FINAL REPORT

MISSION BEACH ROAD RESEARCH: TRAFFIC IMPACTS ON CASSOWARIES AND OTHER FAUNA AND STRATEGIES FOR MITIGATION

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AUSTRALIA

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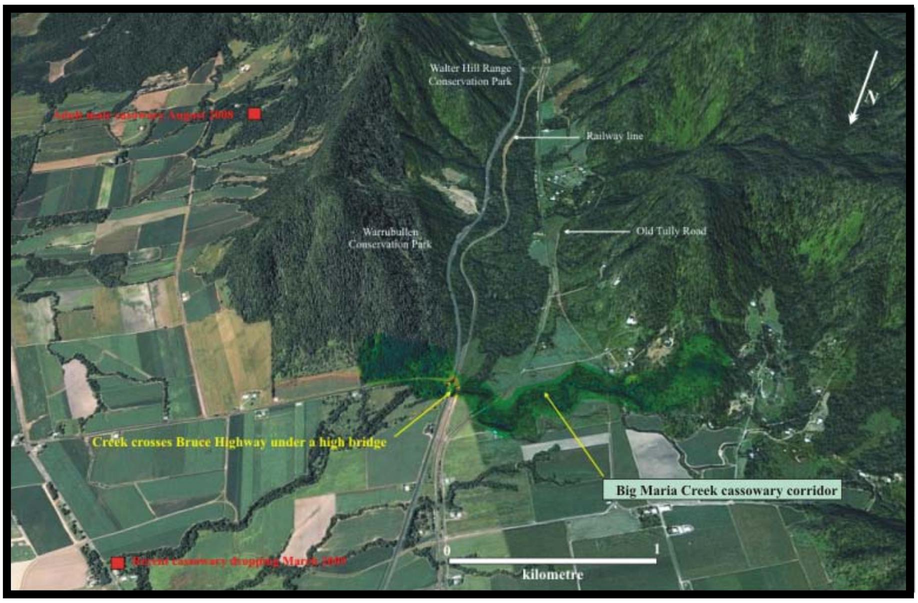

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EXECUTIVE SUMMARY

SECTION 1: ECOLOGICAL IMPACTS OF ROADS ON TROPICAL FORESTS AND HOW THEY AFFECT THE MAJOR ROADS ENTERING MISSION BEACH – LITERATURE REVIEW

Research objectives

This review of scientific literature identified known ecological impacts of roads.
We then applied these to the situation at Mission Beach, in particular the two roads that carry traffic to and from the village.

Significant Findings

Ecological impacts of roads include:

- Habitat loss due to clearing for the road:
  Along the rainforest sections of the El Arish - Mission Beach road about 14.3 ha has been lost whereas 38.1 ha have been lost along the Tully-Mission Beach Road, due its very wide road verges. If road verges were only 4 m wide on either side of the road, habitat lost would reduce to only 8.8 and 18.7 ha respectively.

- Edge effects – alterations to microclimate, vegetation and fauna at the forest edge adjacent to the road clearing:
  Along the rainforest sections of the El Arish - Mission Beach road about 52 ha of forest with changed microclimate and 104 ha with altered vegetation structure and faunal composition. Along forested sections of the Tully – Mission Beach Road the area affected would be in the vicinity of 114 or 228 ha for microclimate and vegetation/fauna edge effects respectively. The distance that edge effects penetrate is increased by wide clearings.

- Disturbance – traffic using roads emit pollutants, noise and light which penetrate the forest and/or are washed into streams:
  Pollutants from road runoff can be detected at river estuaries.
  Noise and headlights penetrate into the forest more than 200 m and at least 50 m respectively. In the forested sections of Mission Beach, the area noise-affected along the El Arish – Mission Beach Road is >208 ha, and noise affected areas along the Tully – Mission Beach Road comprise >456 ha.
  Cassowaries communicate at the very low frequencies that could be masked by traffic noise because traffic noise includes a very high level of low frequency noise. This would be particularly severe at the edge of roads, and could affect parents communicating with chicks. Because low frequency noise penetrates much greater distances than higher frequencies, traffic noise could affect communications between widely-spaced cassowaries deep inside the forest..

- Invasions by weeds, diseases and alien fauna:
  Roads facilitate invasions by the movement of vehicles carrying seeds or diseases and by the clearing and extra light that encourages growth of weeds and movements of non-rainforest fauna and pests.

- Roads can become barriers to movements of specialised rainforest species:
  This fragmentation can potentially causing population division and isolation in severe cases, with chances of local extinctions. Cassowaries do not appear to be affected but many rainforest species at Mission Beach could be.

- Road mortality:
  Many tropical forest species are vulnerable, particularly mobile species with large home ranges such as the cassowary, but also small slow-moving species, species that undertake mass movements, those that fly close to the ground, scavengers, roadside foragers and animals that get dazzled by headlights.
  Mortality is exacerbated by high vehicle speeds and traffic volumes while road features often determine where road kill 'hotspots' occur. If a large proportion of a species' population is killed, roads could cause problems for that local population.

Recommendations

- Existing wide traffic verges along the Mission Beach entry roads should be revegetated to reduce habitat loss, edge effects, invasions by weeds and pests and barrier effects for susceptible fauna.
- Studies should examine the effect of traffic-noise on cassowaries
- Reductions in traffic speed could reduce road mortality

Management Implications

- Maintenance of road verges should consider the additional habitat loss, edge effects, weed and feral animal invasions and barrier effects caused by wide cleared road verges.
- Increasing road design speed and speed limits can have impacts on fauna. Policies that allow lower design speeds and reduced speed limits on main roads through environmentally sensitive areas should be implemented.

Further research

- The impacts of traffic noise at low frequencies and infrasound and vibrations on cassowaries requires research.

SECTION 2: ROAD IMPACTS ON CASSOWARIES

Research objectives

This section of the project was designed to:

- Identify the active cassowary road crossing areas on the El Arish-Mission Beach Road, Bingil Bay Road, Cassowary Drive, Tully-Mission Beach Road and South Mission Beach Road;
- Establish usage patterns of these cassowary crossings on a daily, seasonal and annual basis;
- Determine the frequency of use and demographics at each crossing area i.e., proportional use by adults, family parties and subadults;
- Estimate risk levels and contributing factors associated with each crossing point;
- Establish the frequency of cassowary road crossings at Smiths Gap to determine its potential to effectively connect the Mission Beach cassowary population and the Wet Tropics World Heritage Area cassowary population west of the Bruce Highway;
- Identify and track individual cassowaries using crossings and establish bird profiles.

Significant Findings

- Road mortality is the greatest cause of known cassowary deaths at Mission Beach - 89.4% of deaths in the DERM database since 1992 are due to vehicle collisions. Since March 2007, 13 deaths were recorded in database with 63% being caused by vehicles, while in 12 months after Cyclone Larry, 82% were from roadkill..
- Tully Vet data shows a lesser proportion of deaths related to roadkill (54%), probably because many road mortality victims did not make it to veterinary care. However, most road victims referred to the vet died (78%). Disease and illness also caused a high proportion of deaths (23%). Dog attacks were more common in the past (18% of deaths recorded at Tully Vet between 1986 and 2004) but more recently the DERM database shows this cause of death only from other areas, and the Tully Vet lists only two victims.
- From 1992 till June 2010, of the 60 cassowary deaths at Mission Beach recorded in the DERM database that were definitely attributable to road mortality , 38% occurred on the Tully-Mission Beach Road, 27% on the El Arish-Mission Beach Road, 13% on Cassowary Drive and 18% on the South Mission Beach Road or Wheatley Road.
- As not all cassowary deaths are reported, these numbers represent the minimum road toll. For example, of seven cassowaries monitored in this study for 6 months at least two were killed on the road.
- Deaths occur almost throughout the forested sections of the higher speed roads.
- The DERM database shows several areas of very high cassowary mortality. These include the Lindsay Road/Carmoo area on the Tully-Mission Beach Road, the area on the South Mission Beach Road near Wheatley Road and Frogs Hollow, and the area between the Bingil Bay turnoff and Mountain View Close on the El Arish-Mission Beach Road. Altogether there are 28 areas where mortality has been recorded.
- From searches adjacent to the road, C4 cassowary sighting sheets, and prior knowledge, 80 individual cassowary road crossings were located in the Mission Beach study area. Other crossings undoubtedly exist on the study roads and on unsurveyed local roads in urban areas. Of the crossings marked, 60 were active and used by cassowaries during the 12 months of the project and 20 were past crossings that did not appear to be in use, but may still be active.
- The two major access roads of El Arish to Mission Beach and Tully to Mission Beach contain approximately 44% of total identified road crossings (35/80).
- Studies over more than a decade indicate that cassowaries tend to use the same crossing zones – many crossing zones reported in 1992, 1998, and from 1999 to 2007 are still in use. However, other sites can also be used.
- A total of 2400 cassowary road crossings were recorded by visitors filling out C4 sighting sheets from 1997 to 2008. As birds frequently cross outside the sight of visitors, this figure represents the minimum number of road crossings made by cassowaries in the 12 year period.
- Around 6-8 crossings per 1000 visitors were recorded per year, but this dropped significantly after Cyclone Larry in March 2006.
- During the year, crossings are more common in February and to a lesser extent January and March, than the other months. Crossing observations are evenly distributed throughout the day, other than very early morning and late afternoon, with no crossing recorded during hours of darkness. Adults cross most frequently (61% of crossings), while family parties (28%) and subadults (11%) are also often observed.

- In sixty-one cassowary road crossings observed along the El Arish to Mission Beach Road: 41 walked across after standing by the roadside or within the vegetation line; 5 stood by the roadside until a break in traffic then crossed; 3 ran across in front of approaching cars; 5 were sighted in the middle of the road in the act of crossing; 7 stood by the roadside but moved back into the forest without crossing. The mean length of time to cross the road was 13.5 seconds, but varied with behaviour.
- Constant vehicle noise did not appear to upset crossing cassowaries. However sudden noises such as bangs from trucks or trailers frightened birds. Their reactions were unpredictable varying from running across the road in front of the vehicle or retreating into the forest. Some birds were habituated to roads and calmly attempted to cross between passing vehicles, obscuring them from the sight of following drivers or those approaching from the other direction.
- Simplified crossing scenarios suggest that at current traffic flow levels, birds attempting to cross are 60% more likely to suffer vehicle collisions on the Tully-Mission Beach Road than on the El Arish-Mission Beach Road due to greater traffic volume. Higher speeds observed on this road in these simplified model scenarios, suggest that increasing speed from 60 – 80 kph might increase the likelihood of collisions by up to 50% with speeds of 100 kph possibly doubling the likelihood of collision.
- Calculations of time taken to traverse forested areas of the main entry roads to Mission Beach show that decreasing speeds from an average of 90 km/h to 60 km/h in forested areas would
  a) add 1.6 minutes to the journey between El Arish and Mission Beach: and
  b) add 2.8 minutes to the journey between Tully and Mission Beach.
- Several major crossing zones on the main Mission Beach roads were identified and compared in terms of types and numbers of cassowaries crossing in each zone, where they cross and crossing seasonality. These comprise:

  a) El Arish to Mission Beach Road in the vicinity of Lacey Creek
  b) Fenby Gap
  c) Cassowary Drive (Tully-MB Rd in vicinity of Wongaling)
  d) South Mission Beach Road
  e) Tully-Mission Beach Road in the vicinity of Licuala
  f) Tully-Mission Beach Road in the vicinity of Sugarcane Creek and Lindsay Road.
- The greatest numbers of crossings were observed by visitors at Lacey Creek, followed by Licuala and Sugarcane Creek. Crossings at Sugarcane Creek and Licuala comprised the greatest numbers of family parties, with implications for recruitment of birds into the population.
- Significantly fewer cassowaries crossed the Mission Beach roads after Cyclone Larry compared with numbers before the cyclone. This decrease may be due to behavioural changes in the cassowary population resulting in fewer road crossings (e.g., siting of feed stations away from the roads until forest fruiting recommenced). However, the continued decrease in numbers through 2008/09 suggests that the cassowary population near roads decreased significantly following the 2006 cyclone. Similarly family parties and subadults were sighted significantly less frequently after the cyclone. The impacts of Cyclone Yasi on crossings by cassowaries remains to be seen. .

Management Implications

- The high proportion of cassowary mortality attributable to vehicle strike emphasises the urgent requirement to institute cassowary road mortality mitigations in the area.
- Both higher speeds and greater traffic volumes are likely to increase cassowary mortality. Reducing speed by 20 kph may have a large effect on mortality by increasing the time that drivers and birds have to react to each other.
- Reducing speed in forested areas would only add 2-3 minutes to most trips between Mission Beach and the highway.
- High number of crossings recorded in the C4 cassowary crossing database often occur at the areas with greatest records of deaths, but this is not always the case.
- In some areas, either high mortality levels or high number of observed crossings or both provide areas where implementation of road mitigation strategies should be attempted.
- The area with greatest mortality and many crossings occurs on the high speed Tully-Mission Beach Road and two other high mortality area with many crossings occur on high speed section of the El Arish-Mission Beach Road and the South Mission Beach Road.
- Damage from Cyclone Larry appeared to have a significant impact on the population of cassowaries that cross the roads.
- It appears unlikely that the road toll on what is believed to be a relatively small population is sustainable, especially when other factors including cyclone damage to habitat and foraging resources are taken into account.
- Unpredictability of behaviour and slow crossing times increase vulnerability of cassowaries when crossing roads.

Further research

- Comparison of the 60-80 areas that cassowaries often cross with those 28 area where they suffer mortality is an important next step in order to determine factors of road design that may assist in safe crossing as well as factors that increase vulnerability. Data have been collected and databased to continue this examination.
- Results from genetic studies that provide further information about the size of the population at Mission Beach is desperately needed.

SECTION 3: ROAD MORTALITY OF OTHER VERTEBRATES AND USE OF POTENTIAL UNDERPASSES

Research Objectives

The objectives of this section of the project were to:

- Examine road mortality of fauna on four 0.5 km transects chosen along El Arish – Mission Beach Road and Tully Mission Beach Road between April and July 2008.
- Monitor faunal use of three potential underpasses at Hull River bridge, Laceys Creek culvert and Stony Creek retrofitted culvert using sand tracks, assisted by camera traps when available.

Significant Findings

- Mean road mortality was 81.8 specimens per kilometre per day, with Cane Toads (*Bufo marinus,* 458) being most common. A variety of invertebrates, particularly insects, were also recorded (14 orders). Native vertebrates were much less common as roadkill statistics, with White-lipped Tree Frog (*Litoria infrafrenata*, 10), Dainty Green Tree Frog (*Litoria gracilenta,* 8), Long-nosed Bandicoot (*Perameles nasuta*, 4) and a skink (*Carlia rubrigularis*, 4) recorded most often.
- We found ten species of amphibian, five reptile species, three species of birds and five species of mammal that could be identified to species.
- Cassowary fencing, road marking, rumble strips and warning signage had no effect on vertebrate road mortality, with the highest toll occurring near a cassowary awareness sign.
- Transect location was an important factor, with significantly less roadkill occurring on the 500 metre transect west of the Bean Tree Track (the walking track from the El Arish – Mission Beach road through to the Licuala day use area) than the 500 metres in the vicinity of Lacey's Creek, although both occur on the El Arish – Mission Beach Road. Tully – Mission Beach Road transects had intermediate levels of road mortality and were similar in numbers. Although data were insufficient to analyse road microtopographic and habitat information with respect to mortality, it appeared that greater roadkill rates occurred near creeks.
- Long-nosed Bandicoots were the most frequent users of the underpasses as determined by sand tracks and scats (36). Eighty-four tracks and signs were recorded during the four month intensive data collection. Other vertebrates included Cape York and/or Bush Rat (13), Water Rat (11), Southern Cassowary (6), Cane Toad (3), Fawn-footed Melomys (2), Red-legged Pademelon (1) and Giant White-tailed Rat (1).
- The majority of these tracks were found under the North Hull River bridge (63) and this was the only place that Southern Cassowary tracks were observed. No Southern Cassowary tracks or traces were observed in either of the culverts at Lacey's Creek or Stoney Creek.

Management Implications

- It appears unlikely that culvert-type underpasses will be used to any great extent by Cassowaries.
- Rather, the large bridge-style underpasses such as at the North Hull River provide opportunities for Cassowary utilisation.

Recommendations

- We recommend that alternative means of road mortality mitigation be trialled, and especially legislated speed limit reduction in forested areas.
- We also suggest that the Stoney Creek retrofitted underpass and accompanying Cassowary fencing could be upgraded to encourage more faunal usage of the underpass. Similar inclusions of cover, ensuring that vegetation reaches underpass entrances and provision of dry passage could be included at Laceys Creek.

Further research

- Further research is required to examine the efficacy of all mitigation measures that are implemented in the Mission Beach region.

SECTION 4: TRAFFIC LEVELS AND SPEEDS ON TULLY-MISSION BEACH AND EL ARISH-MISSION BEACH ROADS

Research Objectives

This study aimed to determine the defining characteristics and patterns of traffic volume and speed along two roads leading to Mission Beach, one from El Arish in the north (EAMB Rd) and the other from Tully (TMB Rd) in the south.

Significant Findings

- We placed traffic counters at three sites on each road, all in important cassowary habitat, and with different types of psychological traffic calming. We recorded vehicle characteristics and speed over a four year period..
- Results showed that both traffic volume and speed were greater on the Tully Mission Beach Road (TMB Rd: mean numbers = 2177 vehicles/day, mean car speed = 85.2 km/h; EAMB Rd: 1214 vehicles/day, 78.7 km/h).
- Annual patterns of traffic flow coincided with the seasons, with peak numbers on the road during the dry tourist season (June-October) and less traffic during the wet season (December-April).
- Highest traffic volumes occurred on weekdays, with Friday consistently the busiest day and Sunday the least busy.
- Daily patterns occurred with directional variability in traffic volume, reflecting the movement of workers and students to and from Mission Beach in the morning and afternoon.
- Speeds were generally greater on weekdays than weekends.
- Vehicle speeds were highest during early morning (0000 hrs - 0700 hrs) and lowest during later daylight hours when traffic volume was greatest and police presence increased.
- Average monthly speeds along the Tully Mission Beach Road generally exceeded the speed limit of 80 km/h (car 83.8-87.6 km/h, buses and medium-sized trucks 86.7-89.7 km/h.
- Speeds along the Tully-Mission Beach Road were consistently greater than along the El Arish-Mission Beach Road (cars 77.1-82.4 km/h, buses and medium-sized trucks 77.8-83.5 km/h).
- Maximum speeds on both roads exceeded the 80 km/h limit by up to 120 km/h (EAMB Rd cars 180 km/h, buses and medium-sized trucks 164.5 km/h; TMB Rd: cars 199.6 km/h, buses and medium-sized trucks 199.8km/h).
- Psychological traffic calming along the Tully Mission Beach Road, in the form of lines painted to create an appearance of a narrower carriageway at Stoney Creek and lines perpendicular to the road at Hull River, appear to have little effect on traffic speeds, as speeds were greatest at Hull River.
- At Lacey's Creek there is a reduction in speeds to an average of 73.7 km/h, but it is difficult to assess whether this is due to the rumble strips installed on either approach or to the winding nature of the road in that area. The large cassowary road accident signs in the vicinity may also have some small effect, in that tourists often slow to take photographs. Similarly vehicles move slowly when entering or leaving the car park at Lacey's Creek and these could also affect the average traffic speeds in the vicinity

Management Implications

- Average traffic speeds on the Tully-Mission Beach Road are always greater than the 80 kph legislated speed limit, with buses and truck travelling faster than cars.
- Maximum speeds are far in excess of this.
- These speeds place cassowaries that attempt to cross at greater risk on the Tully-Mission Beach Road.
- Average speeds on the El Arish-Mission Beach Road are in excess of the 80 kph speed limit both near Mountain View Close and near the Clump Mountain Cooperative. These are two areas of high cassowary mortality.
- Psychological traffic calming trials using rumble strips and various types of road painting appear to have had little effect on the Tully-Mission Beach Road,
- The Lacey Creek area experiences lower speeds. However a variety of causes may be involved, rather than the rumble strips and road shoulder painting.

