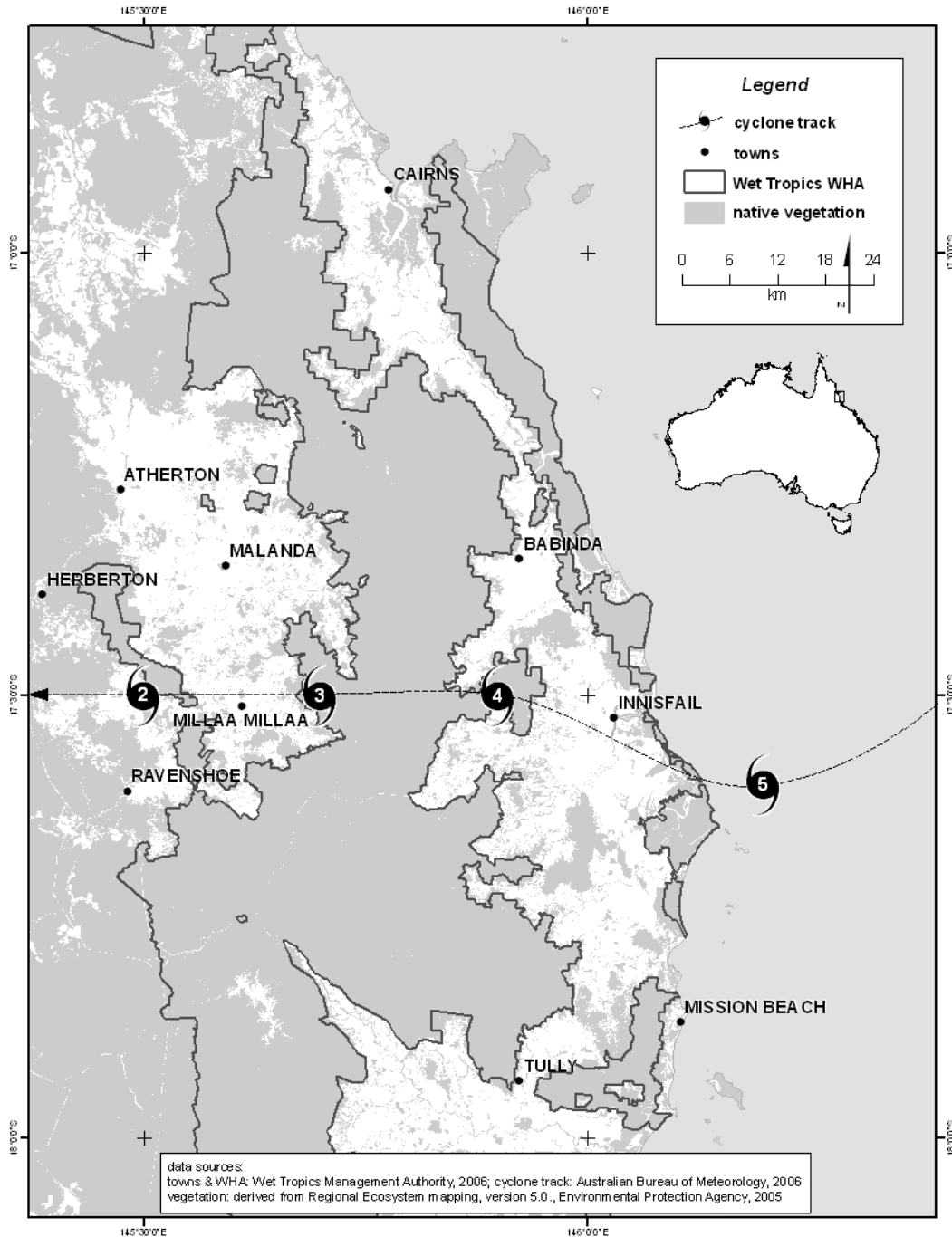


Figure 1: The track of Cyclone Larry with respect to continuous and fragmented forest areas (Map prepared by Caroline Bruce, CSIRO, Atherton).

Aerial surveys of forest damage following Cyclone Larry

Two weeks after Cyclone Larry helicopter aerial surveys were conducted to examine landscape-scale impacts from what has been described as a severe but 'compact' cyclonic system (BOM, this report). Aerial surveys covered the main impact area, from Cairns to Tully and as far west as Herberton and Ravenshoe (Fig. 1). Cloud cover prevented surveys of higher elevation forests above 1000 m as, but such forests constitute less than 5 per cent of the study area (Fig. 1).

Adopting a rapid assessment methodology, developed by Unwin *et al*¹ following Cyclone Winifred, four classes of initial forest damage were identified from the aerial surveys: 1) severe and extensive, 2) severe and localised, 3) moderate canopy disturbance and 4) slight canopy disturbance (see Table 2 for classes). GPS readings were also taken to allow for identification of damaged areas of forest for subsequent mapping purposes.

Cyclone impacts on the Wet Tropics region

Table 1 provides a summary of notable severe cyclones (Categories 3-5) that have impacted on the Wet Tropics region from 1858 - 2006². Cyclone Larry was the second strongest cyclone to impact along the wet tropical coast since records began in 1858, with only the un-named 1918 cyclone, that crossed in a similar location, considered to be more powerful. It would therefore be reasonable to consider Cyclone Larry to be about a 1 in 75 year event for the Wet Tropics region.

Table 1: Notable east to west moving tropical cyclones by code-name that have impacted along the wet tropical coast (Cooktown-Ingham) over the period 1858-2006 (after Callaghan, BOM).