Recommendations

- We recommend that psychological traffic calming not be considered for further implementation at Mission Beach unless it is combined with constructed traffic calming measures such as speed humps, chicanes and roundabouts. These are mitigation measures that are more likely to succeed.
- We recommend reducing the speed limit on these two entry roads to Mission Beach to 60 kph in forested sections, together with enforcement in the form of vehicle-based speed cameras, speed camera installations with cameras that can be moved between sites, and/or signs that alert the driver (and potentially the enforcer) when speed limit is exceeded.

Further research

- Vehicular speeds should be monitored for any form of traffic calming and speed limit reduction along the Mission Beach Roads to determine effectiveness of these measures.

SECTION 5: REVIEW OF POTENTIAL OPTIONS FOR MITIGATION OF ROAD MORTALITY IMPACTS ON LARGE FAUNA INCLUDING CASSOWARIES

Research Objectives

We reviewed research undertaken on the many types of mitigation strategies used to ameliorate road mortality and fragmentation worldwide, concentrating on those installed for large fauna. We considered their application to road management for increasing habitat connectivity and reducing road mortality for cassowaries.

Significant Findings

- The first principle of mitigating the impacts of roads on wildlife is to avoid the impact by routing new roads and road upgrades to avoid sensitive habitats. For existing roads that pass through protected areas this is generally not possible.

- Other mitigation approaches aim either to change driver behaviour or to attempt to change the behaviour of the target species or species group.
- The speed travelled by a vehicle has a large effect on road deaths and the severity of injury to both driver and wildlife, as slower speeds have shorter stopping distances and provide greater time for both driver and animals to respond and attempt to avoid the collision. Slower speeds also result in less severe injuries should a collision occur. Therefore reduction in vehicle speed is a primary aim of many types of road mortality mitigation strategies. In Queensland most crashes involving animals occur in high speed (≥100kph) zones.
- Reducing the legislated speed limit is one potential measure to mitigate road impacts.
- However, simply reducing the limit generally does not produce the desired effect if the road design speed remains unchanged. The road design speed is the speed environment for which the road was designed and is increased by factors such as wider lanes and road shoulders, wider roadside clearings, fewer curves and dips and overall greater driver visibility. Unless speed limit is continuously enforced, drivers tend to maintain higher speeds because of the perception that it is safe to do so.
- To reduce actual speeds, a variety of road features and traffic calming mitigations can be implemented. These include reducing lane width and sight distances, and incorporating in-road structures including speed humps, chicanes and roundabouts.
- A variety of psychological traffic calming methods have also been trialled, some on the Mission Beach roads, but have proved ineffective. These include painting road shoulders in various ways, painting stripes across the road and rumble strips.
- In contrast, in-road traffic calming structures including speed humps appear very successful in limiting speeds on Council-controlled roads in the Daintree Lowlands. Roundabouts, chicanes, and curved, divided roads with planting to limit sight distances are also successful in reducing speeds in urban areas and on highways in the Cairns region.
- Roadside wildlife warning signs are a very common mitigation measure. Evidence shows that passive signs in a fixed location with a static message do not have any effect on traffic speeds due to driver habituation. Signs such as these are most useful in public education rather than reducing mortality.
- More unusual permanent signs such as those showing cassowary collisions possibly have more effect, particularly for visitors to an area who are not habituated to them.
- Signs with active messages are more noticeable due to flashing lights or variable messages. If they are used only when animals are likely to be on the road, such as migration times, speeds can be reduced by 5 – 10 kph in comparison with standard warning signs which have little effect.
- Recent innovations include permanently visible signs that are blank until activated by a speeding vehicle, when they show drivers their speed, and potentially can also provide automated information for enforcement.
- Speed cameras are another device which may assist in enforcing speed limits.
- Temporary warning signs tend to be more effective than standard signs by providing a more specific warning signal to a driver. The temporary cassowary crossing signs erected for short periods of time at Mission Beach locations where a bird has recently crossed fall into this category although there has been no monitoring of effectiveness in reducing driver speed.
- Animal detection systems are activated only when large animals are near the road. These sensor-driven systems can be very effective in reducing driver speeds and

road mortality, with reductions of 82 and 91% in animal collisions recorded. However, these work most effectively with herding species that migrate, using a specific route. Solitary animals such as cassowaries that can cross in a wide range of locations are unlikely to be successfully protected by such a mechanism. They are also subject to reliability issues in extremes of humidity, heat, rain and wet or moving vegetation.

- Wide road clearings free of vegetation are often implemented with the aim of providing greater visibility and therefore longer times for drivers to respond if an animal attempts to cross. However, this also encourages faster speeds which tend to negate any advantage from increased visibility. Speeds are higher on Mission Beach roads with wider clearings. Wider road clearings also cause greater loss of cassowary habitat and potentially longer periods of stress when crossing exposed areas away from habitat cover.
- Successful road mortality mitigation for large animals in other parts of the world is achieved using large underpasses such as viaducts and high bridges. Large overpasses are similarly successful. Design of the structure including furnishings needs to be targeted to the species of concern. Structures are teamed with exclusion fencing to prevent animals crossing in other areas and to direct them to the crossing structures.
- High bridges with vegetation underneath have also proven successful for cassowaries. However cassowaries will still cross the road surface not far from these large structures. Smaller structures such as box culverts have proved ineffective, with regular monitoring not recording use. However, in the past decade there are at least 3 records in the Wet Tropics of a cassowary or a family party using a culvert in the Wet Tropics.
- Exclusion fencing designed to guide animals to crossing structures poses a number of serious issues for cassowaries, although successful for large mammals. Fences must include escape routes to allow animals trapped between the fence and the road to escape back into habitat on the other side of the fence. Certainly wire mesh fences should not be considered when dealing with cassowaries, due to danger of injury to the birds. Shadecloth fencing has yet to be satisfactorily tested due to faults in design implementation and difficulties in monitoring.

Recommendations

- Designs for crossing structures and fencing for cassowaries should be incorporated on Mission Beach Roads and monitored systematically. During road upgrades, high bridges or overpass structures should be seriously considered for crossing and/or mortality hotspots and connectivity bottlenecks, such as larger stream crossings and the Bruce Highway at Smith's Gap.
- Other measures that warrant consideration, trials and implementation include roundabouts, chicanes, speed humps, and revegetation of wide road clearings with low growing vegetation to reduce the design speed of roads.
- These design speed measures should be teemed with reduced legislative speed limits, and enforcement with permanent speed monitoring equipment.
- All measures need to be monitored to determine effectiveness. The community can assist with this to reduce monitoring programme costs.
- Public education programmes and temporary sign placements are continuing measures that can assist in raising awareness of cassowary mortality issues.

SECTION 6: ROAD SECTIONS, CONNECTIVITY, CROSSINGS AND MITIGATION OPTIONS

Research Objectives

This section summarises the major road sections, general road crossing hotspots and potential mitigation measures that could be used at each site using tables which address each of the nine major road sections.

Significant Findings

- In many cases, application of mitigation measures to the complete road section may be the most appropriate approach, particularly in areas where road mortality is high, numbers of crossings are also high, and birds tend to cross in many areas or anywhere along the road segment. These include the major rainforested sections of the El Arish-Mission Beach Road, Tully-Mission Beach Road and South Mission Beach Road, together with Garners Beach Road.
- However, in these tables we also provide information about individual crossing zones, noting that in several road sections these are not discrete entities.
- Brief comments on each crossing area are provided including identified threats and a range of mitigation techniques which may be appropriate at that site. Current risks were identified by personal observation (L. Moore). Information from the EPA Cassowary Road Mortality database and the C4 Cassowary Sightings database has been incorporated where appropriate.

Recommendations

- A risk-based and ecological benefit analysis should be undertaken to determine the highest priority crossing zones and the most effective techniques to employ over particular road sections or individual road crossing zones. It is essential that consultation with all relevant stakeholders should form part of this assessment, including QTMR, CCRC, DIP, WTMA, EPA, SEWPAC, JCU, Terrain NRM, CSIRO, Traditional Owners, C4 and the local community.

SECTION 7: SYNTHESIS – TOWARDS AN INTEGRATED STRATEGY FOR ROAD MANAGEMENT, MISSION BEACH REGION

Research Objectives

Here we synthesise the results of the road research and reviews of mitigation options, including policy level and landscape level and provide examples of alternatives for individual cassowary crossing and road mortality hotspots.

Significant Findings

- At the level of government policy, measures of regulatory provisions and policies implemented to protect koala habitat and reduce road mortality offer great potential. The Queensland Biodiversity Strategy should reinforce this as it provides for iconic species and uses the cassowary as an example.

- QTMR Manual for uniform traffic control devices and advice from QTMR personnel show that there is potential for reducing road speed environments in ecologically sensitive areas.
- Landscape level needs to improve connectivity across the Bruce Highway and the major Mission Beach entry roads were considered including improving vegetation along Maria Creek and increasing potential crossing structures at Smiths Gap.
- Landscape level mitigations also include the need to reduce vehicle speeds on all the major Mission Beach Roads. Potential means of achieving this described.
- Several examples of sites where mitigations are of high priority are described in greater detail e.g. Carmoo/Lindsay Creek area; El Arish Mission Beach Road between Bingil Bay turnoff and Mountain View Close; South Mission Beach Road and Wheatley Road area.

Recommendations

- All measures need to be integrated to avoid overload of particular measures and driver habituation. The best way to achieve an integrated strategy for road management in the Mission Beach region is through consensus obtained between stakeholders in a series of workshops that discuss these mitigatory measures.

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Miriam Goosem

AGREEMENT BETWEEN TERRAIN NRM AND JAMES COOK UNIVERSITY FOR: MISSION BEACH CASSOWARY ROAD MANAGEMENT STUDY

General aims and methodology

1. PROJECT AIMS:

The primary aims of the Mission Beach Cassowary Road Management Study include:

Based on knowledge of cassowary road use at Mission Beach:

1. Devise a strategy to minimise cassowary road death;
2. Incorporate in this strategy methods to improve habitat connectivity throughout the Mission Beach area;
3. Consult with the Mission Beach Habitat Network Action Plan Committee to ensure integration of the findings of this study into an integrated road strategy, i.e. MBHNAP traffic strategy.
4. To investigate the cassowary population in the area of Smiths Gap (including the Bruce Highway and adjacent railway line) to:
    1. Monitor the use of the area by cassowaries and locate current crossing points;
    2. Establish which of the current crossing points provide the best site for a permanent safe crossing point;
    3. Evaluate the contribution such a connection would make to the viability of the Mission Beach cassowary population;
    4. Advise methods and strategies to facilitate this connectivity.

The objectives of the study include :

1. To locate all active cassowary road crossing areas on the El Arish-Mission Beach Road, Cassowary Drive (Wongaling Section), Tully-Mission Beach Road and South Mission Beach Road, Bingil Bay Road and compare with previous data.
2. To investigate crossings in the Smith's Gap area.
3. To identify birds that are using these crossings as far as possible.
4. To create a set of identikit profiles of these birds.
5. To examine temporal usage patterns of road crossings.
6. To examine seasonal changes in demographics at crossing points.
7. To systematically collect cassowary droppings at each active crossing point for future DNA analysis and disease load studies.
8. To examine risk factors associated with crossing points and any crossing points receiving multiple usage.

2. INTRODUCTION

Populations of the endangered cassowary, *Casuarius casuarius johnsoni* (EPBC 1999) appear to be declining from the Wet Tropics coastal areas south of Cairns. There are a number of factors implicated in this apparent decline but a major contributor is the high level of cassowary road death. Continuing residential development, rapidly expanding tourist activity, and the associated upgrading of the coastal road system will undoubtedly see a concomitant increase in cassowary road deaths. Pre-Cyclone Larry studies established that 33 adult birds i.e. 67% of the total known adult population of Mission Beach crossed the El Arish-Mission Beach and Tully-Mission Beach Roads (Moore 1998, 2000, 2001, 2003, 2005a, 2005b, 2007a, 2007b, 2007c, 2007d). Most made use of more than one crossing point. As a result, road death is the greatest cause of cassowary mortality at Mission Beach, and responsible for approximately 70% of all cassowary deaths since 1989.

Moreover, traffic flow along some of the Mission Beach roads is increasing at a fast rate, particularly traffic flow between the townships and towards Tully. For example, in 1998, GHD measured the existing traffic volume on the El Arish – Mission Beach road at 1450 vehicles per day (vpd, in both directions), with a predicted traffic flow of 2400 vpd in 2017 (i.e. 20 years hence). Between November 2005 and December 2006 traffic flow at Lacey's Creek on the El Arish-Mission Beach Road ranged between 1000 and 1500 vpd, peaking in October and lowest around 1000 between November and March (pers. obs.). In 2005, QDMR measured average daily traffic volume on the El Arish-Mission Beach Road 200m west of the Tully-Mission Beach Road turnoff at 1060 vpd, increasing to 1150 vpd in 2006. In comparsion 200m east of the same turnoff, the average Mission Beach township traffic volume was 3140 vpd in 2005, increasing to 3470 in 2006 (QDMR 2005, 2006). The average annual daily traffic flow (AADT) on the Tully-Mission Beach Road near the boundary of Johnstone and Cardwell Shires increased suddenly from 3135 vpd in 2000 and 3072 in 2002, to 3502 in 2003, 3727 in 2004, 3429 in 2005 and 3600 vpd in 2006 (QDMR 2007). Further towards Tully at Licuala National Park, average daily traffic volume increased suddenly from 1636 in 2000 to 1847 in 2001, 1803 in 2002, 1853 in 2003, 1845 in 2004 and 1865 in 2005 and jumped again to 1912 in 2006 (QDMR 2007). The additional traffic flow generated by residential subdivisions, resort developments and increased tourism has apparently increased what is already an unsustainable level of cassowary road death at Mission Beach (Moore 2003, Moore 2007, Moore and Moore 2008).

The following excerpt from a recent study (Moore and Moore 2008a) indicates the severity of this decline and the negative prognosis for the species in this region unless management initiatives, based on research, are implemented.
"At Mission Beach, Cyclone Larry caused the death of at least 18% of the adult and subadult population. Approximately 70% of confirmed deaths post-cyclone were from vehicle strike and 22% from dog attack. It also concluded that the coastal subpopulations are in deterministic decline and that this decline will intensify as individual subpopulations decrease." (Moore and Moore 2008).

3. STUDY AREA and METHODOLOGY

The primary study area for the Mission Beach project is shown on Figure 1 and includes the following major access roads:

1. El Arish – Mission Beach Road
2. Tully – Mission Beach Road
3. Bingil Bay Road
4. South Mission Beach Road
5. Smiths Gap

General Field Methodology

1. Locate and evaluate status of previous crossing points and use field survey along forest edges on both sides of the road to a maximum distance of 100m to investigate new crossing areas. Input into GIS database.
2. Systematic observations will be conducted at all active crossing points using telescopes and still and video photography where possible. Observations will include different periods of the day at each crossing point and cassowary behaviour during crossing events will be described.
3. Crossing points will be observed in both wet and dry seasons, where possible.
4. Systematically collect cassowary droppings from each crossing point for future DNA and disease load analysis.

5. Where possible, identikits/profiles will be prepared for individual birds.
6. Data regarding birds and crossing points will be analysed for diurnal and seasonal patterns, as well as spatial patterns in terms of multiple use of crossing points and where alternatives may be available for individual birds, allowing categorisation of importance of each crossing point.
7. Analyse risk factors associated with each crossing point and bird behaviour patterns.

ACRONYMS

C4	Community for Coastal and Cassowary Conservation
CCRC	Cassowary Coast Regional Council
DERM	Queensland Department of Environment and Resource Management
EPA	Queensland Environment Protection Agency (now part of DERM)
JCU	James Cook University
MBHAN	Mission Beach Habitat Action Network
MBHANP	Mission Beach Habitat Action Network Plan
NRM	Natural Resource Management
QPWS	Queensland Parks and Wildlife Service (part of DERM)
QTMR	Queensland Department of Transport and Main Roads
WTMA	Wet Tropics Management Authority
WTWHA	Wet Tropics World Heritage Area

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MISSION BEACH ROAD IMPACTS ON CASSOWARIES AND OTHER VERTEBRATES

SECTION 1:
ECOLOGICAL IMPACTS OF ROADS ON TROPICAL FORESTS AND HOW THEY AFFECT THE MAJOR ROADS ENTERING MISSION BEACH
– LITERATURE REVIEW

1. ECOLOGICAL EFFECTS OF ROADS ON TROPICAL FORESTS AND HOW THEY AFFECT THE MAJOR ROADS ENTERING MISSION BEACH – LITERATURE REVIEW

Miriam Goosem

Summary.

Roads and highways traversing tropical forests fragment these forests, causing a variety of insidious impacts within the surrounding forest habitats. Tropical rainforest biota are often especially vulnerable to fragmentation by roads due to their specialisations in terms of habitat and behaviour. The Mission Beach region suffers a raft of impacts, the most well-known being the toll of cassowaries through collisions with vehicles.

Ecological impacts of roads include:

a) Habitat loss due to clearing for the road
In the forested sections of the Mission Beach entry roads this comprises approximately 14.3 ha along the El Arish-Mission Beach Road and 38.1 ha along the Tully-Mission Beach Road, due to the very wide road verges along these roads. If the road verges were only 4 m on either side of the road, the habitat loss to the road would be reduced to only 8.84 and 18.7 ha respectively.

b) Edge effects – alterations to microclimate, vegetation and fauna at the forest edge adjacent to the road clearing.
In the forested sections of the El Arish - Mission Beach entry roads the area of habitat that is edge-affected comprises approximately 52 ha when considering microclimate edge effects penetrating the forest to 50 m or 104 ha when considering vegetation structure and faunal composition changes which can penetrate the forest to 100 m. Along the forested sections of the Tully – Mission Beach Road the area affected would be in the vicinity of 114 or 228 ha for microclimate and vegetation/fauna edge effects respectively. The distance that edge effects penetrate is increased by wide clearings and varies among forest types – edge effects are less prominent in woodlands than rainforest.

c) Disturbance – traffic using roads emit pollutants, noise and light which penetrate the forest and/or are washed into streams.
Pollutants from road runoff can be detected at river estuaries.
Noise and headlights penetrate into the forest more than 200 m and at least 50 m respectively. In the forested sections of Mission Beach, the area noise-affected along the El Arish – Mission Beach Road is >208 ha, and noise affected areas along the Tully – Mission Beach Road comprise >456 ha.
Cassowaries communicate at the very low frequencies that could be masked by traffic noise which also includes a very high level of low frequency noise. This would be particularly severe at the edge of roads, and could affect parents communicating with chicks. Because low frequency noise penetrates much greater distances than higher frequencies, communications between widely-spaced cassowaries could be affected deep inside the forest.

d) Invasions by weeds, diseases and alien fauna
Roads facilitate invasions by movements of vehicles carrying seeds or diseases and by the clearing and extra light that encourages growth of weeds and movements of non-

rainforest fauna and pests.

e) Roads can become barriers to movements of specialised rainforest species
This fragmentation can potentially causing population division and isolation in severe cases, with chances of local extinctions. Cassowaries do not appear to be affected by many rainforest species at Mission Beach could be.

f) Road mortality
Many tropical forest species are vulnerable for a variety of reasons, particularly mobile species with large home ranges such as the cassowary, but also small slow-moving species, species that undertake mass movements, those that fly close to the ground, scavengers, roadside foragers and animals that get dazzled by headlights. Mortality is increased by high vehicle speeds and traffic volumes while road features often determine where road kill 'hotspots' occur. If a large proportion of a species' population is killed, roads could cause problems for that local population.

1.1 BACKGROUND – ROADS AND MISSION BEACH FORESTS

Tropical rain forests have been destroyed or degraded in most parts of the world (Laurance and Goosem 2008). The most common result is a mosaic of forest fragments surrounded by modified habitats such as cattle pastures, agricultural fields or urban areas. Often internal clearings such as those for highways and roads perforate those remaining rain forests and this is the case in the Mission Beach region. This 'internal fragmentation' of remaining continuous and remnant forests can cause a variety of insidious effects within the surrounding rainforest habitat, even when that habitat is protected by conservation tenures (Goosem 2007). The potential for loss of biodiversity caused by this group of impacts should not be underestimated. Therefore the Mission Beach region also suffers 'internal fragmentation' by roads, which cause a raft of impacts, the most well-known being the mortality of cassowaries through vehicle collisions.

Mission Beach is recognised regionally, nationally and globally for its high biodiversity values. These include the largest contiguous stands of lowland rainforest south of the Daintree River, comprising approximately 13% of remaining lowland forests in the Wet Tropics World Heritage Area. The vegetation communities are extremely diverse (Hill *et al.* 2010), with 47 regional ecosystems being found in the area, of which 8 are endangered and 31 are classified as 'of concern' (Chenoweth EPLA 2007). The largest areas remaining of Licuala fan palm forests comprise 50% of the remaining area of that vegetation type and there are wetlands of national and international significance. Roads traverse the majority of these vulnerable ecosystems.

In terms of species, the Mission Beach region contains habitat for at least 5% of all Australian vascular plants, 17% of all Australian mammals and about 36% of all Australian birds in an area approximating 0.005% of the continent (Chenoweth EPLA 2007). Many of these wildlife species are considered threatened under Federal or State legislation. However, one of the major attributes of the region is the dense population of the endangered southern cassowary (Johnstone Shire Council 2004). The cassowary is a unique disperser of some forest tree species and thus integral to their persistence (Westcott *et al.* 2005). The cassowary is considered to be an ecological focal species—protection of the ecological and habitat requirements of which will secure the future of multiple species and communities in the same area (Lambeck 1997; Hill *et al*. 2010).

Additionally, the Mission Beach region forms part of one of the two best east-west corridors in the Wet Tropics bioregion, providing the only wide section of rainforest connectivity south of the Daintree River. This connectivity potentially allows the movement of animals and plant propagules from the coast to the ranges and beyond the ranges connects through to the potential climate change refuges for cool-adapted species in the highlands. Therefore the east-west corridor will become of even greater importance as global temperatures rise. The critical requirement to maintain this connection has been recently recognised by the provision of a Federal “Caring for Country” grant to increase protected connectivity and allow restoration and rehabilitation of degraded areas. Again, roads bisect this potential ‘corridor’, in particular the Bruce Highway as it traverses the rainforested section at ‘Smith’s Gap’ between El Arish and Tully.

The Mission Beach Habitat Network Action Plan (Hill *et al.* 2010) recognises urgent threats to the nationally and internationally significant values of Mission Beach due to pressures of human population growth and coastal development. Over 30% of the original forests and woodlands had been cleared by 2004, particularly in areas which are fertile (for agriculture) or accessible and near the beach (for urban areas). This loss included 30% of rainforests, 50% of woodlands and open forests and 67% of fan palm forests near Stony Creek and the North Hull River (Chenoweth EPLA 2007).Of the remaining forests, 40% are threatened by development and other activities (Williams *et al.* 2009). Scenarios for the future in 2025 were developed by Williams *et al.* (2009). These showed that if current trends in human population and land use change continue unabated, approximately 500 ha of forest would be cleared and another 300 ha of remnant vegetation also converted. These would mostly be coastal forests but also areas in the forested corridor which provides lowland-upland connectivity (Hill et al. 2010).

A variety of threats to the Wet Tropics cassowary population have been recognised in the Cassowary Recovery Plan (Latch 2007). These include habitat loss from clearing; habitat fragmentation that isolates groups and disrupts movements; habitat degradation; threats from roads and traffic through roadkill; dog attacks; hand feeding; diseases; and natural catastrophes such as cyclones. At Mission Beach incremental losses to the already severely fragmented habitat may eventually render the cassowary population unviable (Latch, 2007). Cassowaries are particularly vulnerable to habitat loss and degradation because they naturally exist at relatively low population densities and require large areas to survive. They also have long life spans, reproduce slowly and the majority of juveniles do not survive (Hill *et al.* 2010). Clearing and fragmentation, including internal fragmentation of continuous forests by roads, reduces the small, remaining areas of habitat. Clearing and fragmentation also disrupts local movements by individuals, potentially dividing feeding and breeding sections of cassowary home ranges, and therefore increasing the probability of genetic isolation and local extinctions. Local extinctions are much more likely to occur in small populations because low numbers reduce the potential to breed and increase the likelihood of all individuals dying during catastrophic events. The threat of road mortality is believed to be one of the major factors threatening the Mission Beach cassowary population (Kofron and Chapman 2006; Moore 2007).

1.2 ECOLOGICAL EFFECTS OF ROADS THROUGH RAINFORESTS

Roads are a basic requirement for economic development, providing necessary services for growing human populations (Goosem 2007). They are one of the most ubiquitous features of human activity (Laurance *et al.* 2009). However, they cause a variety of impacts during construction and operation (Goosem 2007). Environmental impacts of the operation of roads and highways include the loss of habitat caused by clearing and the alteration of habitat surrounding the clearing due to edge effects. Disturbance by vehicle movement and emissions of noise, light and pollutants also occur during road construction and operation. The spread of weeds, feral animals, diseases and biota from other habitats are mediated by roads and vehicular traffic. Additionally, fauna can be killed during collisions with vehicles. In combination, these effects can cause a substantial impediment to movements of fauna and flora between habitats on either side of the clearing (Goosem 2004; Laurance and Goosem 2008).

The impacts of roads and highways appear to be particularly acute in tropical rainforests (Laurance *et al.* 2009). There are at least two reasons for this. First, rainforests are characterised by a complex architecture in the form of complex layers of trees, understorey plants and ground cover. They also have a uniquely dark, humid and stable microclimate (Pohlman *et al.* 2007). Because many rainforest species are specialised for the forest interior and understorey conditions, many avoid forest edges (Murcia 1995; Goosem 2000; Laurance 2004) and are unable to cross even narrow clearings through the forest (Develey and Stouffer 2001; Goosem 2001; Laurance et al. 2004). Other tropical species are particularly susceptible to road kill or to elevated predation or invasions of species near roads (Laurance *et al.* 2009). A second reason for large impacts of roads in tropical forests is that roads and highways play a key role in opening up forested areas to exploitation of the adjacent lands. This often results in expanding clearings along roads and also the ingress of humans into otherwise inaccessible areas.

1.2.1 Habitat Loss

Roads and highways can result in substantial loss of habitat. For example, road clearings through the Wet Tropics World Heritage Area cover about 3,700 ha for roads in use, and another 2,000 ha of unused roads which may be regenerating, or approximately 0.5% of the total protected area (Goosem 2007).

Consider the two main entry roads to Mission Beach that pass through protected areas:

The **El Arish-Mission Beach Road** traverses approximately **5.2 km of forested sections** from the western end of Tam O'Shanter National Park (Lacey Creek) to the Clump Mountain Cooperative Society.

The clearing width along the road averages approximately **27.5 m**
(mean = 27.52, SE = 2.70, n = 13).
Thus the loss of forested habitat to the road is **14.3 ha.**

If this road was only the width of the bitumen paved surface (9 m) with an additional 2 m width of verges on either side for drainage,
it would have a **13 m clearing width.**
The habitat loss would then only be **6.76 ha.**

If the verge widths were 4 m on either side,
the clearing width would be **17 m**
and the habitat loss would be **8.84 ha**

Therefore, maintaining the road clearing at the current 27.5 m width,
rather than maintaining a narrow road verge
causes an additional loss of **7.54 ha** of forest for a **2 m** wide verge,
or **5.46 ha** at a wider verge width of **4 m**.

The **Tully-Mission Beach Road** traverses approximately **11.4 km of forested sections** from the South Mission Beach Road turnoff to the Merryburn area, but omitting cleared sections and sections cleared on one side of the road only.

The **clearing width** along the road averages approximately **33.4 m**
(mean = 33.43, SE = 1.70, n = 12).
Thus, the **loss of habitat to the road is 38.08 ha.**

If the road clearing was only the width of the bitumen paved surface (9 m) with an addition 2 m width of verges on either side for drainage,
it would also have a **13 m** clearing width.
The habitat loss would then only be **14.82 ha.**

If the verges were 4 m wide the road clearing would be **17 m** wide
and the habitat loss would be **19.38 ha**

Thus maintaining the road clearing at the current width
causes a loss of **23.3 ha** of forest if verges were 2 m wide on either side,
or if 4 m wide on either side the loss is **18.7 ha**.

1.2.2 Edge Effects

1.2.2.1 Microclimate

Edge effects are a diverse group of physical and biotic changes associated with the abrupt, artificial margins at the forest-verge edge (Murcia 1995; Laurance and Goosem 2008). These changes can influence diverse aspects of forest structure, microclimate, species composition and functioning. For example, within 50 – 100 m of edges forests experience greater diurnal fluctuations in light, air and soil temperature and humidity (Pohlman *et al.* 2009). The forest therefore experiences greater moisture stress. The severity of these effects and the distance that they penetrate into the forest is increased when clearings are wide with no canopy over the road surface (Siegenthaler and Turton 2000) and also exacerbated by the heat-storing properties of road surfaces such as bitumen paving (Pohlman *et al.* 2007). Continual maintenance of forest edges that removes ‘edge-sealing’ vegetation that tends to fill in the spaces between canopy and ground will also increase these edge problems.

1.2.2.2 Vegetation structure and composition; Faunal composition and abundance

The changes in microclimate at the edge drive changes in vegetation structure and floristics, favouring plants that are adapted to disturbance such as weeds, wiry lianas and small, fast-growing tree species with narrow trunks (Pohlman 2006). Forest interior trees may die or lose many branches in such conditions, further opening the canopy. Alterations to vegetation structure and floristics have consequences for fauna, with abundances and species composition of bats, small mammals, understorey birds, entire bird communities, ants and amphibians all known to respond (Goosem 2007). Generalist species tend to increase near roads while forest specialists decrease and may avoid edges entirely (Goosem 2000; Laurance 2004).

1.2.2.3 Edge effects and Mission Beach roads

However, it must be remembered that although edge effects can reduce habitat quality, this does not mean that the edge-affected habitat does not form habitat for the majority of rainforest fauna and flora. In fact, certain species even prefer edges. Only the most specialised of rainforest species would not be expected to occur in edge-affected habitat. Others may reduce in population density but still make use of the habitat. For example, cassowaries are not expected to be greatly affected by the habitat quality in edges, provided resources for food and shelter are available. In fact, several fruiting trees are known to do better at edges, due to the greater availability of light.

Along the **El Arish-Mission Beach Road** in the forested sections between the western end of Tam O'Shanter National Park and Clump Mountain Cooperative Society, the amount of edge-affected forest at the conservative **50 m penetration distance** for many edge effects would be:

5.2 km road length x **2 sides** of the road x **50 m edge** penetration = **52 ha.**

If we instead consider vegetation microclimate effects that penetrate about **100 m,**

the area of habitat suffering edge effects would be **104 ha**.

Along the **Tully – Mission Beach Road** in the forested sections between the South Mission Beach Road turnoff and the Merryburn area, the amount of edge-affected forest suffering microclimate alterations (to 50 m) would be;

11.4 km road length x **2 sides** of the road x **50 m edge** penetration = **114 ha**

For alterations in vegetation structure that can penetrate **100 m,**

the area of habitat suffering edge effects would be **228 ha**.

1.2.3 Disturbance from Roads

1.2.3.1 Pollutants

Use of roads causes a variety of disturbances from vehicles which emit gas, liquid and solid pollutants as well as energy in the form of noise, headlights and vibration (Goosem 2007). The dust raised by moving vehicles, particularly on unsealed roads, can cover leaves and reduce photosynthesis, transpiration and respiration. Chemical pollutants such as heavy metals found in soils and in stream sediments (Pratt and Lottermoser 2007a), can bio-accumulate through the food chain. Polycyclic aromatic hydrocarbons from vehicles and chemicals used for roadside maintenance such as herbicides and surfactants can cause toxicity problems for amphibians (Mann and Bidwell 2001). Although pollutants generally do not penetrate long distances into rainforest vegetation (Diprose *et al.* 2000; Pratt and Lottermoser 2007b), the runoff from roads can carry pollutants great distances down streams (Pratt and Lottermoser 2007a). For example, heavy metals including lead found at the mouth of the Barron River were identified as originating from exhaust gases emitted on the Kuranda Range behind Cairns (Pratt and Lottermoser 2007a).

1.2.3.2 Noise and headlights

Noise and headlights from vehicles can penetrate long distances into rainforest. For example, traffic noise is easily detectable at 200 m inside the forest near highways both during the day (Dawe 2006; Dawe and Goosem 2008) and night (Goosem *et al*. 2007), and sudden, loud noise from road construction can be heard at distances of 500 m (Goosem and Dawe, 2010). Headlights can be detected at distances of at least 50 m when vehicles travel around bends in the road (Wilson and Goosem 2007). These distances are often much greater than those generally seen for non-vehicular edge effects. These impacts can be almost continuous on highways and major roads, although less of a concern on minor roads (Goosem 2007). Noise can have a range of effects on fauna including masking the sound of a predator's approach or preventing the predator hearing its prey (Goosem and Dawe 2010). For birds and frogs that communicate using sounds impacts can be severe. Both birds and frogs are known to change their call to make it louder or higher in pitch. These alterations to calling patterns can cause problems for the animal by increasing the energy required to produce a call and by changing the potential for other individuals of the species to understand it, thereby altering breeding success. Other species may completely avoid high noise areas (Dawe and Goosem 2008; Hoskin and Goosem 2010). Headlights affect many species, changing communication in fireflies, and dazzling many vertebrates, making them more susceptible to road kill (Wilson and Goosem 2007).

1.2.3.3 Noise-affected habitat on Mission Beach roads

Along the **El Arish-Mission Beach Road** in the forested sections between the western end of Tam O'Shanter National Park and Clump Mountain Cooperative Society, the amount of noise-affected forest at a **200 m penetration distance** which we know to be conservative (the penetration distance is certainly further) would be:

5.2 km road length x **2 sides** of the road x **200 m noise** penetration = **208 ha.**

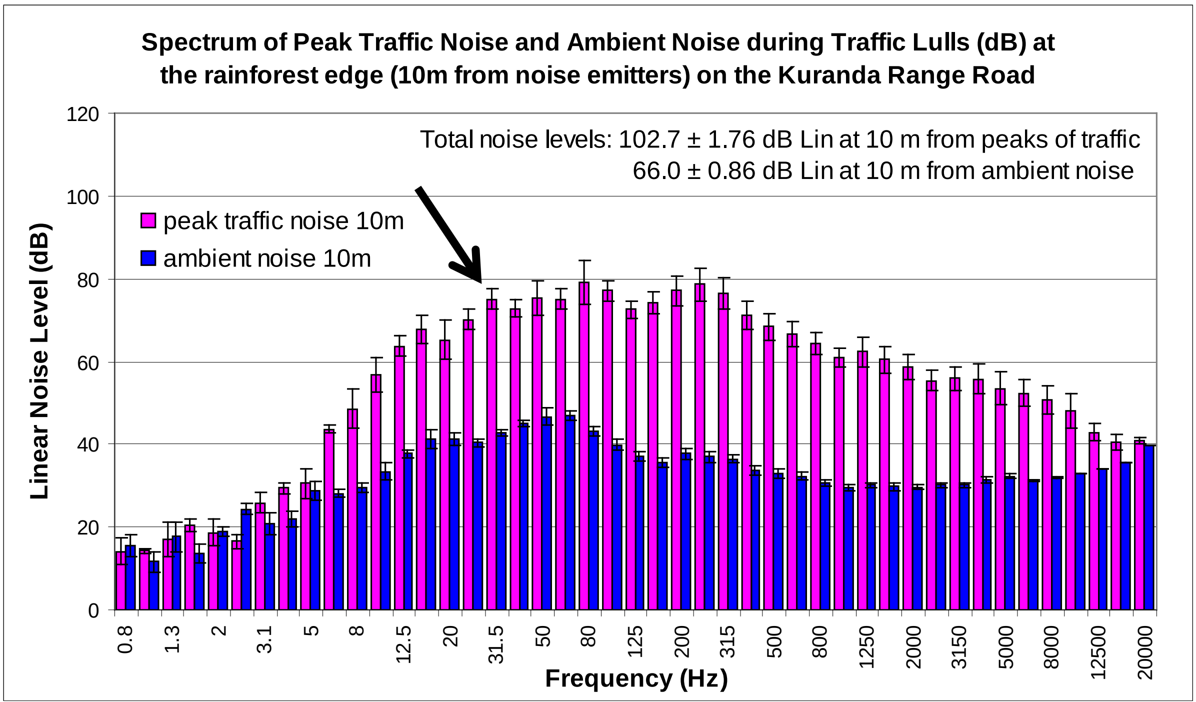
Along the **Tully – Mission Beach Road** in the forested sections between the South Mission Beach Road turnoff and the Merryburn area, the amount of noise-affected forest would be;
11.4 km road length x **2 sides** of the road x **200 m noise** penetration = **456 ha**

1.2.3.4 Cassowaries and Traffic Noise

Cassowaries are known to communicate at low frequencies (pitch) (32 Hz, Mack and Jones 2003). Humans with extremely good hearing can detect noise down to a frequency of 20 Hz. Cassowary calls could be severely masked by the low frequency of traffic noise, particularly close to the road where traffic noise is loudest. For example, traffic noise reaches levels of 102 dB(lin) at 10 m from the road edge on the Kuranda Range Road (Goosem and Dawe 2010). Levels just in the cassowary communication range at 31.5 Hz are almost 80 db at that distance from the road (Figure 1.1). This approximates the total noise level heard by a person standing 1 metre from a food blender (Dawe and Goosem 2008). If cassowary calls are masked by traffic noise near roads, it is possible that juveniles may have difficulty detecting calls of the parent bird.

Cassowaries may even use frequencies lower than humans have the ability to detect (infrasound), possibly by feeling the vibrations in their casque (Mack and Jones 2003), although this is a supposition that needs scientific testing. Low frequency noise penetrates into forest much further than the higher frequencies of most bird and frog calls (1000 – 3000 Hz; Goosem 2006; Goosem and Dawe 2008; Hoskin and Goosem 2010). Because cassowaries are solitary animals which are widely spaced in the forest, the use of such low frequencies means their communications can be heard for much greater distances and they may therefore be able to communicate over distances of 0.5 km or more. However, traffic noise at that frequency will also penetrate to long distances, and therefore could cause problems in cassowary communication deep within the forest.