Code Name	Date	Area most impacted	Estimated lowest barometric Pressure (hPa)
Un-named	8 March 1878	Cairns	not available
Un-named	16 March 1911	Port Douglas	not available
Un-named	10 March 1918	Innisfail region	910
Un-named	3 February 1920	Port Douglas	962
Un-named	9 February 1927	Cairns-Port Douglas	971
Un-named	12 March 1934	Cape Tribulation	978
Un-named	18 February 1940	Cardwell	965
Agnes	6 March 1956	Cairns-Townsville	961
Winifred	1 February 1986	Cairns-Tully	958
Rona	11 February 1999	Daintree-Cape Tribulation	970
Larry	20 March 2006	Innisfail region	915*

* Subject to verification

¹ Unwin, G. L., Applegate G. B., Stocker G. C. & Nicholson D. I. (1988): Initial effects of tropical cyclone Winifred on forests in north Queensland. *Proceedings of Ecological Society of Australia* 15, 283-296.

² Callaghan J. (2004): Tropical cyclone impacts along the Australian east coast from November to April (1858 to 2004). Bureau of Meteorology, Brisbane Regional Office, australiasevereweather.com/cyclones/impacts-eastcoast.pdf

Landscape scale impacts of Cyclone Larry on forests across the Wet Tropics

Table 2 summarises the results of the aerial surveys of the area impacted by Cyclone Larry according to the four damage classes described above. Figs. 2-5 provide photographic examples of the four classes of forest damage described in Table 2. Figs. 2 and 3 provide examples of windward and leeward forest damage (both Class 2), respectively.

Table 2: Initial effects of Severe Cyclone Larry on forests in the Wet Tropics of northeast Queensland derived from aerial surveys. Forest damage classes adopted from Unwin et al. (1988: Initial effects of tropical cyclone Winifred on forests in north Queensland. Proceedings of Ecological Society of Australia 15, 283-296).

Forest Damage Classes (areal extent of damage)	Definition (by essential characteristics)	Occurrence in rainforests	Occurrence in open forests
1. Severe and extensive (mostly within 30 km from centre of cyclone)	Boles or crowns of most trees broken, smashed or wind-thrown. Impact multi-directional.	Extensive among coastal forests, riparian forests, forest remnants and foothills in area along track of the cyclone's core, including foothills as far west as Millaa Millaa.	Rarely evidenced
2. Severe and localised (mostly 30-50 km from centre of cyclone)	Severe canopy disruption (as above) restricted to windward aspects. Direction of destructive winds clearly identifiable.	Defoliation, tree falls and stem breakage common on windward aspects only. Leeward forest areas more or less intact except for patches of lee wave damage.	As above, (transitional understoreys, defoliated as for rainforests)
3. Moderate canopy disturbance (mostly 50-75 km from centre of cyclone)	Structural injury mostly branch and foliage loss. Some treefalls; most stems erect.	Extensive areas on exposed uplands & tablelands, beyond most destructive winds. Widespread canopy thinning, exposure of epiphytes and understorey. Heavy litter and branch fall.	Most common injury in open forests of <i>Eucalyptus</i> and <i>Melaleuca</i> , on lowlands, foothills and uplands near Ravenshoe. Widespread defoliation and loss of twigs
4. Slight canopy disturbance (mostly 75-120 km from centre of cyclone)	Partial foliage loss on forest edges only. Subsequent leaf desiccation and heavy litter fall. Occasional stem or branch breakage.	Common on exposed margins of cyclone affected area. Canopy interior intact.	On main ridges and spurs peripheral to damage Class 3 areas above. Foliage desiccation short-lived and inconspicuous.



Figure 2: Severe and extensive (Class 1) forest damage along the lower North Johnstone River. Photo: S.M. Turton.



Figure 3: Severe and localised (Class 2) forest damage near Kurrimine Beach. Note severe windward forest damage and intact forest in leeward (sheltered) areas. Photo: S.M. Turton.



Figure 4: Severe and localised (Class 2) forest damage on the east face of the Murray-Prior Range. This is an example of forest damage due to severe lee (gravity) waves propagating over the mountain range from the west leaving an adjacent area of intact forest. Photo: S.M. Turton



Figure 5: Moderate (Class 3) and slight (Class 4) at Lake Eacham. Photo S.M. Turton

Severe forest damage (Classes 1 and 2) from Cyclone Larry (Table 2) appeared to be more extensive than that caused by Cyclone Winifred that impacted on same area in February 1986. In the case of Cyclone Larry, moderate and severe forest damage (Classes 2 and 3) extended much further north, south and west than that reported for Cyclone Winifred despite their similar paths across the landscape. However, slight forest damage (Class 4) for Cyclone Larry appeared to be less extensive than that reported for Cyclone Winifred. The latter may be explained by the compact nature of Cyclone Larry's area of destructive winds, compared with the less intense but much larger diameter of Cyclone Winifred. Compared with previous cyclones, Larry moved inland unusually fast while maintaining its intensity. This caused extensive damage to upland forests as far inland as 100 km that normally escape the worst impacts of cyclones.

In the Wet Tropics region, topography plays a significant role in accounting for forest impact patterns and recovery processes after cyclones at the landscape scale. Cyclonic winds exhibit complex interactions when they encounter steep topography. Depending on the location of the cyclone centre and the direction and speed of movement of the cyclone, forests in mountainous areas may experience severe windward exposure, topographic shading (leeward protection) and, under certain circumstances, severe lee turbulence. The latter explains observed areas of severe forest damage in parts of the landscape that would normally be expected to be protected from cyclonic winds due to topographic shading.

Figures 3-5 collectively, demonstrate the patchy nature of forest damage at the landscape scale, with many areas of forest remaining intact despite being close to the centre of the cyclone. Intact forest areas will become important refuges for many non-volant fauna while adjacent areas of damaged forest recover. In the Wet Tropics this includes the endangered frugivorous Cassowary and several rare folivorous marsupials.