Figure 1.1
Spectrum of peak traffic noise compared with ambient noise during traffic lulls at the rainforest edge (10 m from closest vehicles) on the Kuranda Range Road. The dominant frequency of cassowary calls are indicated by the arrow (32 Hz, Mack and Jones 2003) and corresponds to one of the traffic noise peak frequencies.



1.2.4 Invasions by weeds, alien fauna and diseases

Roads facilitate widespread species invasions in the tropics, for taxa ranging from little fire ants, exotic earthworms and non-rainforest vertebrates to fungal dieback caused by *Phytophthora* spp. and a huge variety of weeds (Dawson and Weste 1985; Gascon *et al.* 1999; Byrnes 2002; Goosem 2002; Walsh *et al*. 2004; Goosem and Turton 2006; Brown *et al.* 2007). This is particularly the case when roadsides are managed to maintain low vegetation along wide road verges without trees. The dense closed canopy and low light penetration in rainforests means that the forest is often relatively resistant to invasions, but roads and roadsides can become a conduit for the movements of fauna and flora that can then penetrate deeply into otherwise relatively undisturbed forest tracts.

Roads facilitate weed invasions through several feedback loops. First, greater light availability allows establishment of light-requiring weeds including grasses and woody weed shrubs. Second, these types of weeds can greatly impair ecosystem function as ‘transformer species’ that become self-perpetuating in roadsides. Dense tropical grasses tend to promote fires which kill rainforest seedlings (Brooks *et al.* 2004) and, even without fire, will out-compete native seedlings. Dense thickets of woody, scrambling shrubs exclude recruitment of native trees and rainforest understorey by competition. Certain species such as lantana

(*Lantana camara*) are also able to discourage establishment of native seedlings by allelopathy (extruding toxic chemicals into the soil)(Sharma *et al*. 2005). Third, repeated spraying, burning or mowing of vegetation along roadsides favours exotic and disturbance-adapted species at the expense of native species (Goosem and Turton 2006). Finally, vehicles and people can be extremely effective dispersers of propagules along clearings without canopy. Diseases like plant dieback (*Phytophthora* spp.), and the chytrid fungus that causes death in many frog species are both dispersed along roads and tracks in damp soil being carried by vehicles on wheels and on footwear (Worboys and Gadek 2004; Johnson and Speare 2005). Likewise, seeds of many weeds are transported by vehicles.

Fauna from other habitats also can move along roads and penetrate further into habitats, sometime invading the forest itself. Roads are recognised as conduits for many species (Gascon *et al.* 1999). The cane toad, *Bufo marinus,* is a well-known example. Cane toads invade new areas via roads (Brown *et al.* 2007), and also penetrate rainforest from a road base (Goosem 2000; Goosem 2006), although generally preferring the road and its verge (Hoskin and Goosem 2010). Carnivores such as feral cats and dogs also travel along roads (Byrnes 2002), and feral pigs use road verges for both for movement and foraging (Mitchell and Mayer 1997; Byrnes 2002). Road verges can provide habitat for entirely separate faunal communities from those living inside the rainforest. Grassland and feral small mammals rather than rainforest species are found in grassy road verges (Goosem 2000a,b; Goosem *et al.* 2001) and ant and bird communities are also altered in road verge habitat that is dissimilar to interior forest (Dejean and Gibeneau 2000; Laurance 2004).

Along the Mission Beach roads, many weed species are obvious in the road verges, particularly Guinea Grass and Wild Raspberry. Cane toads are extremely common in road kill (see Chapter 3). However, the extent of these invasions and how far various weeds and alien fauna such as cats, dogs, mice and rats penetrate the forest remains to be quantified.

1.2.5 Roads as barriers to faunal movements

In some cases, roads can create barriers to movements of fauna. As a result of the combination of these various road impacts, roads, their verges, and the adjacent edge-affected and disturbed rainforest habitat many animals will not cross the road clearing (Goosem 2007). In severe cases, this internal fragmentation can cause population and genetic isolation (Clark *et al*. 2010) and reduce the efficiency of ecosystem processes including pollination and dispersal that rely on faunal movement. According to some theoretical models, this impeded dispersal might be sufficient to depress species richness near highways (Chave and Norden 2007).

Tropical rainforests have a high proportion of species including beetles, flies, ants, bees, butterflies, amphibians, reptiles, birds, bats and small and larger mammals that tend to avoid even narrow road clearings or forest edges (Laurance *et al.* 2009). The avoidance of clearings and edges is believed to occur because many tropical fauna have specialised mobility, such as being strictly tree-dwellers (Wilson *et al.* 2007) or adapted for flying in dense, cluttered environments (Crome and Richards 1988). Others require the dark humid microclimate of the rainforest or specialised food resources not found in disturbed areas (Laurance 1991; Laurance 2004; Goosem 2000, 2001) or avoid open areas probably due to fear of predators (Laurance 2004; Laurance *et al.* 2004). Others may be strongly disturbed by the presence of humans, noise, light, movement and pollutants or can be repelled by invasive or generalist species in the road verge (Goosem 2000b) or by individuals of the same species that have territories on the forest edge (Goosem 2001; Laurance *et al*. 2004).

As the road clearing becomes wider, this barrier effect becomes greater, until movements by many animal species are strongly or even completely prevented. For example, movements of small rainforest rodents fell by 67-90% across narrow (6-12 m wide) road clearings and by 90-100% across larger (20-60 m wide) clearings (Goosem and Marsh 1997; Goosem 2000b; 2001; 2002).

The width of roads seen at Mission Beach (mean of 27-33 m) may be sufficient to prevent most movements by small rodents and is very likely to affect other small, relatively immobile animals as well as rainforest specialists. Groups likely to be inhibited from crossing include many small, understorey birds, microhylid frogs and specialists such as musky rat-kangaroos. Highly mobile animals with large home ranges such as the cassowary are unlikely to be affected by this type of road impact, and cassowaries are well-known to cross roads seemingly at will.

1.3 ROAD MORTALITY

Many tropical species suffer heavy mortality from vehicle roadkill (Goosem 2000b). If such effects are strong enough, the road could become a population sink, contributing to local extinctions of species. Species that are rare such as carnivores at the top of the food pyramid and large-bodied mammals and birds, which require large home ranges or have low reproductive rates are generally the most vulnerable to elevated mortality. Because narrower roads facilitate road-crossing movements by animals, they also can lead to greater roadkill rates if traffic volumes and/or speeds are high (Goosem 1997; 2000b).

The means and frequency of movements, ecology and behaviour of animals collectively determine their vulnerability to road kill by vehicles (Laurance *et al.* 2009). Especially susceptible are slow-moving, ground-dwelling species, including many amphibians, reptiles and small mammals (Goosem 1997, 2000b; Aresco 2005). Predominantly arboreal species that occasionally traverse open-ground such as tree-kangaroos and slower-flying birds, bats and insects with flight paths that are close to the ground are also vulnerable (Goosem 1997; Goosem *et al.* 2006; Rao and Girish 2007). Species with poor eyesight and those that 'freeze' in response to approaching vehicles, such as echidnas and other mammals and amphibians are common in statistics (Goosem 1997).

Road kill is also heavy among reptiles that bask at night on warm road surfaces (Goosem 2000b) and species that undergo mass movements such as amphibians moving to breeding sites (Goosem 1997; Aresco 2005; Newell 1999; Goosem 2000b). Species whose main activity times coincide with traffic peaks and those that forage along roads or road verges also place themselves at risk. The latter includes predators that favour forest edges and clearings, including hawks, bats and large carnivores (Laurance *et al*. 2004; Crome and Richards (1988); owls and bats that prey on insects attracted to lights along the road (Wilson and Goosem 2007); herbivores attracted to forbs or grasses on roadsides (Vernes 1995) and scavengers feeding on road-killed carrion.

Road features also affect animal mortality. Road kill increases with high vehicle speeds and large traffic volumes (Goosem 2000b; Aresco 2005; Rao and Girish 2007). Narrow road widths also cause increased road kill because the shorter distance to travel encourages road-crossing movements. Curves in roads can reduce driver visibility and the response times of animals to on-coming traffic (Goosem 2000b; Laurance *et al.* 2004). Undulating topography and riparian vegetation tend to funnel amphibians, mammals and other animals towards certain crossing routes that become road kill hotspots, whereas steep cuttings and embankments tend to reduce road mortality by inhibiting crossing attempts for many species

(Goosem 2000b). Continuous fast-moving traffic can also create a barrier effect where many animals will not attempt to cross and those that do are killed. This increases the population and genetic isolation effects associated with roads. If properly designed, bridges, culverts and underpasses reduce road kill by providing safe, alternate routes for crossings of many species. However, others appear not to use such structures (see Chapter 3; Goosem *et al.* 2001; Aresco 2005; Laurance and Goosem 2008; Goosem 2008).

At Mission Beach, cassowaries are recognised as being threatened by road kill (Latch 1997; Hill *et al.* 2010). We will discuss road mortality of cassowaries in much greater detail in subsequent chapters.

1.4 CONCLUSION

A great deal is now known about several of the ecological impacts of roads on tropical forest biota. However, obvious gaps in knowledge remain. For example, little is known regarding the impacts of headlights and other disturbances and not a great deal is known about noise impacts on the majority of fauna. Nothing is known about traffic noise impacts on cassowaries, although these could be severe.

Although a few studies have examined road mortality in tropical forests, little has been published about factors likely to influence the road toll. At Mission Beach, there have been few studies concerning any road impacts besides the road mortality of cassowaries. Therefore the majority of road impacts and the biota they affect remain to be studied in the region. We will discuss a short study of mortality of other vertebrates in Chapter 3 and cassowary mortality in detail in Chapter 2.

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MISSION BEACH ROAD IMPACTS ON CASSOWARIES AND OTHER VERTEBRATES

SECTION 2:

ROAD IMPACTS ON CASSOWARIES

2. ROAD IMPACTS ON CASSOWARIES

Leslie A. Moore and Miriam Goosem*

**Research and reporting summarised in this chapter was undertaken by Les Moore, Updates and data edits from 2008 onwards were undertaken by Miriam Goosem*

Summary

Road mortality is the greatest known cause of cassowary death at Mission Beach, with recent data from the Queensland Parks and Wildlife Service (DERM) cassowary database showing that 89.4% of recorded cassowary deaths since 1992 are due to vehicle collisions. In the 12 months following Cyclone Larry, 82% of recorded deaths were from road mortality. More recently since March 2007, a further 16 mortalities at Mission Beach have been recorded, with 63% due to road kill.

A smaller proportion of cases treated by the Tully Veterinary surgery relate to road trauma (42%), because most road collision victims were not referred to veterinary care. However, the majority of those that receive care after road injury do not survive (78%). The veterinary records show that 54% of cassowary mortality relates to road collisions, with disease and illness (23%) also a notable contributor to deaths. Although dog attacks were recorded commonly in the past (18% of deaths between 1986 and 2004), recent deaths from this cause are only recorded in the QPWS database from other coastal lowland areas, while 2 recent deaths from Mission Beach are found in the veterinary records.

Overall since 1992 till June 2010, of the 60 deaths definitely attributable to road mortality that have been recorded from Mission Beach in the DERM cassowary death database, 38% occurred on the Tully-Mission Beach Road, 27% on the El Arish-Mission Beach Road, 13% on Cassowary Drive and 18% on the South Mission Beach Road or Wheatley Road.

As not all cassowary deaths are reported, these numbers represent the minimum road toll. The numbers will be higher due to unknown numbers of birds not being found after running from the collision injury and chick collisions escaping notice. For example, of the seven cassowaries monitored in this study at least two were killed on the road within six months.

There are several road mortality hotspots in the area. These include:

- the Carmoo/Lindsay Road area on the Tully-Mission Beach Road (13 deaths and 2 more near the banana farm);
- the section of the El Arish-Mission Beach Road between the Bingil Bay turnoff and Mountain View Close (6 deaths):
- the area from west of Clump Mountain Cooperative towards the hardware shop on El Arish-Mission Beach Road (4 deaths); and
- South Mission Beach Road between the quarry and Frogs Hollow including Wheatley Road near the turnoff (8 deaths).

There are also 3 deaths recorded at Lacey Creek and 3 on the Tully Mission Beach Road (Cassowary Drive section) between the police station and South Mission Beach turnoff.

In this research, searches were conducted for a distance of 100 metres into the forest adjoining both sides of the road to identify all active cassowary road crossing points on the major roads of the Mission Beach area by looking for activity (sightings, footprints, droppings, and vocalisations), and movement pads at road edges and monitoring cassowary road crossing behaviour at those sites. Cassowary sighting sheets maintained by the Community for Coastal and Cassowary Conservation (C4) for the period 1996-2009 were used for

crossing frequency analyses after standardisation to monthly visitor data provided by the Cassowary Coast Regional Council.

There were 80 individual cassowary road crossings located in the Mission Beach study area. Other crossings undoubtedly exist on the study roads and on unsurveyed local roads in urban areas. Of the crossings marked, 60 were active and used by cassowaries during the 12 months of the project and 20 were past crossings that did not appear to be in use, however these may also still be active. The two major access roads of El Arish to Mission Beach and Tully to Mission Beach contain approximately 44% of total identified road crossings (35/80).

A total of 2400 cassowary road crossings were recorded, by visitors filling out C4 sighting sheets from 1997 to 2008. As birds frequently cross outside the sight of visitors (pers. obs.), this figure represents the minimum number of road crossings made by cassowaries in the 12 year period. Around 6-8 crossings per 1000 visitors were recorded per year, but this dropped significantly after Cyclone Larry in March 2006. During the year, crossings are more common in February and to a lesser extent January and March, than the other months. Crossing observations are evenly distributed throughout the day, other than very early morning and late afternoon, with no crossing during hours of darkness. Adults cross most frequently (61% of crossings), while family parties (28%) and subadults (11%) are also often observed.

Studies over more than a decade indicate that cassowaries tend to use the same crossing zones – many crossing zones reported in 1992, 1998, and from 1999 to 2007 are still in use. However, other sites can also be used.

In sixty-one cassowary road crossings along the El Arish to Mission Beach Road crossing behaviour was observed: 41 walked across after standing by the roadside or within the vegetation line; 5 stood by the roadside until a break in traffic then crossed; 3 ran across in front of approaching cars; 5 were sighted in the middle of the road in the act of crossing; 7 stood by the roadside but moved back into the forest without crossing. The mean length of time to cross the road was 13.5 seconds, but varied with behaviour.

Constant vehicle noise did not appear to upset crossing cassowaries. However sudden noises such as bangs from trucks or trailers frightened birds and it was unpredictable whether they ran across the road in front of the vehicle or retreated back into the forest. Some cassowaries become habituated to roads and will calmly attempt to cross between passing vehicles, which may prevent sighting by following drivers or those approaching from the other direction.

A number of simplified crossing scenarios suggest that at current traffic flow levels, birds are 60% more likely to suffer vehicle collisions on the Tully-Mission Beach Road than on the El Arish-Mission Beach Road due to the greater traffic volume. Multiple crossings by a bird increase the likelihood of collisions. If the higher speeds observed on this road are also taken into account in these simplified model scenarios, increasing speed from 60 – 80 km/h might increase the likelihood of collisions by up to 50% with speeds of 100 km/h possibly doubling the likelihood of collision.

Calculations of time taken to traverse forested areas of the main entry roads to Mission Beach show that decreasing speeds from an average of 90 km/h to 60 km/h would

a) add 1.6 minutes to the journey between El Arish and Mission Beach: and

b) add 2.8 minutes to the journey between Tully and Mission Beach.

Several major crossing zones on the main Mission Beach roads were identified and compared in terms of types and numbers of cassowaries crossing in each zone, where they cross and crossing seasonality. These comprise:

a) El Arish to Mission Beach Road in the vicinity of Lacey Creek
b) Fenby Gap
c) Cassowary Drive (Tully-MB Rd in vicinity of Wongaling)
d) South Mission Beach Road
e) Tully-Mission Beach Road in the vicinity of Licuala
f) Tully-Mission Beach Road in the vicinity of Sugarcane Creek and Lindsay Road.

The greatest numbers of crossings were observed at Lacey Creek, followed by Licuala and Sugarcane Creek. Crossings at Sugarcane Creek and Licuala comprised the greatest numbers of family parties, with implications for recruitment of birds into the population. These points emphasise the requirement to institute cassowary road mortality mitigations in these areas.

Significantly fewer cassowaries crossed the Mission Beach roads after Cyclone Larry compared with numbers before the cyclone. This decrease may be due to behavioural changes in the cassowary population resulting in fewer road crossings (e.g., siting of feed stations away from the roads until forest fruiting recommenced). However, the continued decrease in numbers through 2008/09 suggests that the cassowary population near roads decreased significantly following the 2006 cyclone. Similarly family parties and subadults were sighted significantly less frequently after the cyclone.

2.1 INTRODUCTION

2.1.1 Background

It is generally accepted that the fragmented populations of the endangered cassowary, *Casuarius casuarius johnsonii* (EPBC 1999) in the Wet Tropics coastal areas south of Cairns are under significant anthropogenic threat (Crome and Moore 1988, 1990; Goosem 1992, 2000; Bentrupperbäumer 1998; EPBC 1999; EPA 2004; Moore 2003, 2007; Latch 2007; Hill *et al.* 2010). The largest of these at-risk coastal cassowary populations is found at Mission Beach, a fast-growing residential and tourist area. Coastal development in the region has reduced connectivity and all but isolated this cassowary population from other coastal populations to the north and south; a tenuous link exists to the west which necessitates bird crossing the Bruce Highway and the railway line, primarily near Smiths Gap, south of El Arish.

However, determining whether there is decline in populations of rare, long-lived animal species is very difficult, requiring years of study. The precautionary principle of managing threatened animal populations, however, suggests that waiting until experimental and evidence-based biology indicates this to be the case (or not) is likely to be a mistake at Mission Beach. The use of the precautionary principle in environmental decision making is not new and provides the contextual background for the species listing regime of the *Environment Protection and Biodiversity Conservation Act 1999.*

There are a number of anthropogenic factors implicated in the apparent cassowary decline at Mission Beach, including the loss of habitat, disease, and dog attacks. But a major contributor is the high level of cassowary road death. If residential development and the tourist industry continue to expand at the current rapid pace, the associated upgrading of the coastal road system will undoubtedly result in a concomitant increase in such road deaths. However, with careful management of developments, urban sprawl and traffic, such as has been regulated in the FNQ Regional Plan 2009-2031, this need not be the case. The implementation of effective road mitigation to reduce the incidence of cassowary road mortality at Mission Beach necessitates the development of a cassowary road management plan, as recommended in the Mission Beach Habitat Action Plan (Hill *et al.* 2010)

Such a plan will require:

- consultation between Queensland Department of Transport and Main Roads (QTMR), Cassowary Coast Regional Council, Wet Tropics Management Authority (WTMA), Queensland Parks and Wildlife Service (QPWS), Department of Infrastructure and Planning (DIP), Terrain NRM, researchers from James Cook University (JCU), C4, traditional owners, appropriate landowners, the community, and other stakeholders;

- consistency with relevant State and Commonwealth legislation;

- best practices in road safety and habitat conservation over the life of the project; and

- adequate funding support from state and federal governments.

As such, specific mitigation treatments for individual crossings are not identified in this chapter. Rather, this chapter identifies the major cassowary road crossing locations at Mission Beach and provides the information with which to evaluate their importance to the local cassowary population. The study and subsequent analyses aim to describe those ecological aspects of cassowary behaviour critical to the formulation of an effective road management plan. These include: annual, seasonal, and daily crossing patterns; crossing demography (age cohorts and breeding birds); an assessment of changes in road crossing behaviour pre- and post- Cyclone Larry (20 March 2006); and a risk assessment of the probability of cassowary-vehicle collision using field data.

2.1.2 Mission Beach Cassowary Road Research Project

Road death is the greatest known cause of cassowary mortality at Mission Beach and is responsible for approximately 70% of all known cassowary deaths since 1989 (Kofron and Chapman 2006). Recent 2010 data from the Department of Environment and Resource Management cassowary death database shows that road kill now comprises 89.4% of known cassowary mortalities at Mission Beach since 1992. Studies in 1998 and 2000 established that at least 35 adult birds crossed the four main roads: El Arish-Mission Beach Road, the Tully-Mission Beach Road between the Wongaling turnoff and South Mission Beach Road turnoff (hereafter termed ‘Cassowary Drive’ to distinguish that section of the road from the main entry point to the Mission Beach village system from Tully), South Mission Beach Road, and the Tully-Mission Beach Road west of the South Mission Beach Road turnoff (Moore and Moore 1998, Moore 1999 - 2007). Most individuals made use of multiple crossing points. As a consequence of the high rate of cassowary road death over the past 20 years and the increased traffic volumes predicted in the future, the Mission Beach Cassowary Road Research Project was initiated in April 2008. The primary aim of this project was to provide information that will inform the development of road crossing mitigation to minimise cassowary road death.

The cassowary road research project had the following objectives:

- Identify the active cassowary road crossing areas on the El Arish-Mission Beach Road, Bingil Bay Road, Cassowary Drive, Tully-Mission Beach Road and South Mission Beach Road;
- Establish the temporal usage patterns of road crossings;
- Determine the annual, seasonal, and daily patterns of road crossing;
- Determine the frequency of use and demographics at each crossing point i.e., proportional use by adults, family parties and subadults;
- Estimate the risk levels and contributing factors associated with each crossing point;
- Establish the frequency of cassowary road crossings at Smiths Gap to determine its potential to effectively connect the Mission Beach cassowary population and the Wet Tropics World Heritage Area cassowary population west of the Bruce Highway;
- Identify individual cassowaries using the crossings and establish identikit profiles of these birds.

Due to the amount of time necessary to identify and track road crossing birds, after 6 months Objective 7 was found to be impractical with only a small amount of data collected relative to effort. Moreover, two of the seven birds being monitored died on the roads within months of each other. This component of the study was subsequently discontinued.

The problems surrounding cassowary road management at Mission Beach are exacerbated by a lack of ecological data, a common situation when working with rare and cryptic species. To determine the scale of the problem and inform future conservation approaches, the following questions are among those that need to be answered:

General questions

1. What characteristics make a species vulnerable to the effects of roads? (see Chapter 1)
2. What are the major road effects and how do they impact on animals? (see Chapter 1)
3. What is the rate of known cassowary death at Mission Beach?
4. Is road mortality the greatest single cause of cassowary death at Mission Beach?
5. What proportion of this known mortality is a result of road death?
6. Are there other factors influencing the impact of roads on cassowaries?
7. What effect did Cyclone Larry have on the frequency of cassowary road crossings?

Road crossings

8. How many road crossing points occur at Mission Beach?
9. Which road sections have the most cassowary crossing points?
10. Where on these roads do cassowaries cross?
11. Are some roads at Mission Beach crossed more frequently than others?
12. Are some crossings used more frequently than others?
13. Do cassowaries use Smiths Gap to cross the Bruce Highway south of El Arish?

Crossing behaviour

14. How many road crossings are made by cassowaries per year, month and day?
15. Does the number of these crossings vary in different years, months, daily?
16. Which cassowary cohorts cross the roads (adults, family parties, subadults)?
17. Are there seasonal trends to cohort crossings i.e., do family parties cross in particular months?
18. Is there a distinct cassowary breeding season at Mission Beach shown in the crossing data?
19. Why do cassowaries cross the roads?
20. How does a cassowary cross the road e.g., run quickly across, watch and then run across, watch and then walk across, or meander aimlessly along the road?
21. How long does a cassowary take to cross the road and how does this affect the probability of being hit by a vehicle?

Risk assessment

22. What measurable risk factors are associated with each crossing point?
23. Which crossings are the most dangerous for cassowaries?
24. What is the probability of an individual cassowary being hit by a vehicle while making a single crossing of the road?
25. How is this probability of collision influenced by multiple road crossings daily and annually?
26. What influence does vehicle speed have in the probability of cassowary-vehicle collision?
27. Does the clearing of wide road verges reduce cassowary road mortality?

Mitigation (see Chapter 5)

28. What mitigation techniques exist with potential to reduce the risk of cassowary-vehicle collision?
29. How effective are these techniques and how applicable are they to the Wet Tropics in general and Mission Beach in particular?
30. Which road mitigation techniques might be appropriate to achieve a safe road crossing?
31. Which road crossings should be prioritised for treatment?
32. What further research needs to be done to determine the appropriate mitigation at specific crossing locations?
33. Are there any crossing points in the Smiths Gap area that have potential as permanent safe cassowary road crossing locations?
34. What contribution would such a connection make to the viability of the Mission Beach cassowary population?

2.1.3 Past Road Research Studies in the Mission Beach Area

There have been a number of research studies of cassowaries and roads at Mission Beach (Bentrupperbaumer 1992, Moore and Moore 1998, Moore 1999, 2000). A summary of findings from these studies is provided. Several other management studies have identified potential habitat linkages along Wongaling Creek (Biotropica 2008) and between Wongaling and South Mission Beach (Biotropica 2009) and at Kennedy Bay (Biotropica 2010). Other management documents have suggested means of dealing with cassowary crossings in the Wongaling area (Chenoweth EPLA 2008; Terrain NRM 2008). These management documents should be consulted in those contexts. This chapter only details past research studies rather than consideration of management options, as we aim to provide data that will assist in determining management options.

2.1.3.1 Bentrupperbäumer (1992)

In a cassowary monitoring report to Queensland National Parks and Wildlife Service, Bentrupperbäumer reported 497 cassowary sightings on or near roads during a two year period (1991-1992). It was concluded that some 'specific' road crossings (*sensu* 'cassowary crossing point') were used on a regular basis when a particular food source was available, and that the road crossing was made at the closest point to that food source. Figure 2.1 is derived from that report and shows the approximate location of identified road crossings. The road and place names used in this chapter (Moore and Goosem 2010) are shown on the figure in blue font. Although the map scale does not allow exact crossing locations to be determined, the majority of the cassowary road crossings identified by Bentrupperbäumer are still extant.

2.1.3.2 Moore and Moore 1998, Moore 1999, 2003, 2007

A four-month field survey of cassowaries crossing roads at Mission Beach was conducted for the Queensland Department of Main Roads (QDMR) in 1998 as part of an evaluation of potential impacts on cassowaries of a proposed upgrade of the El Arish to Mission Beach Road (Moore and Moore 1998). The survey covered the El Arish–Mission Beach and Tully-Mission Beach Roads, and included Cassowary Drive. A second field survey of cassowary road crossings on the South Mission Beach Road was conducted for QDMR in 1999 (Moore 1999) and known cassowary road crossing points were monitored in 2000 (Moore 2003, 2007). The results of the 1998 study are shown on Figure 2.2, which includes approximations of home ranges for individual cassowaries during the survey period.

El Arish-Mission Beach Road

Twelve cassowary crossing points were identified between Bingil Bay Road and the junction with Cassowary Drive. It was established that sixteen different birds (ten adults) crossed this section of road, with some individuals making multiple crossings per day. Five separate crossing points were located within 400m of the Lacey Creek car park (Figure 2.2).

Cassowary Drive- Hull River Bridge - Tully Road

Of the 12 cassowary road crossing points identified along this section of road, eight were located along the 18 kilometre road section between the junction of South Mission Beach Road and the Bruce Highway (Figure 2.2). The crossings were used by at least 17 adult cassowaries, with 10 adults using the four crossing points between South Mission Beach Road and Lindsay Road. At the time of the field survey this road section accounted for >45% of the known Mission Beach cassowary road deaths recorded since 1989. Eight cassowary deaths occurred in the 7.8 kilometres between the South Mission Beach junction and Sugarcane Creek. The remaining four deaths occurred along Cassowary Drive.

Figure 2.1 Location of cassowary road crossings from Bentrupperbäumer 1992

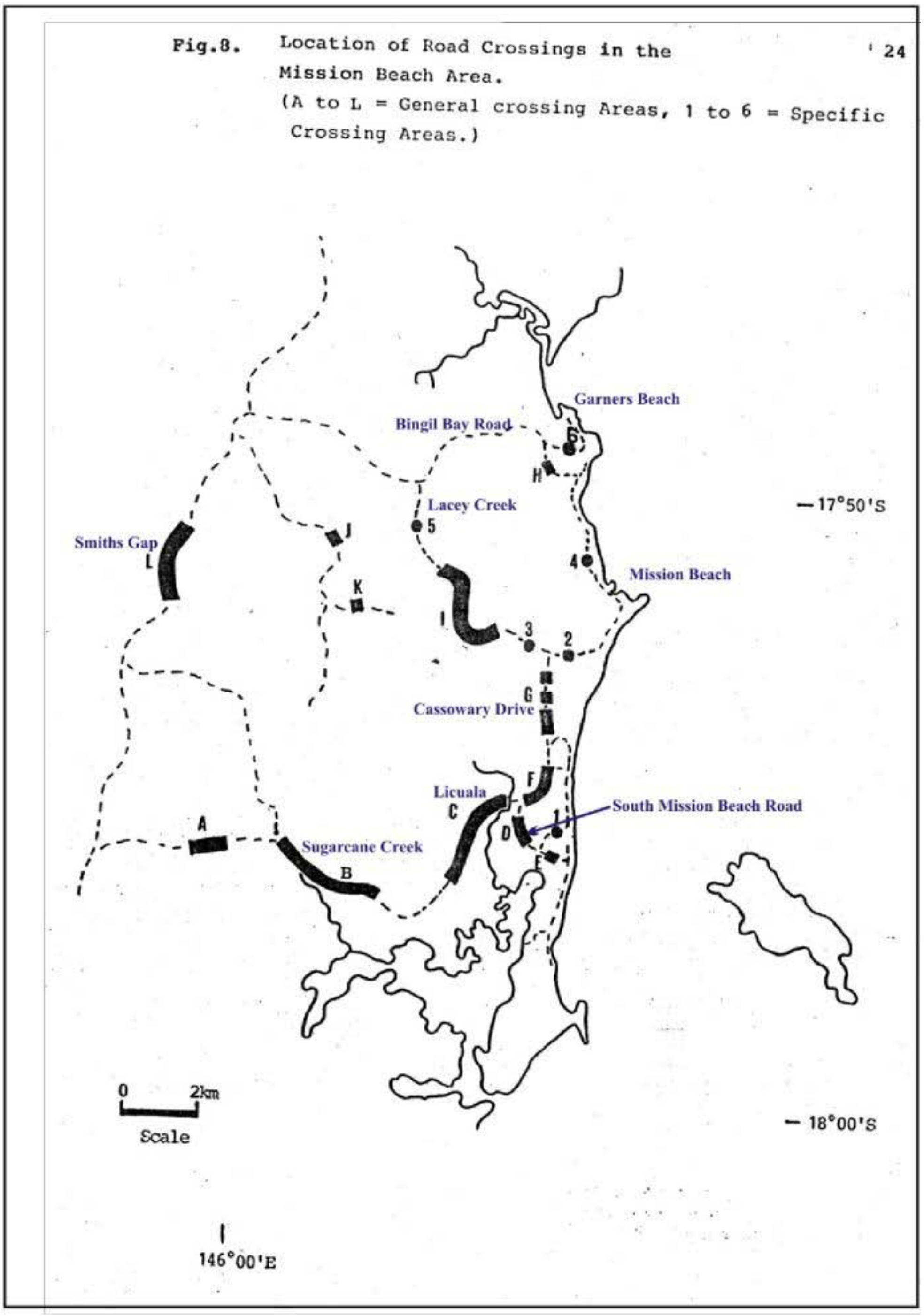


Figure 2.2
Cassowary road crossings July - November 1998
(Moore and Moore 1998)

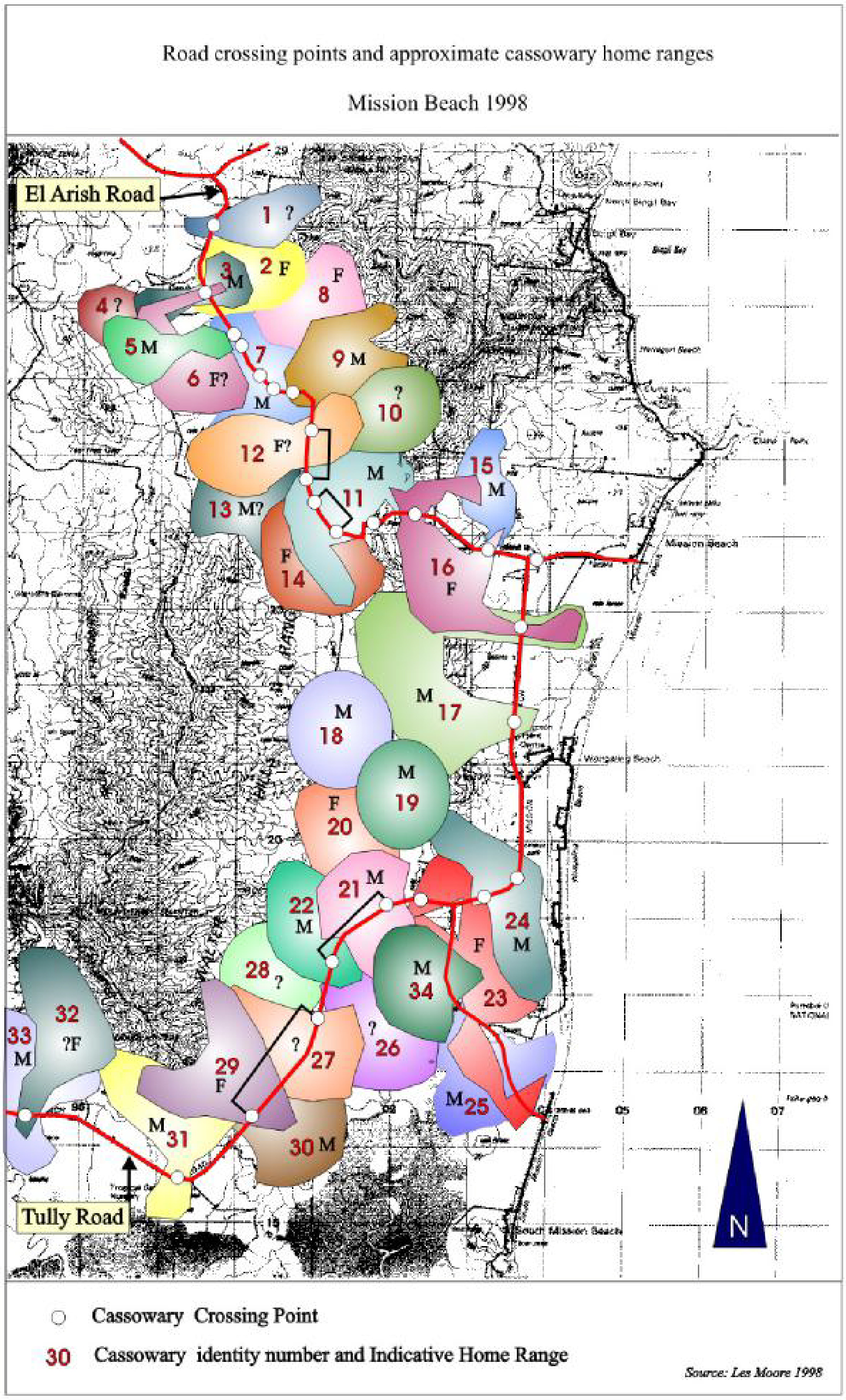
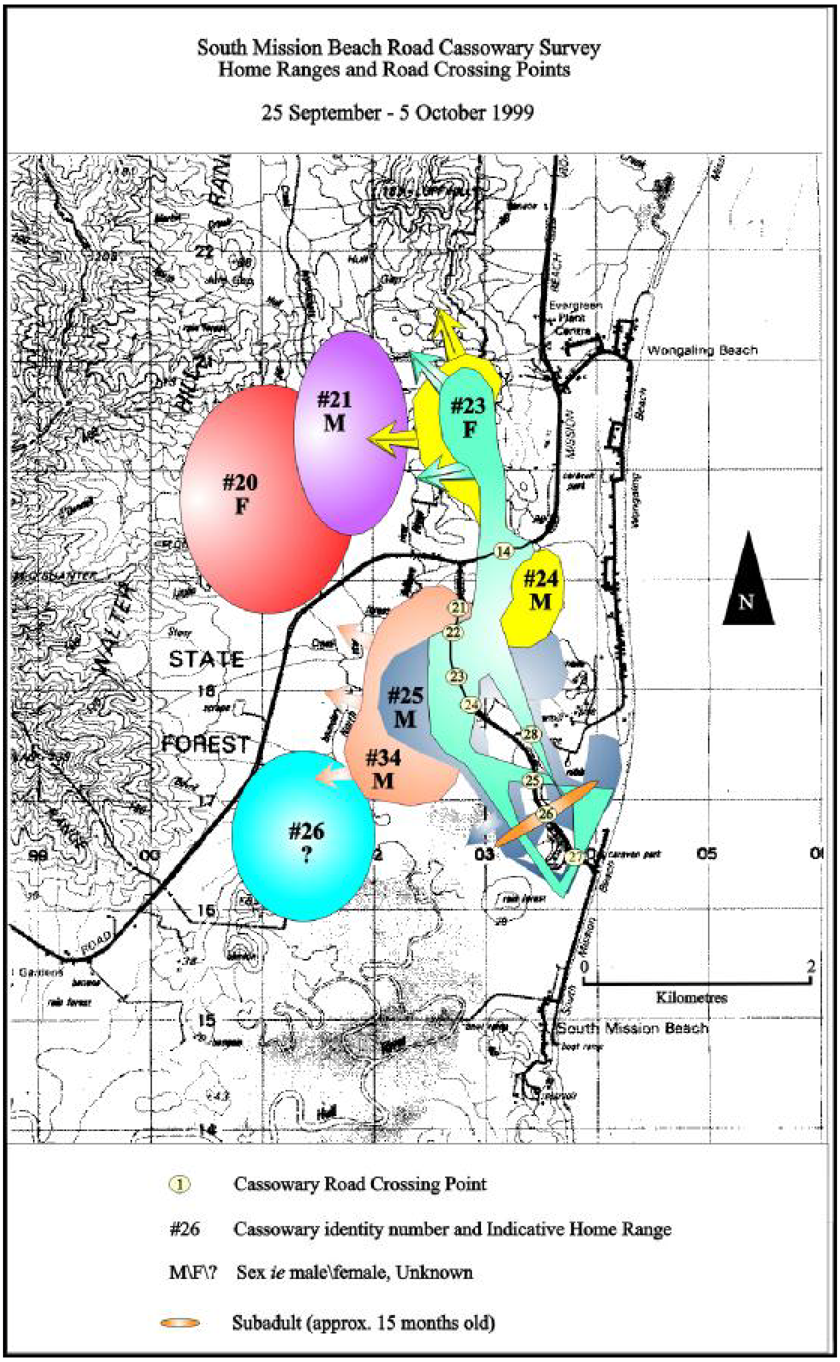


Figure 2.3
Cassowary road crossings on South Mission Beach Road 1999 (Moore 1999)



South Mission Beach Road

Seven cassowary road crossing points were identified in the 3.4 kilometres of South Mission Beach Road, between its junction with Tully-Mission Beach Road and Kennedy Esplanade (Figure 2.3). An eighth crossing point was located on Wheatley Road, 125 metres east of its junction with South Mission Beach Road. These eight crossing points were used by four adult birds, most making use of multiple crossing points. The results of the study are shown on Figure 2.3 and include approximations of home ranges for individual cassowaries during the survey period.