Ongoing ecological research

In the aftermath of Cyclone Larry, several research projects were initiated by CSIRO (Sustainable Ecosystems) and James Cook University, with co-funding from the Skyrail Rainforest Foundation. The results of this extensive program of research will be published in a theme issue of *Austral Ecology* in late 2007. Research topics to be covered in the theme issue include:

- Lowland Bird Communities in Continuous and Fragmented Rainforest; Impacts and Recovery Following Cyclone Larry.
- Assessment of cyclonic damage and community response using long term forest plots.
- Impacts of cyclone Larry on reforested sites and forest fragments.
- Impacts of cyclone Larry on arboreal folivores.
- Trophic impact of a severe tropical cyclone on an endangered ecosystem.
- Wet Tropics scale re-distribution of a threatened species in response to major habitat disturbance: landscape ecology of the Spectacled Flying Fox (*Pteropus conspicillatus*) after Cyclone Larry.
- Evaluating the effectiveness of river and wetland rehabilitation works in relation to impacts of tropical cyclone Larry.
- Satellite remote sensing assessment of rainforest vegetation damage from Cyclone Larry, and vegetation recovery monitoring.
- Impacts of Cyclone Larry on rainforest insects.

Responding to natural resource management issues following Cyclone Larry

The landscape-scale impact of Cyclone Larry had implications far wider than the impact on forested areas. A very wide range of natural resource assets and processes were affected. An opportunity for a level of integrated response to this impact was provided through the State government's Industry Recovery Action Planning process. Within this process, FNQ NRM Ltd undertook wide ranging consultation with affected communities, industry and interest groups. FNQ NRM Ltd, the region's designated Regional Natural Resource Management Body, carried out this work in the context of its role in representing the Wet Tropics community on natural resource issues. The early response issues arising from this consultation were articulated in a Natural Resources Management Recovery Plan. The details of such proposed and actual responses are outlined in Table 3.

Additionally, several months after the cyclone, a broad community forum was held to determine the longer term "Lessons from Larry" with respect to a wide range of natural resource management considerations. A summary of some of the more substantive cyclone response lessons and recommendations are outlined in Table 4. Through these processes, perhaps the most striking natural resource management learning from Larry was that a more resilient landscape has a better chance of withstanding cyclone impacts and recovering more quickly. Securing landscape resilience to cyclonic events in the Wet Tropics region means focusing future natural resource management investments in the following areas:

- 1) Landscape connectivity
- 2) River repair
- 3) Protecting coastal assets
- 4) Cyclone resilient farms
- 5) Education for the future
- 6) Avoiding climate change

The Appendix provides more details of these investment strategies.

Table 3: Responding to natural resource issues following Cyclone Larry

Issue	Impact Considerations	Possible Operational and Policy Response
Landscape Recovery	<p>The ability of the landscape to quickly recover post cyclone depends on the resilience of critical landscape functions to major wind, storm surge and flood events. Key landscape features of importance here include:</p> <ul style="list-style-type: none"> • Stable and secure farmscapes resistant to soil loss and protected as far as possible from excessive wind and flood damage; • Robust vegetation/wildlife corridors between areas of critical mass to protect key regional 	<p>The response to Larry requires both:</p> <ul style="list-style-type: none"> • Immediate recovery and restoration of these key landscape features; and • Continued long term investment in building landscape resilience through enhancement of these landscape features. <p>Securing both approaches requires significant short and long term investment. It is recommended that there are several actions required relating to resourcing these.</p> <p>Short Term:</p> <ul style="list-style-type: none"> • FNQ NRM Ltd and Landcare Australia Limited are jointly

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	<p>ecosystems;</p> <ul style="list-style-type: none"> • Sufficiently wide revegetation and (where appropriate) hard engineering stabilization of riparian areas and protection of wetlands; and • Robust coastal buffers offering protection from coastal winds and storm surges. <p>There has been an emerging process of improving these landscape functions over the last decade. Significant damage has occurred, and recovery will be more limited where these features are not strong (eg thin riparian corridors). This region has been significantly hindered in developing a more robust landscape, as it is not a National Action Plan for Salinity and Water Quality region. This is despite the region having some of the most nutrient and water quality sensitive sections of the Great Barrier Reef. The Regional NRM Body (FNQ NRM Ltd) has access to only one third of the required resources of all other major coastal catchments in Queensland (except the Mackay region).</p>	<p>managing implementation of the Landcare for Larry funding drive. The drive has to date raised in the order of \$500 000 and has a target of over \$1 million. Broad discussion has occurred about the key delivery priorities and implementation mechanisms. There may be value in General Cosgrove lending profile to this corporate funding approach.</p> <ul style="list-style-type: none"> • Immediate Response Teams. Conservation Volunteers Australia and FNQ NRM Ltd have established a small number of immediate response crews to operate on both farm clean up and rehabilitation plot restoration. These crews have been well received, and CVA is currently exploring corporate sponsorship to maintain at least two teams in the field for at least twelve months. Greening Australia is also considering the provision of chainsaw workers. There may be value in General Cosgrove lending profile to this corporate approach. • Given the significance of the farm clean up job ahead, and the current labor shortage for carrying out such work, the emerging Farm Clean Up program, managed by DPI&F will provide a significant vehicle for delivery. Clear mechanisms for determining priority needs will be required as well as effective coordination with other programs. • Consideration should be given to enabling Regional NRM Bodies accessing Natural Disaster Relief Funding to support the immediate responses to NRM issues. <p>Mid to Long Term: To secure long term landscape resilience, the current NRM funding</p>

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		<p>inequity facing the FNQ region should be resolved from the start of the 2006/07 financial year. Additional Commonwealth funding would be required in the 06/07 financial year. State and Commonwealth reconsideration of current indicative allocations should be considered for the 07/08 financial year, allowing FNQ NRM Ltd access to a combination of both NAP and NHT funds.</p> <p>Finally, to hasten the process of building landscape resilience in reef catchments, consideration should be given to the establishment of a significant Federal budget initiative to support on-ground implementation of Reef Plan beyond June 2007.</p>
<p>Short Term Regulatory Bottlenecks</p>	<p>In the recovery process, there are significant urgent works required that would normally rely on fragmented permit approvals to manage their environmental impact. Examples include river improvement work, timber recovery, access track development, new infrastructure, etc.</p> <p>It is expected that there will be a short term demand on permitting processes, as well as considerable community confusion over permitting requirements. This can both lead to delays in essential works, as well as unnecessary environmental damage in cases where people may seek to bypass complex approval processes.</p>	<p>Two possible mechanisms exist to resolve this issue:</p> <ul style="list-style-type: none"> • This first may be for key agencies in high-demand permitting areas increasing staffing levels to ensure backlogs do not develop and to ensure efficient responses to permitting requests; and • A second, and not necessarily separate response may be a single point of permitting coordination being established in Innisfail for the short to mid term to effectively communicate regulatory requirements in the post cyclone period, and to coordinate cross agency permitting requirements.
<p>Development of a Strong Private Forestry Industry</p>	<p>The post-Larry problem relating to the private forestry industry now faced in FNQ stems from the poorly integrated industry restructure package established after World Heritage listing in the early 1990s. At that time, response programs included dollars to grow trees, payouts to the mills (much reinvested outside the region) and limited retraining. Some 15 years later, the region has lots of poorly designed forestry plots,</p>	<p>Private foresters are looking for some Government leadership and support to do some urgent and technically sound work to assess the viability or otherwise of salvage options. Private foresters, however, want this to be done in genuine partnership. They feel the steps needed are:</p> <ul style="list-style-type: none"> • A rapid salvage volume and quality assessment ; • A rapid joint assessment of the viability of the best private salvage options, linked where

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	<p>inappropriate trees, and lots of tree farmers that feel there is no industry infrastructure to help them manage in times of crisis. Effective forestry operations are equally hampered by the lack of a wider industry infrastructure.</p> <p>There is concern among private foresters that they are left as individual producers without a clear structured industry to mount an effective and coordinated respond. Concurrently, however, an opportunity for a collaborative Government/ private sector response exists while DPI&F is focused on the salvage of its State-based forestry resources.</p>	<p>possible with the State's own salvage operations;</p> <ul style="list-style-type: none"> • Concurrent assessment of the storage, milling and treatment options; • Implementation of an agreed industry/ government salvage program; and • A clear mechanism for streamlining regulatory approvals during the salvage process. <p>There are critical time constraints because of rapid wood deterioration (particularly pine species).</p> <p>There is also a longer term issue that needs consideration if the private forestry industry is to become more resilient to future cyclone-shocks. An integrated industry development strategy needs to be developed between State and Commonwealth agencies, the Regional NRM Body and Private Forestry North Queensland. Components would need to include:</p> <ul style="list-style-type: none"> • Assessment of viable production, harvesting and market options for the private industry; • Establishment of the required regional infrastructure and services for developing the industry in a coordinated way; and • The State undertaking policy changes required to facilitate carbon trading within the region.
<p>Damage to Fences in the beef and livestock industries</p>	<p>Two significant areas of fence damage have occurred:</p> <ul style="list-style-type: none"> • Fence damage on the boundaries of protected areas and the World Heritage Area. The cause of this problem arises from insufficient buffers between boundary fences and protected areas; • Internal fence damage and boundaries between agricultural properties. A major concern raised by landholders has been 	<p>Again, there are short term and longer term responses required on this issue.</p> <p>ShortTerm:</p> <ul style="list-style-type: none"> • In relation to World Heritage Boundaries in the upper Palmerston area, it is understood that EPA has been able to access around \$100 000 of Natural Disaster Response funds. A very positive comanagement approach has been established with local landholders, and devolved

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	<p>concerns about their ability to clear sufficient buffers around fencing infrastructure under the <i>Vegetation Management Act</i>.</p> <p>There are several operational impacts arising from this damage, including stock loss, risks associated with stock on roads and interrupted herd management schedules. The problem of protecting fencing infrastructure is made considerably more important to resolve because of difficulties faced by large-scale producers in insuring fences.</p>	<p>grants will be provided to allow producers to lift trees off the fences, repair damage and restore fire breaks on the world heritage boundaries.</p> <ul style="list-style-type: none"> • Some additional funds will be made available for internal and boundary fencing from the Landcare for Larry program. • Consideration should be given to extend Natural Disaster Relief Funding to EPA to spread this comanagement approach to additional localities in the cyclone affected area. <p>Mid Term:</p> <ul style="list-style-type: none"> • In the mid term, consideration should be given to current policy definitions related to clearing widths around fencelines under the <i>Vegetation Management Act</i>. This consideration should be given quickly however, to allow effective fence protection to be carried out during the repair phase. • If resolving the regulatory problem is not an option, the State government should consider establishing some form of insurance system to allow farmers to undertake the required restoration work following cyclonic events.
Impact on World Heritage Values	<p>Cyclone Larry has cut a broad swathe through the World Heritage Area, causing an extensive loss of forest canopy. Damage is particularly severe in smaller forest patches and riparian vegetation strips on the coastal lowlands and tablelands. Larger expanses of healthy forests will have the capacity to recover over time. The rate and extent of recovery from cyclone damage will be dependent on the severity of the structural damage to the forest and the size of the forested area affected.</p> <p>Smaller rainforest patches and</p>	<p>The Wet Tropics Management Authority (WTMA) will play a key role in:</p> <ul style="list-style-type: none"> ▪ providing technical and project management expertise for on-ground rainforest recovery activities; ▪ coordinating strategic environmental assessments to cyclone-affected areas and prioritising landscape recovery efforts; ▪ coordinating research about the impacts of the cyclone on the World Heritage Area and developing strategies for recovery and restoration.