Moore (2003) MSc study

Although not specifically addressing cassowary road crossing points, the 2000 field study confirmed the presence of at least 22 cassowary road-crossing points in the 23.6km of roads included in the study area: the El Arish-Mission Beach Road, Cassowary Drive, and Tully-Mission Beach Road. It was estimated that the road crossings were being used by approximately 70% of the Mission Beach adult cassowary population at that time.

2.1.4 Rate of cassowary mortality at Mission Beach

Due to the network of roads in the Mission Beach area (refer Figure 2.4), many cassowaries cannot avoid approaching or crossing roads, often on a daily basis. Previous studies (Moore 2007) indicated that adult cassowaries maintained home ranges of 2-5km^2 (mean 2.09 ± s.e. 1.02). Birds observed foraging along the coastal strip were often found to have the bulk of their home ranges kilometres inland to the west. This can be seen in Figures 2.2 for birds 16, 17, 23 and 24, and in Figure 2.3 for birds 23 and 24. In addition, interactions during the breeding season entailed further movements by cassowaries searching for mates and identifying potential nesting locations. As the social network of cassowaries at Mission Beach is a complex overlay of home ranges (Moore 2003, 2007), it is possible that most if not all birds in the small population are regularly interacting with the roads and each other in some way. Thus the loss of a breeding female on Cassowary Drive, for example, may have significant flow-on consequences for breeding systems that may span 5-10km^2.

2.1.4.1 Cassowary mortality at Mission Beach 1986–2004 (pre-Cyclone Larry)

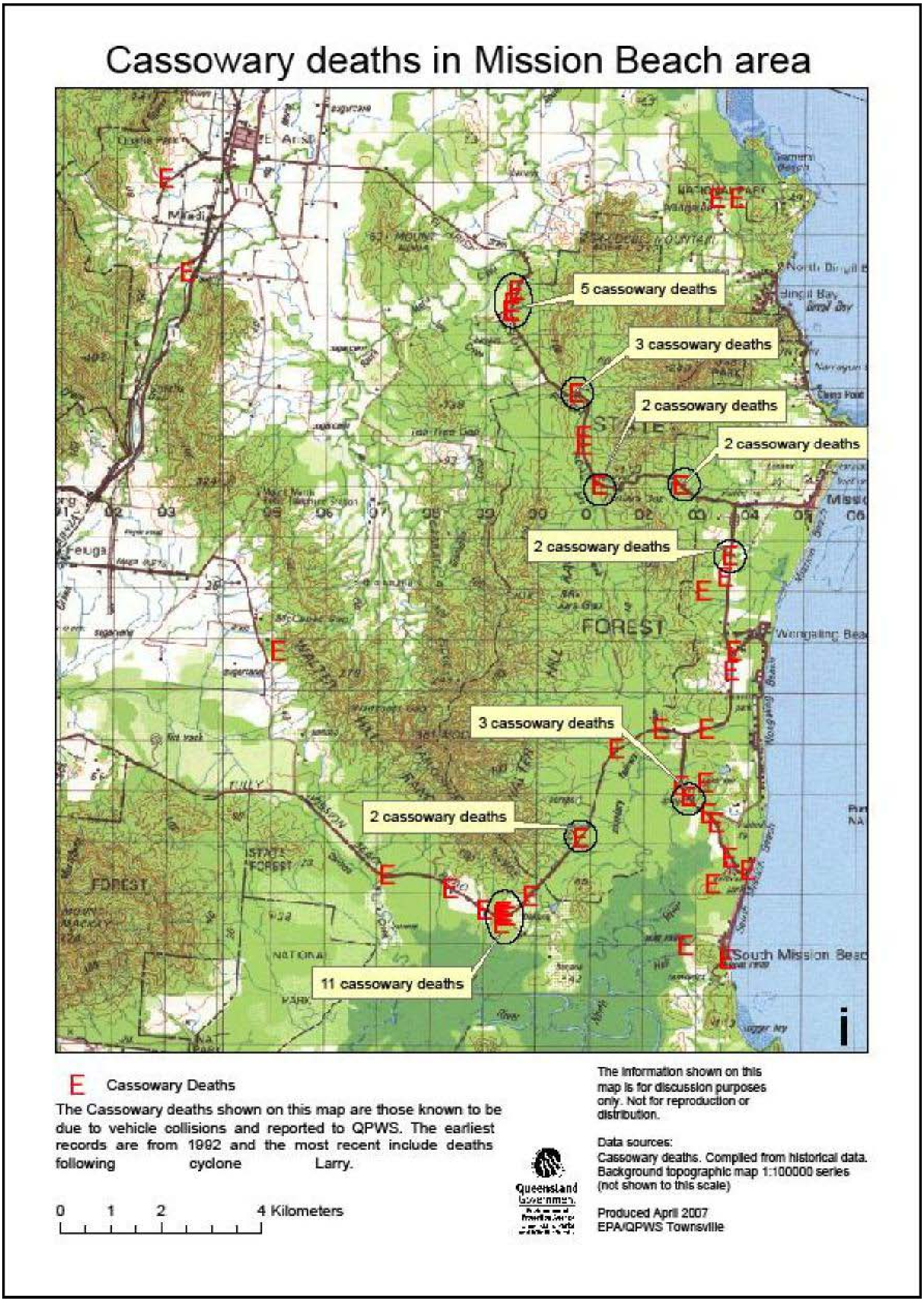
Kofron and Chapman (2006) detailed the known causes of mortality of *C. casuarius johnsonii* in Queensland from 1848 to 2004. In the 19 years between 1986 and 2004, 79 cassowary deaths were recorded in the Mission Beach area, which included El Arish and Tully. Of these deaths, 49 were from collision with vehicles (62%), 14 were killed by dogs (18%) and 7 died from various illnesses (9%). The mean annual mortality rate of all age classes of cassowaries (adults/subadults/chicks) over the 19 years was 4.2 birds/year; mortality of independents only (adults and subadults) was approximately 3.3 independent birds/year. Many of the post-1992 casualties discussed in the paper are represented in the QPWS (DERM) cassowary mortality database (see below).

2.1.4.2 Cassowary mortality 2006-2007 (post-Cyclone Larry)

Records of death and injuries to cassowaries at Mission Beach, Innisfail and Tully for the 12 months following Cyclone Larry were obtained from Queensland Parks and Wildlife Service (QPWS) records. Thirty cassowary deaths were reported to QPWS and 28 were verified, autopsies conducted and data recorded in the database. Of the verified mortalities, the causes of death were vehicle strike (16), dog attack (5), malnutrition (1), and injury sustained in a fight with another cassowary (1). In five cases, the cause of death could not be established (M. Gayler, *pers. comm*. 2007). Therefore, of the known causes of post-cyclone cassowary deaths, 70% were from vehicle strike and 22% from dog attack. It was not known how many cassowaries were killed within the forest itself due to falling debris or starvation.

Of the verified cassowary deaths after the cyclone, 11 were from Mission Beach: two adults, seven subadults and two chicks. The 11 casualties in the 12 months after the

Figure 2.4a
EPA/QPWS map of cassowary road deaths at Mission Beach 1992-2007



cyclone were caused by road mortality (7 verified, 64%) with a further 2 (18%) likely to have been road casualties (total of 82%) and another found near the road with causes of death unable to be established. Four subadult birds were taken into veterinary care due to malnutrition, injury, or disease, and at least one adult cassowary was relocated out of the area. Most birds taken into captivity subsequently died. Therefore, up to 14 independent birds (3 adults and 11 subadults) were known to have been lost to the population in the 12 months following the cyclone due to a variety of causes with the major one being vehicle strike, an increase in mean annual mortality post-cyclone of approximately 400% (14 cf 3.3 birds).

From March 2007 until September 2011, a further 16 mortalities at Mission Beach were recorded in the DERM (QPWS) cassowary mortality database, 10 of these were due to vehicle strike (63%), with another likely (i.e., 69% certainly or likely a result of road mortality) and 2 dying from diseases, two from other causes and one with causes unknown. This suggests a return to pre-cyclone mortality rates at 4.0 birds/year, of which vehicle strike comprises almost 3 birds/year. Six birds killed by cars were adults, with the two diseased birds and one other also being adults. The remainder were chicks or subadults. Therefore 2.25 adult birds/year were removed from the population.

2.1.4.3 Queensland Parks and Wildlife Service (QPWS i.e. DERM) cassowary mortality database

The number and location of the many cassowary road deaths prior to 1992 are not available for analysis. Overall till September 2011, of the 60 road mortality deaths recorded at Mission Beach in the DERM cassowary death database, 38% occurred on the Tully-Mission Beach Road, 27% on the El Arish-Mission Beach Road, 13% on Cassowary Drive and 18% on the South Mission Beach Road or Wheatley Road (Table 2.1). The map generated from the QPWS database in April 2007 (Figure 2.4a) shows that 23% of the QPWS-known deaths from 1992-2006 occurred on the El Arish–Mission Beach Road, 14% on Cassowary Drive, 19% on the South Mission Beach Road, and 38% on Tully-Mission Beach Road west of its junction with South Mission Beach Road. Therefore, it appears that there was little change in spatial distribution of road mortalities after Cyclone Larry in terms of the roads on which birds are killed. Closer inspection shows that the proportions of road mortalities occurring on the different roads were slightly, but non-significantly (χ^2=0.942, df=4, P=0.963), different after Cyclone Larry. Deaths on the Tully-Mission Beach Road were slightly above the 18 year proportion at 47% of deaths since the cyclone whereas the proportions in the South Mission Beach Road area were less at 12%, while vehicle kills remained consistent on Cassowary Drive (12%) and El Arish-Mission Beach Road (24%). Since Cyclone Yasi, 3 road mortality deaths have been reported, one on each of the Tully-Mission Beach, El Arish-Mission Beach and South Mission Beach Roads. The consistently high proportions of road mortality occurring on the Tully-Mission Beach and El Arish Mission Beach Roads suggest that these should be the primary focus of mitigation against road mortality.

Table 2.1
Cassowary road mortality 1992- September 2011 and post- Cyclone Larry and Yasi

Road mortality occurred	Mortality 1992-Jun 2010	% killed on each road 1992-2010	post-Larry mortality	post- Yasi mortality
Bingil Bay – Garners Beach Rds	2	3.3	1	0
El Arish – Mission Beach Road	16	26.7	4	1
Cassowary Drive	8	13.3	2	0
Tully – Mission Beach Road	23	38.3	8	1
South Mission Beach, Wheatley Rds	11	18.3	2	1
	60	100.0	17	3

Figure 2.4 b Google maps images of cassowary deaths in Mission Beach area, including recent deaths: northern area

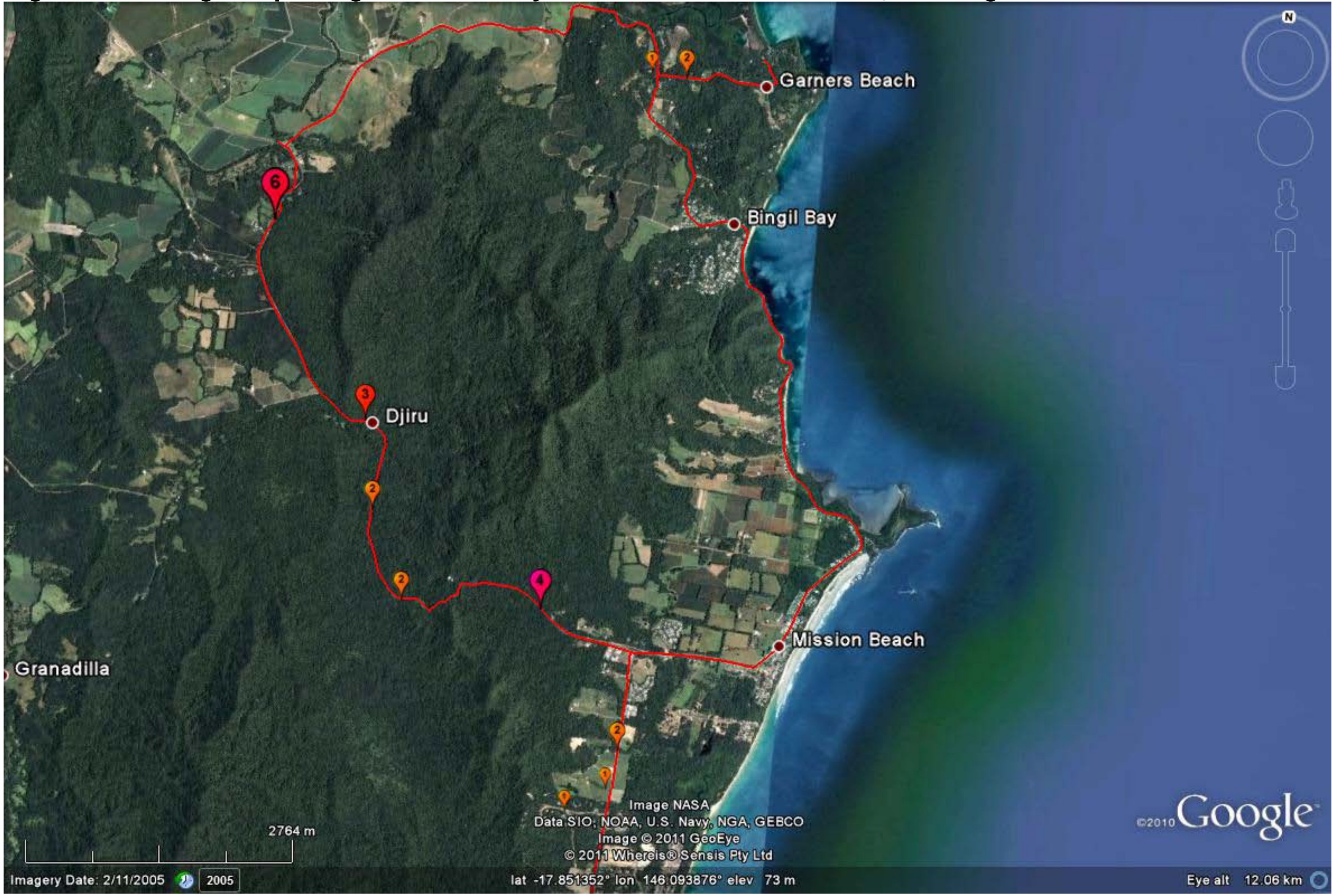
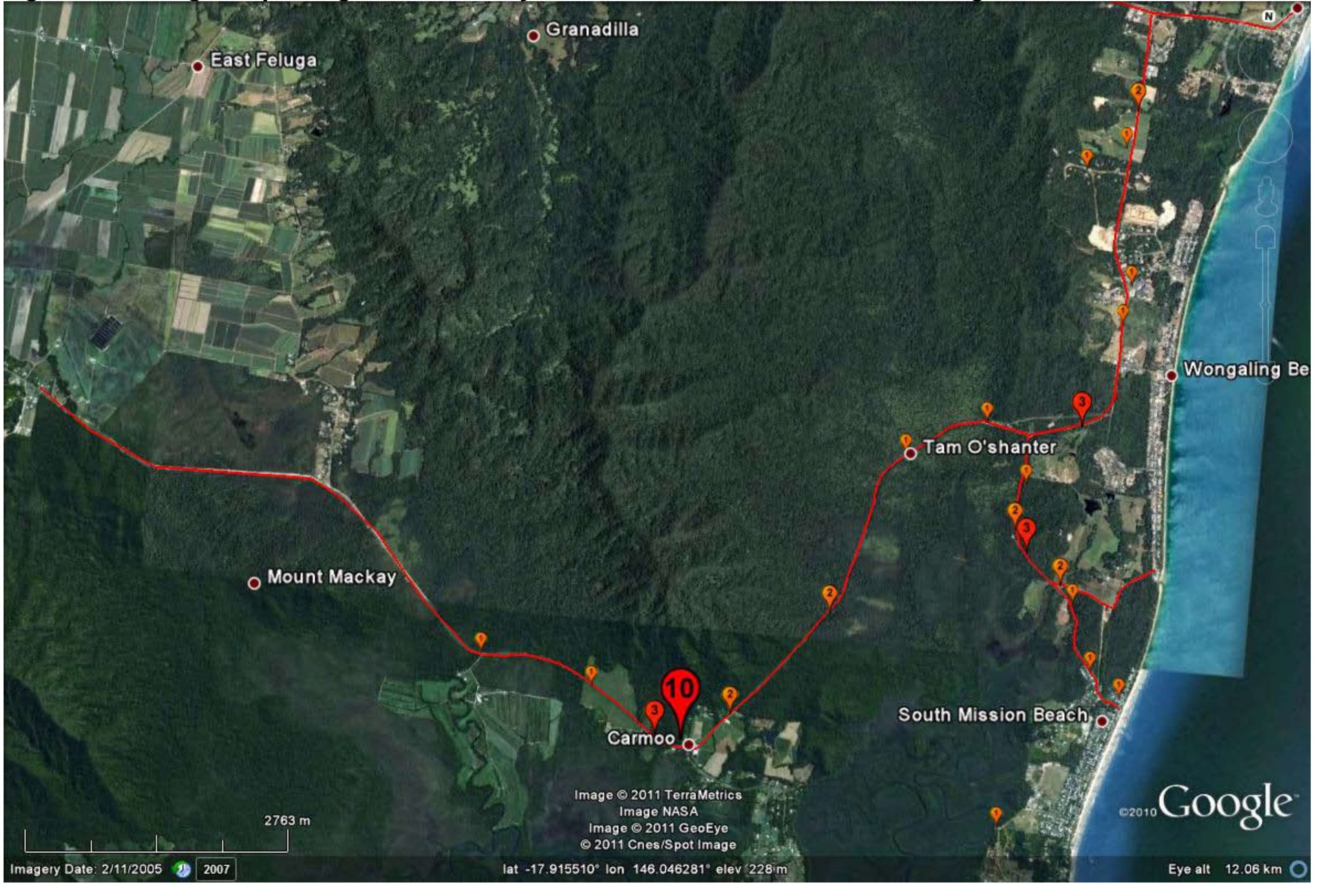


Figure 2.4c Google maps images of cassowary deaths in Mission Beach area, including recent deaths: southern area



Figures 2.4b and 2.4c show the number of road mortality deaths along the roads that have been recorded in the DERM cassowary mortality database. It should be noted that in 3 cases where coordinates fell off road due to location errors, the description of the death location was used. There are several areas that are obvious for their high road kill records:

Carmoo/Lindsay Road area on Tully-Mission Beach Road	13 deaths
Bingil Bay turnoff to Mountain View Close on El Arish-Mission Beach Rd	6 deaths
Near Clump Mountain Cooperative to near hardware shop, El Arish-MB Rd	4 deaths
Lacey Creek area	3 deaths
Cassowary Drive (TMB Rd) between police station and South Mission turnoff	3 deaths
South Mission Beach Road near water tank track	3 deaths
South Mission Beach Road, Wheatley Rd and Frogs Hollow area	3 deaths

Areas recording 2 deaths include
Garners Beach Road,
Cassowary Drive (Tully Mission Beach Rd) at Porters Creek
El Arish Mission Beach Road between Lacey Ck and Bean Tree Track entrance
Bean Tree Track entrance area
Tully Mission Beach Road near western traffic counter location
Tully Mission Beach Road near banana farm
South Mission Beach Road near old quarry

2.1.4.4 Veterinary Records (from Dr Graham Lauridsen – Tully Veterinarian)

Veterinarian Graham Lauridsen (Tully Vet Surgery, Tully) has treated 123 individual cassowaries since 1999. Of these birds, 65 came from Mission Beach. Of the Mission Beach birds, 27 had been hit by vehicles, 7 were suffering lameness which could relate to vehicle strike or other factors, 4 were victims of dog attack, 4 were victims of cassowary attack, 8 were treated for other reasons such as relocation, being orphaned, running into a fence or malnutrition, and 14 were admitted suffering from disease or other illness (Table 2.2). The survival rate varied between 20% for cassowary attack and 22% for vehicle strike to 85% for lameness.