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	<p>narrow riparian strips have generally suffered more damage and have less resilience to recover. Some impacted patches represent already endangered ecological communities such as Mabi Forest. The loss of canopy cover in these areas may allow the invasion of weed species and could result in major disruptions to ecological processes including succession. In some instances natural recovery is unlikely. This is likely to have significant adverse impacts on the functioning of lowland and tableland habitat corridors.</p> <p>Some of the surviving fauna face potential food and shelter shortages while the vegetation recovers. While it is expected that many species will be able to move or adapt their feeding patterns, in some areas there is a lack of food for folivores such as possums and tree kangaroos and frugivores, notably cassowaries. There is likely to be increased interaction between wildlife and humans as a result of the vegetation damage and food shortages. This has already become an emerging problem at Mission Beach.</p>	<p>Responses to the environmental impacts on the World Heritage Area require cooperation and coordination between government, business and community organisations such as the QPWS (Queensland Parks and Wildlife Service), local governments, FNQ NRM Ltd, research organisations and local community groups such as C4 (Community for Coastal and Cassowary Conservation), TREAT (Trees for the Evelyn and Atherton Tablelands) and TKMG (Tree Kangaroo and Mammal Group).</p> <p>In response to the impacts of Cyclone Larry, the Authority is currently working collaboratively to:</p> <ul style="list-style-type: none"> • Map and monitor the extent and severity of cyclone damage to native forests and identify the location of refuge areas in the landscape. • Identify, prioritise and cost rainforest restoration activities (including weed, disease and fire management) critical to landscape conservation. <p>The cost of processing, rectification, interpretation of images, and comparisons to pre-cyclone mapping is estimated at approximately \$50,000. It is intended that a consultant be employed to conduct the on-ground environmental assessments in consultation with land management agencies on the basis of the remote sensing mapping, interpretation and prioritisation. Landscape recovery efforts will be prioritised in consultation with researchers and land managers. Funding for on-ground environmental assessments and recovery effort prioritisation is estimated at approximately \$50,000.</p> <p>This information will also form the basis for:</p> <ul style="list-style-type: none"> • developing a detailed costed conservation recovery plan of critical landscape features and connections;

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		<ul style="list-style-type: none"> • identifying increased fuel loads and assessment of fire risk; and • monitoring rainforest recovery processes/ rates. <p>Rainforest recovery efforts will be prioritised and costed on the basis of the above recovery planning process. These costs are likely to be significant.</p> <p>The establishment of a Weed Hit Team in the Cyclone Larry affected World Heritage area would be the major most effective long-term rainforest recovery initiative. Start-up and establishment costs of \$2.5M in the first year followed by a six-year recurrent commitment of \$2.0M would be of major benefit. Very importantly, such an initiative would also reduce the potential for major environmental weed establishment, expansion and penetration into damaged forests within the World Heritage Area.</p> <p>It is envisioned that contingency funds of a further \$500,000 be identified to address impacts which are likely to be revealed following the proposed assessment and research priorities above.</p>
Repairing foreshore damage	<p><i>To date the Regional Organisation of Councils have been advised of significant foreshore damage to the areas of:</i></p> <ul style="list-style-type: none"> • Cardwell • Mission Beach • Tully Heads, and • Hull Heads <p>There has been no support to build these up other than the 25% subsidy available regularly available.</p>	Councils need assistance to evaluate, monitor and mitigate or rectify damage caused as a result of Cyclone Larry.
Improving Coastal Buffers	Anecdotal evidence suggests that intact coastal vegetation offered some protection to infrastructure and vegetation on the coast (eg Bramston Beach). It is also well known that wider	In the short term, resources (Landcare for Larry and the suggested additional State/ Commonwealth investment) is required to continue to develop effective native vegetation in coastal

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	<p>coastal buffers provide protection from beach erosion and place some distance between infrastructure and storm surges. Potential for significant loss of life comes from the risk of storm surges in major cyclonic events. Given continuing development pressure on the coastal zone in FNQ, more coordinated regional action is required to protect coastal vegetation and to establish a reasonable buffer between development and the coast is required.</p>	<p>buffers.</p> <p>Long term, however, regional agreement between Councils, the State government and FNQ NRM Ltd is required to ensure that agreed standards for coastal buffering and vegetation protection/management are developed and implemented. This could become a key activity within the context of the FNQ Regional Growth Management Framework.</p>
<p>Improving Critical Biodiversity Corridors</p>	<p>The damage from Larry has reinforced the need for effective wildlife corridors for iconic species in the Wet Tropics. Particular problems have been faced by Cassowaries on the coast and tree kangaroos and other arboreal folivores on the Tablelands. While there have been improvements in connectivity in Tree Kangaroo and other arboreal folivores habitat due to the efforts of organizations such as TREAT, there remains considerable fragmentation of Cassowary habitat on the Coast. Additional problems may emerge in the Kuranda area as future development occurs.</p>	<p>In the short term, resources (Landcare for Larry and the suggested additional State/ Commonwealth investment) are required to continue to develop effective biodiversity corridors.</p> <p>Longer term however, a more coordinated approach (both regulatory and incentive-based) is required to protect cassowary corridors in the Mission Beach and the Kuranda area.</p>
<p>Improving River Stability</p>	<p>Experience from River Improvement Trusts, Councils, Landcare and Catchment groups has shown the need to stabilize rivers and major tributaries in intensive land use areas through a combination of appropriate hard rock and the restoration of effective riparian vegetation. Restoration of these areas is a major job facing the region over the next decades. The cyclone has trashed many inadequate (narrow) areas of revegetation and contributed to bank erosion where improvement works have not yet occurred.</p>	<p>In the short term:</p> <ul style="list-style-type: none"> • Councils and RITs to explore immediate post cyclone erosion risks, and to establish an immediate response program to remove these risks supported by Natural Disaster Relief Funding. • Resources (Landcare for Larry and the suggested additional State/ Commonwealth investment) are required to continue to develop effective riparian corridors. <p>Longer term policy responses of value would include:</p> <ul style="list-style-type: none"> • The development of stronger rehabilitation alliances between River Improvement