Table 2.2
Cassowary injuries from Mission Beach treated by Tully Vet Surgery

Cause of injury or death	No. cases	Mortality	% Mortality	% Total Mortality Recorded
Cassowary-vehicle collisions	27	21	77.7	53.8
Disease/sickness	14	9	64.2	23.1
Dog attacks	4	2	50.0	5.1
Lameness	7	1	14.3	2.6
Cassowary attack	5	4	80.0	10.3
Other	8	2	25.0	5.1
	65	39	60.0	100

Thus, the greatest individual cause of cassowary injury and mortality at Mission Beach treated by the Tully Vet Surgery was a result of cassowary-vehicle collision (41.5% and 53.8% respectively). However, approximately 22% of those animals struck by cars survived the trauma with treatment. It is probable that the majority of cassowaries taken for veterinary attention are still alive when found (e.g. diseased/sick). The high incidence of disease-related mortality (~23%) is of significant concern, although there is no evidence that cases are increasing. Several of the early cases relate to avian tuberculosis or parasites; however, mostly the illness is not identified.

Many of the mortality victims mentioned in this veterinary treatment database are also included in the DERM cassowary mortality database, as the two datasets overlap since 1999. However, not all cassowary-vehicle collisions were attended by the veterinarian and not all those records appearing in the veterinary database appear in the cassowary mortality database.

2.1.4.5 Summary

Table 2.3 shows the different numbers of cassowary deaths recorded by the three sources for the same cassowary population and shows considerable differences between road deaths recorded by QPWS (4 deaths/year), Kofron and Chapman (adults only: 2.7 deaths/year), and those of the Tully Veterinary Surgery (all ages: 1.9 deaths/year). It is important to remember that these figures represent three separate totals from different tallies, which include some of the same individual deaths. These data are not independent, although evidence demonstrates that not all individuals are included in each dataset, even in those years where they overlap. Regardless of the differences between the figures, they indicate that there is known to be a continual loss of individuals from the Mission Beach cassowary population from human-related rather than natural causes.

Table 2.3
Cassowary mortality data from the Mission Beach population

Source	Road death	Dog attack	Illness	Other/ Unknown
Kofron and Chapman 1986-2004	49	14	7	9
QPWS 1992-2010	57		3	6
Lauridsen 1999-2010	19	2	10	8

Not all collisions between cassowaries and vehicles are reported. Dead cassowaries are often in an advanced stage of decomposition when discovered, and are subsequently left on the side of the road where they are found (Moore pers. obs.). Others remain unsighted in tall grass or roadside vegetation and are found only by chance. For example, of the seven cassowaries being monitored in this study at least two were killed on the road within six months: an adult female was found badly decomposed in a roadside drain many days after its death at Lacey Creek; another bird (adult male cassowary) was found by following a blood trail left when the bird was dragged from the road at Sugarcane

Creek (Moore pers. obs. 2009). Although some birds may initially survive a collision and run off (e.g., Moore and Goosem 2009), the proportion of these that die afterward as a result of the collision is unknown. Additionally, the road deaths of young cassowary chicks frequently escape notice as their small bodies degrade to flattened 'parchments' on the road pavement in a very short time (Moore pers. obs.).

There are several obvious hotspots of cassowary mortality on the Mission Beach Roads, as shown on the DERM map (Figure 2.4). More recent records do not appear to have changed this pattern (Figure 2.5). Hotspots include the Lindsay Road – Carmoo area, the South Mission Beach Road/ Wheatley Road/ Frogs Hollow area and the area between the Bingil Bay turnoff and Mountain View Close on the El Arish Mission Beach Road. Other areas with several deaths include the Lacey Creek to Fenby Gap area, the area around the Clump Mountain Cooperative, Porter's Creek and near the South Mission Beach turnoff on the Cassowary Drive section of El Arish Mission Beach Road and a section of the Tully Mission Beach Road.

2.1.5 Road Effects on Wildlife

The effects of roads on wildlife can be grouped into three categories (Forman *et. al.* 2003) (Figure 2.5):

- effects on individual animals (**traffic mortality/barrier effect**);
- effects on local animal populations (**reduced population size/reduced landscape connectivity**); and
- reduction of regional population size and persistence.

While the most obvious effect of roads on wildlife is the sight of dead animals killed within the road corridor (direct mortality), the indirect effect of roads as barriers to movement is less apparent and must also be remembered (see Chapter 1). Roads have been shown to be significant barriers to the movement of small mammals, reptiles, and amphibians (e.g., Forman and Alexander 1998, Oxley *et. al*. 1999, Hels and Buchwald 2001, Goosem 2001, 2004, 2007, Goosem et. al. 2001, Gibbs and Shriver 2005, Roe et. al. 2006) and genetic effects on animal populations caused by this potential isolation has also been observed for several taxa (Forman *et. al*. 2003).

Time lags

Road effects on wildlife populations show a lagged response as habitat loss, reduced habitat quality, mortality, and reduced connectivity generally occur at different rates (Forman *et. al.* 2003). Figure 2.6 illustrates the four sequential but overlapping road effects impacting on an animal population and shows that population size is normally smaller after the time lag, with greater relative fluctuations over time (Forman *et. al.* 2003). The process goes as follows:

Stage 1: habitat lost to roads is the first effect on wildlife and results in roughly equivalent losses in population numbers;

Stage 2: reduced habitat quality caused by edge effects increases the habitat lost to forest-interior species and this loss may extend as much as 100 metres either side of the road corridor (Pohlman *et. al.* 2007);

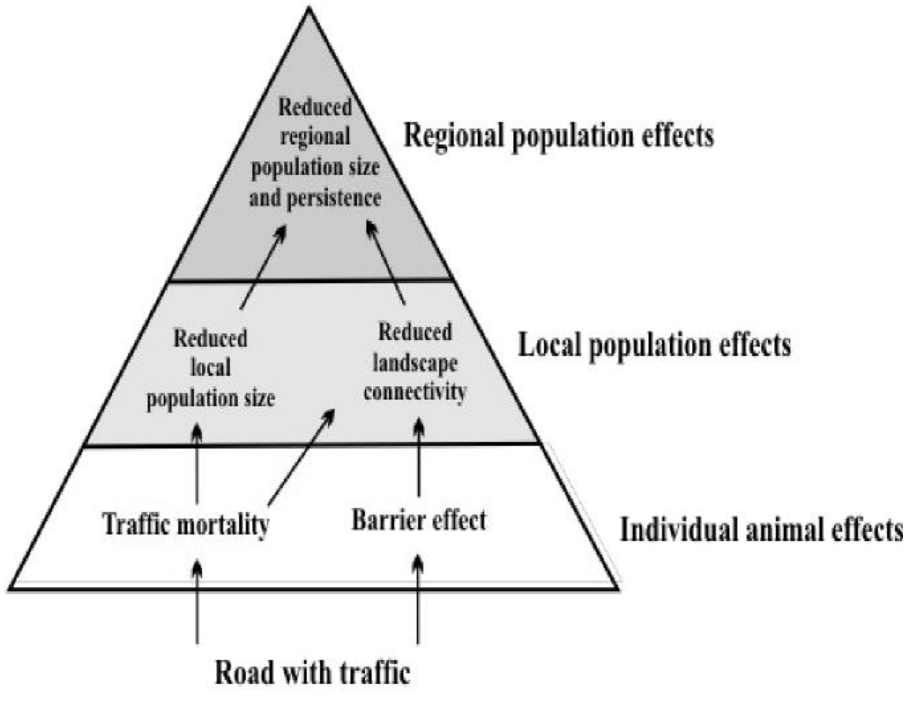
Stage 3: wildlife deaths accumulate as road traffic increases, although their effects are not generally perceptible for at least 1-2 generations of an animal species (cassowaries ~50 years);

Stage 4: landscape connectivity is reduced by the barrier effect of the road but may take several generations to occur.

(from Forman *et al.* 2003).

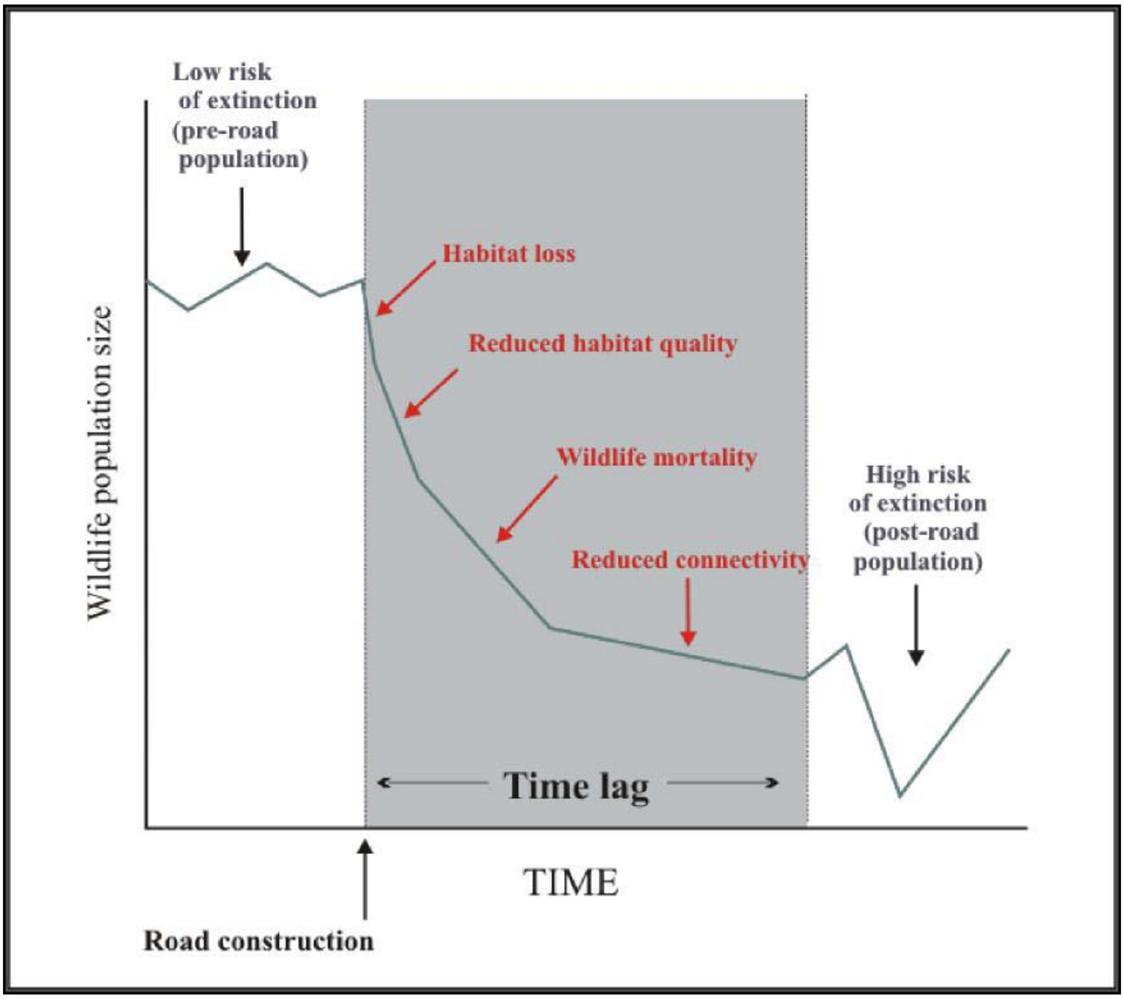
In a study of the loss of wetlands biodiversity (Findlay and Bourdages 2000), the time lag for road effects was estimated at 30-40 years. This finding highlights that to be effective, road mitigation needs to address ecological effects that may not be currently evident, but which may occur in decades to come (Forman *et. al.* 2003). We should remember that, without effective mitigation, cassowary deaths on the Mission Beach roads are likely to continue and that this loss in a long-lived species will reduce the population not only by removing individuals, but also the potential to breed.

Figure 2.5
Effects of roads on wildlife



Effect of road system on individual animals and wildlife populations (Adapted from Forman et al 2003)

Figure 2.6
Time lag of road effects (adapted from Forman *et. al.* 2003)



Cumulative effects

The combination of a series of barriers such as roads and powerlines or roads and railways may affect the movement of some animals to a greater degree than that of a single barrier. Caribou were found to cross roads readily but crossing frequencies dropped when a pipeline was constructed parallel to the road (Curatolo and Murphy 1986, Forman *et. al.* 2003). A similar response was observed in Spanish wolves which frequently crossed a multi-lane highway but decreased their crossings when a small road was constructed adjacent to the highway (Forman *et. al*. 2003).

For other ecological effects of roads see Chapter 1.

2.1.6 What makes a species vulnerable to road mortality?

Several factors appear to influence the vulnerability of a species to road mortality, some being related to roads while others are intrinsic species traits:

1. Vehicle speed and traffic volume influence the risk of wildlife collisions (Rolley and Lehman 1992, Joyce and Mahoney 2001, Forman *et. al*. 2003).
2. For species of concern, roads generally reduce population sizes and therefore increase the risk of population extinction (Forman *et. al.* 2003).
3. Populations of species with low densities, low reproductive rates, and long generation times are susceptible to high levels of mortality because they cannot recruit replacements into the population rapidly enough to replace those lost (With and King 1999; Forman *et. al*. 2003).
4. Highly mobile species are more vulnerable to road mortality because they are more likely to cross roads in their movements (Chruszcz *et. al.* 1980, Levin *et. al.* 1984, Forman *et. al*. 2003).

Forman *et. al.* (2003) list a number of characteristics that increase the vulnerability of a species to road effects. Two-thirds of these characteristics (8/12) are possessed by cassowaries (highlighted in bold font) and all but one of these predisposes the species to road mortality (Table 2.4).

Table 2.4
Characteristics making a species vulnerable to road effects (Forman *et. al.* 2003)

CHARACTERISTICS	EFFECT OF ROADS		
	Road mortality	Habitat Loss	Reduced Connectivity
Attraction to road habitat	*		
High intrinsic mobility	*		
Habitat generalist	*		
Multiple-resource needs	*		*
Large area requirement/low density	*	*	*
Low reproductive rate	*	*	*
Behavioural avoidance of roads			*
Territoriality	*		*
Large home range size	*	*	*
Longevity	*		
Habitat restricted	*	*	*
Dietary requirements		*	*

2.2 METHODS

2.2.1.Study Area

The Mission Beach study area is located approximately 120 kilometres south of Cairns and approximately 20 kilometres east of Tully. Cassowary habitat at Mission Beach comprises approximately 130km^2 of mosaic vegetation that varies significantly from areas of poor quality or privately-owned cassowary habitat to some of the highest quality cassowary habitat remaining on the lowlands south of Cairns.

Detailed descriptions of the climate, vegetation, and geology of the area are presented in Goosem (1992), Bentrupperbäumer (1998) and Moore (2007).

Approximately 63 kilometres of roads were surveyed and described in this study. The location and names of the Mission Beach cassowary study roads are presented on Figure 2.7. The locations of place names mentioned in the text of this report are shown on Figure 2.8.

2.2.2 Cassowary Road Crossing Points

Searches were conducted for a distance of 100 metres into the forest adjoining both sides of the road to identify all active cassowary road crossing points on:

1) the El Arish-Mission Beach Road from El Arish to Bingil Bay Road turnoff;

2) Bingil Bay Road -Garners Beach Road turnoff;

3) Bingil Bay Road from Garners Beach Road turnoff to Alexander Drive and Garners Beach Road:

4) Alexander Drive from end of Bingil Bay Road to Tully-Mission Beach Road (Cassowary Drive) turnoff;

5) El Arish-Mission Beach Road from Bingil Bay Road turnoff to Cassowary Drive turnoff;

4) Cassowary Drive (i.e. Tully-Mission Beach Road between the El Arish–Mission Beach Road and South Mission Beach Road);

7) South Mission Beach Road;

8) Tully-Mission Beach Road (from the South Mission Beach Road turnoff to the Bruce Highway); and

9) Bruce Highway near Smiths Gap.

No private property was surveyed without permission of the landowner. The study was confined to main roads (State controlled roads and the major connections listed above). Low traffic local roads were generally not studied.

Cassowary road crossings were identified by recording the location of cassowary activity (sightings, footprints, droppings, and vocalisations), and movement pads at the road edges and matching opposite entrance and exit points. These points were determined by the presence of defined pads or the presence of fresh droppings and footprints.

All crossings were subjected to two-hourly watches designed to represent a complete diurnal pattern (i.e. seven 2 hour watches at each site (05:00 – 19:00 hours)). However, the number of birds observed using the crossings was not sufficient to justify continuing this monitoring. Instead, observations were made at selected crossings known to have been frequently used in the past. The time to cross the road, the time of day the crossing occurred and the behaviour of birds using these sites was recorded.

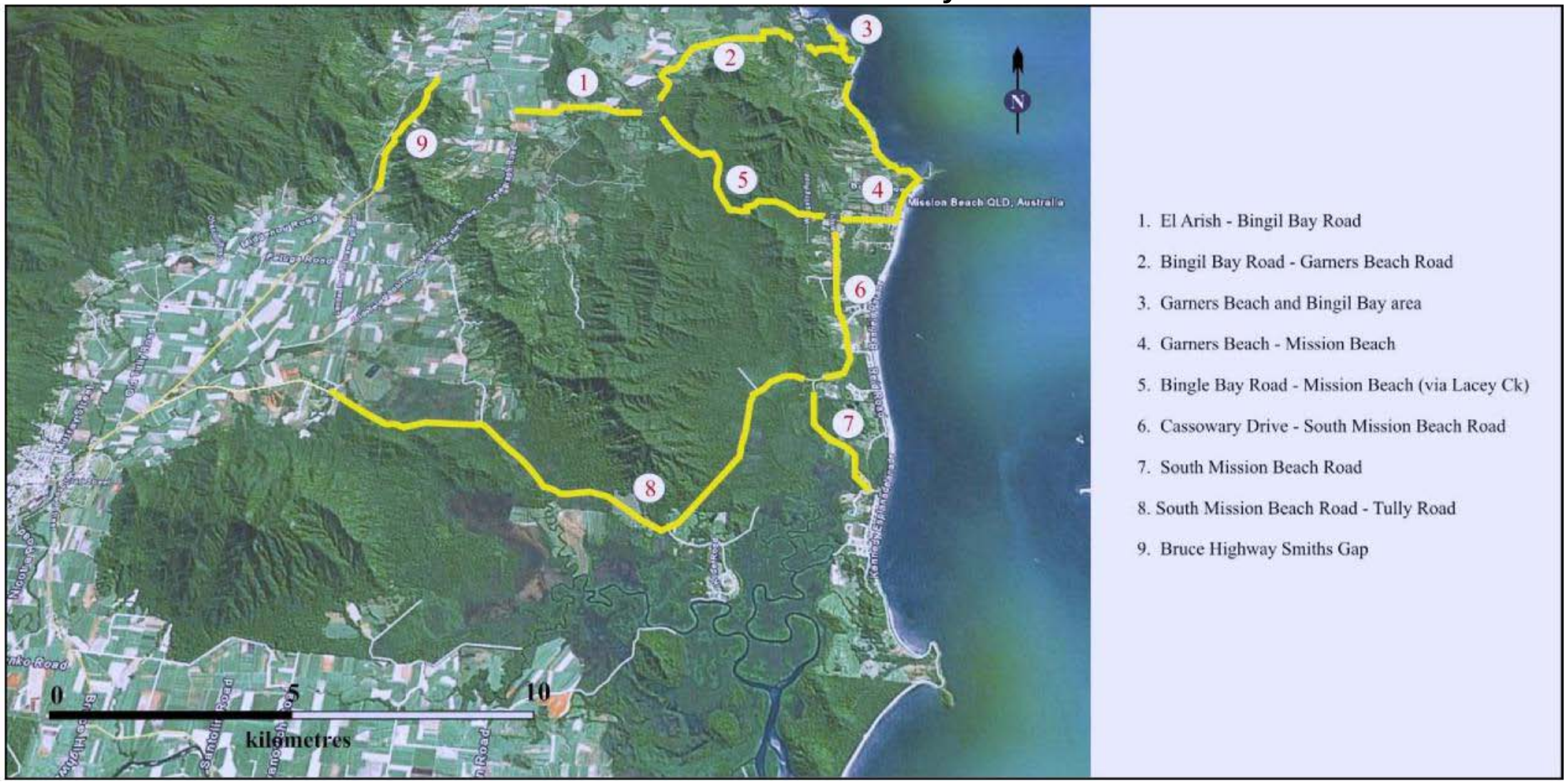
Current and past cassowary road crossings were mapped using a geographical positioning system (Magellan GPS 2000XL) and described using a variety of measurements including road and vegetation variables and landscape factors. These data were used to calculate risk assessments for individual crossings and sections of road.