Issue	Impact Considerations	Possible Operational and Policy Response
		<p>Trusts, Councils, Revegetation Nurseries, ICM and Landcare Groups and FNQ NRM Ltd to prioritise and progress significant river improvement priorities.</p> <ul style="list-style-type: none"> • Securing the future of River Improvement Trusts and in particular, those aspects of the <i>River Improvement Act</i> that allow the protection of repaired riparian areas as assets. More defined State government contribution to the emerging riparian alliances is required.
Pest Management	<p>The risk of pest plants invading/spreading further not only in the region but also further south and west has been significantly increased. The Regional Organisation of Councils has had numerous instances where people in the recovery effort have been through infested areas with little or no knowledge of local pest plants and operations required to manage the spread. Much of this has occurred due to people from outside the area who are unaware of prevention or have had no contact with this issue prior to coming here.</p> <p>The risk of further incursion into our forests has also been increased due to the once closed canopy now allowing sunlight to penetrate the forest floor. This then provides favourable conditions for weeds currently on the fringes to invade these forests.</p> <p>Weed spread risk has also been increased with the amount of 'green waste' being mulched as part of the cleanup after cyclone Larry. Whilst this mulch should be allowed to sit for 6 – 8 weeks before being released councils have to release it earlier due to the amount of debris being processed.</p>	<p>The Regional Organisation of Councils needs:</p> <ul style="list-style-type: none"> • Assistance in providing educational material so that pest plants can be identified. Whilst the majority of landowners recognise the common species, e.g. Sicklepod, others such as Siam Weed are not so well recognized; • Fast tracking of WONS project approvals by the DNRM&W (submitted 12 months ago). This was to work on Hymenachne and Pond Apple in waterways, which will also provide opportunity for local employment; • To limit the issuing of notices by local government to lessen pressure on landowners who are coping with the expense of cleanup • To be able to access small plant that could be loaned to effected landowners so that broad scale weed spraying could be facilitated; • Chemicals that could be made available either free of charge or at significantly reduced price for landholders; • To have staff from various agencies available to confirm weed species if the landowner is unsure; • To track/map where weed incursions are and what they are;

Issue	Impact Considerations	Possible Operational and Policy Response
		<ul style="list-style-type: none"> • To assist landowners to prioritise based on growth habit of weeds, potential to spread, capacity and class; • Secure support for the Weed watcher programs that have been slow due to time required for management. <p>The region, through FNQROC, is in the initial stages of trialing new approaches to Pest Management. Despite this, FNQROC has only one person dedicated to the Regional Pest Management role and these activities are either in the early stages of implementation or in development. Assistance could be provided in the way of extending the hardware and technical resources FNQ ROC are trialing should these be successful in pilot.</p>
Post Cyclone Fire Management	Moderate to high risks to the region's World Heritage listed rainforest estate exist over the coming dry season.	<p>Two critical strategies are required to prevent burning significant areas of rainforest communities and very destructive fires in wet sclerophyll areas. These include:</p> <ul style="list-style-type: none"> • The continued implementation of the 2 tier Cooperative Fire Management Forums coordinated by Emergency Services. Tier 1 will provide a conduit between land managers, fire forums, government and the post cyclone taskforce. Tier 2 forums are organised locally and have the following aims: Identify and report on hazards which immediately form a threat to persons property or the environment from wildfire; Formalise an action plans and strategies for hazard mitigation within the prescribed district; Ensure that their objectives do not clash with the individual agencies legislative requirements and responsibilities; and Recognise agencies roles in utilising fire as a prescription for land management such as

Issue	Impact Considerations	Possible Operational and Policy Response
		<p>weed control or ecological sustainability.</p> <ul style="list-style-type: none"> • Additional resources be provided to EPA to conduct strategic fire management activities in sclerophyll forests. <p>WTMA will research and develop suitable fire management strategies for the World Heritage Area and surrounding lands in order to deal with increased fuel loads and changes to forest structure. This will include consultation with QPWS rangers, scientists, neighbouring landholders, primary industry groups and Aboriginal Traditional Owners.</p>
<p>Post-Cyclone Community Attitudes to Vegetation</p>	<p>New environmental impacts are likely to arise from post cyclone clean up and replanting activities. Two factors will contribute to the extent of post-cyclone environmental impacts. These include:</p> <ol style="list-style-type: none"> 1. Poor vegetation management or intentional vegetation destruction post cyclone. 2. Limited knowledge of appropriate tree species for urban and revegetation plantings. <p>Community concerns have been raised by a number of community-based NRM organizations regarding either more than necessary disturbance of vegetation in clean up campaigns or the intentional removal of additional vegetation to improve views or to offer additional future protection of infrastructure. The impact of this may be to increase weediness in native vegetation or to make weak corridors even more fragile.</p> <p>Equally, an opportunity exists to ensure more appropriate urban and rural planting of trees and other species, and to prevent wide replacement of native species with introduced and potential invasive exotic species.</p>	<p>Given the urgency of short term clean up work, it is considered that focused community communication and the provision of incentives for appropriate plantings are considered more effective than regulatory strategies. Key components of an effective strategy may include:</p> <ul style="list-style-type: none"> • A focused short and mid term regional communication strategy/ campaign focused on community education about post-cyclones plantings (eg plant to protect infrastructure), planting more appropriate wind resistant natives in urban areas, outlining the benefits of effective vegetation buffers in managing coastal and crop damage, etc); and • A focused approach from Council and commercial nurseries to ensure they are able to supply adequate and appropriate replacement trees/shrubs to urban and rural landholders.

Issue	Impact Considerations	Possible Operational and Policy Response
Community Building to Retain Individuals, Families and Businesses.	The cyclone has been an event that has sparked many individuals, families, businesses and entire small communities to rethink their future. Many are now making their decisions about whether to remain in the region. It is important that a positive and engaging process is put into place to give people confidence that there is a gathering, collective approach to rethinking the future. Without such an engaging community-wide approach, it is likely that many decisions to leave particular industries, communities and the region will be made in isolation and without support.	A broader process of community-building or collective futuring could be run in parallel to the immediate recovery effort. This would provide a real opportunity to participate to rethinking the future of their communities, and might make the difference between a broad despondence post cyclone. Such events would need to be run at the community level (eg Babinda, Innisfail, Atherton, etc). They would need to have strong ownership from the Councils and State/ Commonwealth agencies. They should also need to be inclusive and integrative events, perhaps comprising several activities and approaches over a reasonable period of time, and resulting in structured longer term responses and a commitment to implementation.
Management Actions Vs Regulatory Approach	State government effort in relation to NRM has largely focused on the establishment of new regulatory regimes (eg <i>Vegetation Management Action, Land Protection Act, Water Act, Wild Rivers Policy</i> etc). There is considerable community and industry concern about the possibility of new regulatory arrangement arising in relation to Reef Water Quality. In particular, industry has raised fears of having to respond to additional regulatory approaches while also responding to Larry's impact. The regional community has a strong view that in the short term, a much strong focus on trying to achieve water quality improvements through incentive-based approaches is required.	A stronger commitment from State government to work in the next three years towards focusing on a management action target-based approach to improving water quality in the reef lagoon. This would involve greater coordinative effort in monitoring and reporting on reef water quality and more tangible support for the water quality improvement programs of FNQ NRM Ltd.
Measuring Impact and Monitoring Long Term Recovery	To assist the response and long term resilience program, there is a need to measure more effectively the impact of the cyclone on communities and natural resources and their recovery.	JCU/CSIRO Tropical Landscapes Joint Venture has committed some resources to examine the impacts of Larry on NQ environmental assets. Marine and Tropical Research Facility to fund the TLJV to undertake short-term impact assessment and long term monitoring of community and environmental responses to the impact of the cyclone. Parties have committed \$125,000

Issue	Impact Considerations	Possible Operational and Policy Response
		seed funding, however, more resources will be required following initial investigations. Matching funding of \$125,000 would assist in ensuring management relevance of much of this research effort.

Table 4: Critical “lessons from Larry” for natural resource management and regional natural resource management bodies.

Category	Issues	Solutions	Lead Agencies
Institutional	<p>The resilience of FNQ’s landscape to cyclones is being enhanced by the State and Commonwealth’s significant investment in improving the health of natural assets through FNQ NRM Ltd. Critical response strategies are needed to protect this investment and maintain landscape resilience. Despite this, FNQ NRM Ltd had no direct role in the Larry Taskforce or the regionally based Operations Committee.</p> <p>Also, despite FNQ NRM Ltd’s extensive community consultation and its development of an NRM Recovery Plan (within the DPI&F led Industry Recovery Process) there was never a formal Government response to issues raised (see attached Strategy).</p>	<p>Regional NRM Bodies to be automatically invited onto the local operational group established under Disaster Response Taskforces. Consideration should also be made in giving the Regional Groups Collective access to Taskforce Structures at the State level.</p>	Emergency Services
Institutional	<p>Further to the above, FNQ NRM Ltd and Landcare Australian Limited raised over half a million \$ in corporate cash investment for the disaster response effort. With the exception of Joint Steering Committee’s support, there was no designated State or Commonwealth investment in repairing the region’s natural assets outside the crown estate (eg parks) and infrastructure responsibilities (eg Riverclear).</p>	<p>Regional Bodies need to be enabled to access NDRA funding for critical “natural asset repair”. To achieve this, the State would also need to resource Regional Bodies to take on responsibility for coordinating response strategies within the non-government sector.</p>	NRW
Operational	<p>Significant community conflict arose from perceptions that many infrastructure agencies used the cyclone response to over-clear vegetation in infrastructure reserves/State lands (eg Schools).</p>	<p>At the State level, agreed protocols should be developed across agencies and LGAQ that should be applied to the flexible by environmentally sound oversight of post cyclone clean up activities. These protocols would bind Councils and State agencies to particular codes of behaviour with penalties for significant breaches. Mechanisms for ensuring compliance need to be</p>	NRW Lead

		<p>pre-arranged as part of the protocols.</p> <p>The protocols would also include pre-agreed relaxation of permit requirements to enable fast but sensible actions to be taken by landholders, organisations and agencies (e.g. adjust WHA requirements about mulch management, fence-line clearing).</p>	
Operational	<p>In the cyclone cleanup, many industries, agencies and landholders were extremely frustrated about the lack of information about permitting requirements. In many cases, this led to no action being taken or the reverse (illegal action). In this period, agencies were reluctant to pursue compliance responsibilities. This led to very significant community conflict, and even though it has no statutory responsibilities, FNQ NRM Ltd wore the brunt of community frustration on this issue on behalf of both Governments and Councils.</p>	<p>Government to appoint a “Disaster Response Regulator” to facilitate a one stop shop for rapid but competent permit approval mechanisms and effective communication of permit requirements. It would also play an important role in education of communities, response agencies and contractors. Finally it would regulate the adherence of response agencies to the response protocol.</p>	NRW Lead
Operational	<p>Emergency Strategic Reserve Funding was made available to FNQ NRM Ltd to establish longer term, more strategic responses to the cyclone. This substantively supported the organisation to respond to the impacts of the cyclone.</p>	<p>State and Federal governments should establish a standing Disaster Response Fund from the next round of Regional NRM Funds to assist Regional Bodies to support affected communities to address the environmental impact of disasters rapidly and effectively.</p>	<p>Commonwealth – DEW and DAFF</p> <p>State NRM Lead</p>

Summary and Conclusions

- Tropical cyclones are significant disturbance phenomena for forest ecosystems in the Wet Tropics of Queensland, especially those near the coast. Continuous forests in the region have been described as hyper-disturbed ecosystems with patches of damaged forest constantly recovering from previous cyclonic events, often in concert with floods, droughts and fires. Cyclones are part of the ecosystem dynamics of these forested landscapes and recovery following such events is often remarkably rapid. However, compared with continuous forest areas, forest fragments and restoration areas are particularly vulnerable to impacts of tropical cyclones and their associated strong winds, largely due to their high forest edge to area ratios.
- Given the relatively high frequency of tropical cyclones in many tropical and sub-tropical regions there is a general consensus that they contribute to the structure and function of tropical rainforests in cyclone-prone areas, with ecosystem impacts and recovery processes occurring at several spatial and temporal scales. Wind damage is an important source of landscape-scale (≈ 10 km) patterning in forests and is a major factor initiating vegetation dynamics at that scale. At the local scale (≈ 1 km), extensive toppling of trees and canopy thinning is considered to be an important factor regulating hydrological, energy and nutrient regimes at that scale.
- Impacts of tropical cyclones on forests at the landscape-scale are the result of the complex interaction of anthropogenic, meteorological, topographical and biotic factors. In the Wet Tropics region, topography plays a significant role in accounting for forest impact patterns and recovery processes after cyclones at the landscape scale, where winds exhibit complex interactions when they encounter steep topography. Depending on the location of the cyclone centre and the direction and speed of movement of the cyclone, forests in mountainous areas may experience severe windward exposure, topographic shading (leeward protection) and, under certain circumstances, severe lee wind turbulence associated with gravity waves.
- Cyclones provide a spectrum of disturbance regimes across forested landscapes, a process that undoubtedly promotes biodiversity at that scale. However, cyclonic disturbance also promotes the risk of forest fires and the spread of invasive species, including soil pathogens, weeds and feral animals, especially in fragmented forests.
- Impacts of cyclonic winds at the local scale are largely controlled by forest composition and structure as well as smaller scale topographic features. Higher elevation forests are generally more resistant to cyclonic winds than lowland forests, mainly due to their lower stature and aerodynamically smooth canopies but have low rates of recovery. Despite their lower resistance to cyclonic winds, lowland tropical forests are more resilient than their less productive montane counterparts due to their high rates of primary productivity.
- Continuing to build landscape resilience is critical to reducing the short and long term ecological and social impacts of cyclonic events. Additionally, more effective natural resource management response strategies are needed to facilitate effective landscape recovery.
- Global warming is predicted to increase the intensities of tropical cyclones by the end of the century, while cyclone frequency is predicted to remain unchanged. Increases in cyclone intensity in the future, even with cyclone frequency remaining stable, may lead to shifts in forest succession direction, higher rates of species turnover, and hence opportunities for species change in tropical forests. Such changes will be in concert with other ecological and

physiological effects of global warming on forest biota and ecosystem function.

Appendix

(Photo credits: FNQ NRM Ltd)

1) Landscape connectivity. Cassowaries, Mahogany Gliders and tree kangaroos are examples of iconic species in the Wet Tropics. The rainforests of the coastal plain and tablelands are critical habitats to them and many other rare and/ or regionally endemic species. These forests are already fragmented and fragments in particular were badly damaged by Larry. While areas of forest with a critical mass will recover well, a lack of effective corridors meant these rare animals had fewer recovery options.



2) River repair. Healthy rivers and streams in the Wet Tropics reduce erosion and crop damage on-farm and contribute to the health of the Great Barrier Reef. One way to achieve this is through restoring healthy native vegetation along the region's rivers. Thin riparian vegetation was prone to serious degradation by Larry, exacerbating water quality and erosion risks in post cyclonic flooding.



3) Protecting coastal assets. The region's unique coastal zone provide a significant natural buffer to cyclonic and storm surge events. Additionally, increasing urban development in recent years has boxed coastal ecosystems between the sea and urban landscapes, leaving these ecosystems very much at risk in the even of storm surges. Despite this, there is still inadequate effort going towards coastal protection.



4) Cyclone resilient farms. The adoption of sound management practices on farm (eg grassed inter-rows in Banana plantations) and grants to landholders enable significant land repair and critical on-farm changes. This will ensure greater resilience against future climatic threats.



5) Education for the future. Community resilience comes from community knowledge of how to manage for a cyclone resilient landscape. Investing in education is about making an investment in the capacity of future generations to sustainability manage the region's natural resources.

6) Avoiding climate change. Climate change scenarios suggest an increasing frequency of high intensity cyclones in Far North Queensland. This means the region has to play its part in reducing Greenhouse gas emissions.