2.2.2.1 Physical environment

Photographs of 20 of the previous cassowary road crossing points from 1998 were compared with photographs from the same point in 2008.

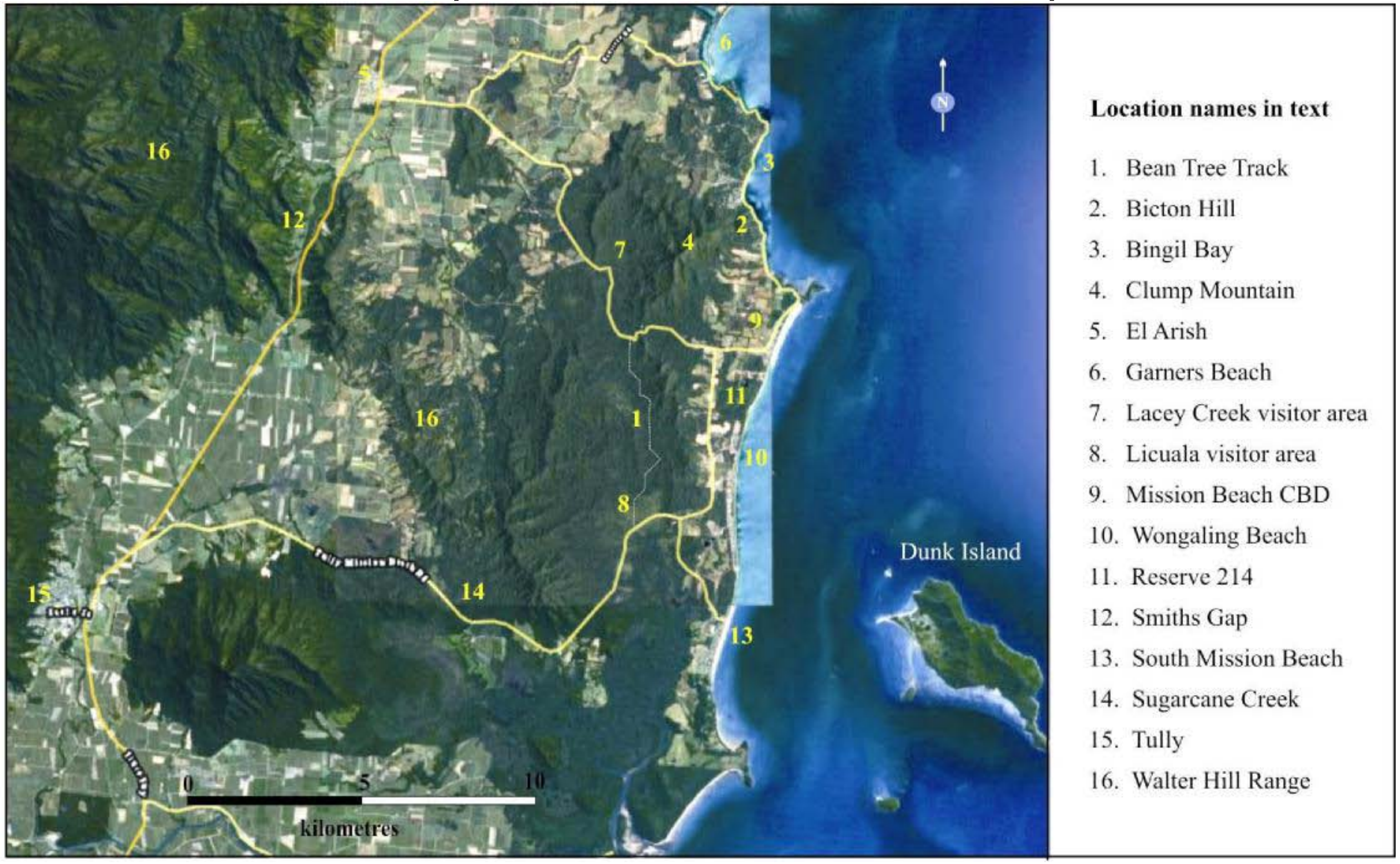
Habitat at each road crossing point was assigned to one of four dominant categories: intact forest, disturbed forest, vegetated corridor/fragment and riparian corridor. Crossings that occurred in urban or cleared areas all happened near fragments of riparian corridors and were thus assigned to those categories. Crossings were also examined for contiguous forest on either side of the road.

Figure 2.7
Location and names of study roads



Yellow lines represent roads that are included in this study. Crossings may exist on other roads not investigated in this study.

Figure 2.8
Location of place names mentioned in the text of this report



2.2.3 Historical data

The field data from this project and previous road studies at Mission Beach (Bentrupperbäumer 1992, Moore and Moore 1998, Moore 1999, 2003) provided additional information on crossing time, location and status of the crossing bird(s) e.g. adult, subadult, family party (328 records). These data were not included in the analyses of crossing frequencies.

Cassowary sighting sheets maintained by the Community for Coastal and Cassowary Conservation (C4) for the period 1996-2009 were used for crossing frequency analyses. Figure 2.9 presents an example of a sighting sheet. Cassowary sightings are mapped by numbered grid square which covers the Mission Beach area, with detailed location information also provided where known. The database of 2400 records was analysed in a variety of ways to establish annual, seasonal, daily, and temporal crossing behaviour. Only those records with certain locations were used.

2.2.3.1 Using community sighting sheets – biases and corrections

It would have been preferable to use the results of scientifically designed monitoring programs to estimate the state of the cassowary population and the frequency of road crossings by the birds at Mission Beach. However, scientific monitoring data were not available. The cassowary sightings sheets maintained by C4 provided an alternative approach, as many of the sightings are of birds crossing the roads. The great majority of records derive from visitors to the area, as most locals who see birds do not usually submit sightings to C4. The data is collected at the visitor information building which locals, other than volunteers, do not tend to visit.

There are a number of biases associated with any community survey and this is the case for the visitor cassowary sighting sheets (biases tend to send results in a certain direction because samples are not random). Major statistical issues include achieving an unbiased sample of the population that is being examined, and obtaining a sufficiently large sample for analysis. In the case of the Mission Beach sighting sheets, the sample size was adequate for many statistical analyses.

However, unbiased samples are difficult to obtain, partly due to the act of sampling itself (Cochran 1977). The C4 sighting sheets can be considered a targeted sample rather than a random sample i.e. only certain members of the population were targeted based on availability (those people who submitted cassowary sighting information to C4). This is often the approach required when dealing with rare events and was the only option available in this instance. In the case of the Mission Beach visitor reporting, biases include:

1. The visitor centre opening hours and how consistent these were in the time period i.e. records would not be included if the centre was closed, although visitation would still occur. Unfortunately this bias could not be corrected due to insufficient information. However, those visitors that stay overnight or for longer periods will often return to the visitor centre when it is open, so day visitors are the main ones missed in this bias. This bias could have affected sightings particularly those immediately after Cyclone Larry because the C4 environment centre was closed for much of that period. However, the standardisation by number of visitors would negate some of this problem, because visitors were few in the immediate aftermath of the cyclone. In contrast, the feeding stations implemented by QPWS after the cyclone may have encouraged the birds to stay away from the roads, so visitor sightings would be few. However, this lack of sightings would reflect a real lack of road crossings.

2. Accuracy of visitor information e.g. how well they can describe the location of the crossing, how well they remember the time of crossing, recognise age and sex etc.

These biases need to be considered in interpretation of the final results.

The assumption in this analysis is that visitors randomly decide to submit a cassowary sighting when they visit the area i.e. the chance of submitting a record is similar for all visitors. This may not be the reality, but it is the approach taken in the analyses of cassowary crossings observed by visitors in this study. The result cannot be a perfect product, no survey really is, but it provides insights into cassowary road crossing behaviour not currently available by any other means.

When tabulated, the number of cassowary sightings varied considerably, both on a yearly and monthly basis. This latter variation was assumed to be caused by variations in visitor numbers – for example, through the normal increase in visitors to Mission Beach during the drier, winter months. To attempt to remove this source of bias (increases and decreases in visitors over varying temporal scales) the data were standardised to cassowary road crossings observed per 1000 visitors for each year and month.

2.2.3 Analysis Methods

2.2.3.1 Data sources and extraction

Cassowary crossing data were extracted from the C4 Environment Centre sighting sheets. Only those records with a certain location were used. Of those with a certain location, crossings of the major roads described in section 2.2.2 were included for analysis.

The Cassowary Coast Regional Council (Angi Matveyeff pers. comm. 2009) provided the known annual and monthly visitor numbers to Mission Beach.

Cassowary crossing data from the C4 sheets were standardised using these monthly visitor numbers. Crossing totals are expressed as N crossings/1000 visitors. Unless otherwise stated, this is the data used in analyses.

2.2.3.2 Statistics

Yearly mean visitor numbers were calculated for the years 1997 – 2008 and monthly means were also calculated over that time period.

Cassowary road crossings per 1000 visitors were grouped by years, year and month, months and by site and explored for patterns before and after Cyclone Larry in 2006.

Using road traffic theory and risk-of-collision statistics, the probability of birds being hit was calculated for a range of traffic flows and vehicle speeds on the Tully-Mission Beach and El Arish-Mission Beach Roads.

Data were analysed using the software program Statistical Package for the Social Sciences (SPSS) for Windows, Version 12.0.1. (11/11/2003). Graphical displays were generated by SPSS and Microsoft Excel 2003 (11.6355.6408). Univariate Analysis of Variance (ANOVA) and paired t-tests were conducted to compare yearly, seasonal and locational aspects of the data. Kruskal-Wallis and other non-parametric tests were performed on data which failed to meet the assumptions of normality. Chi-squared contingency analysis was used to compare overall frequencies of road mortality on the 5 major roads with post-cyclone mortality on those roads.

Figure 2.9
Example of Committee for Coastal and Cassowary Conservation (C4) visitor sighting sheet used for crossing frequency analysis

Adult up to 2 metres tall
- glossy black plumage
- helmet or casque on top of head
- brilliant blue neck with red wattles
- difficult to tell male and female apart

Independent sub adult
- brown plumage (gains black plumage by 3 years)
- smaller wattles, orange-red
- beginnings of casque

Male adult with striped chicks
- chicks remain striped from 0 - 5 months
- an adult with chicks is always a male

Male adult with brown older chick
Any time after 5 – 16 months the chicks are chased away

Date	Time	What you saw [see description above]	What was the bird doing?	Location [please give full details and compass directions E W S N]	Grid No [if known]	Informant
Example May 97	*10am*	*sub adult or adult or male adult with chicks*	*Crossing the road or on side of road or feeding or drinking*	*Tully-Mission Beach Road crossing E to W approx 3 k from Licuala entrance or on children's walk Licuala*	*Map available at C4*	*Your name and contact number*
30/12/07	1630	ADULT	WALKING DOWN PATH	BICTON HILL WALK	T 11	NIALL
30/12/07	1300	ADULT + 2 CHICKS	ATTEMPTING TO CROSS ROAD AT POLICE STATION	WONGALING BEACH	S 18	NIALL
10/01/08	1000	ADULT	SITTING BY ROAD (ILL?)	GARNERS BEACH RD	T 09	VISITOR
10/01/08	1030	ADULT	WALKING IN RAIN FOREST	BICTON HILL WALKING TRACK	T 11	VISITOR
15/01/08	0745	ADULT WITH ONE CHICK	CROSSING ROAD NEAR POLICE STATION	WONGALING BEACH (DID HAVE 2 CHICKS)	S 18	NIALL
14/01/08	0745	ADULT WITH ONE CHICK	WALKING ON ROAD	MISSION HEIGHTS (DID HAVE 2 CHICKS)	S 22	NIALL
20/01/08	5pm	2 adults	confronting each other!	Bicton Hill track	T 11	visitor
25/01	3pm	1 Subadult	On Ken Campbell's farm	Boyett Road		KEN CAMPBELL
31/01/08	0900	1 ADULT	EATING ON SIDE OF ROAD	TULLY SMB ROAD	?	VISITOR
31/01/08	1700	1 ADULT 1 Chick	crossing the road	South mission Beach RD	S20	Anthony Cowell visitor
10/2/08	1030	1 adult	" " "	Cassowary drive Wongaling	S16	visitor

THIS SIGHTING SHEET HAS BEEN FUNDED BY A STATE GOVERNMENT GRANT

2.3 RESULTS AND DISCUSSION

2.3.1 Identified Crossings

The study roads at Mission Beach were classified into road sections as shown in Figure 2.7. Table 2.5 presents a summary of the number and density of crossings for each of the identified sections of road. The two major access roads of El Arish to Mission Beach and Tully to Mission Beach contain approximately 44% of total identified road crossings (35/80).

There were 80 individual cassowary road crossings located in the Mission Beach study area. Other crossings undoubtedly exist on the study roads and on unsurveyed local roads in urban areas. Crossings categorised as ‘past crossings’ may also still be active, although not observed to be in use during this study. Of the crossings marked, 60 were active and used by cassowaries during the 12 months of the project and 20 were past crossings that did not appear to be in use. The general locations of road crossings are shown on Figure 2.9 and an example of detailed mapping of crossing points is given in Figure 2.10. The GPS locations for all cassowary crossings are provided in Appendix 1.

Although these crossings were identified with location data, it should be emphasised that these are generally not exact points of crossings – many areas actually constitute zones of crossing where pads exist but cassowaries may cross anywhere in the vicinity.

Table 2.5

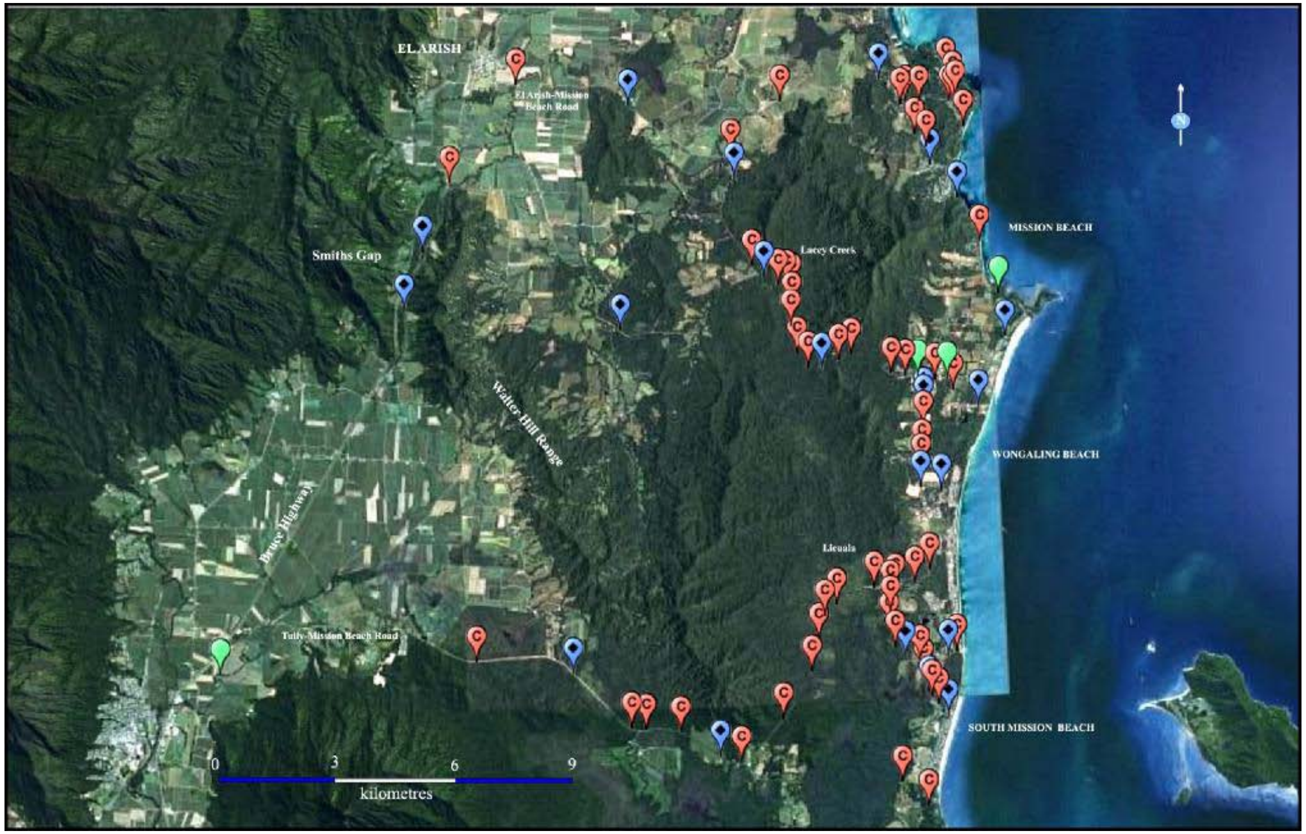
Road locations of identified cassowary road crossings

Road Section Number	Road location	Number of Crossings	Crossings per kilometre
1	El Arish- Mission Beach Road – Bingil Bay Road turnoff	2	0.36
2	Bingil Bay Road – Garners Beach Road turnoff	3	0.60
3	Garners Beach and Bingil Bay area	7	2.52
4	Alexander Drive – Cassowary Drive	6	0.8
5	El Arish – Mission Beach Road from Bingil Bay Road – Cassowary Drive (through Lacey Creek)	19	2.38
6	Cassowary Drive – South Mission Beach Road	6	1.16
7	South Mission Beach Road	8	2.55
8	Tully Mission Beach Road from South Mission Beach Road – Bruce Highway [1]	14	1.02
9	Bruce Highway - Smiths Gap	3	0.77

1 The 14 crossings along this road section are of much greater length than elsewhere at Mission Beach.

Figure 2.9

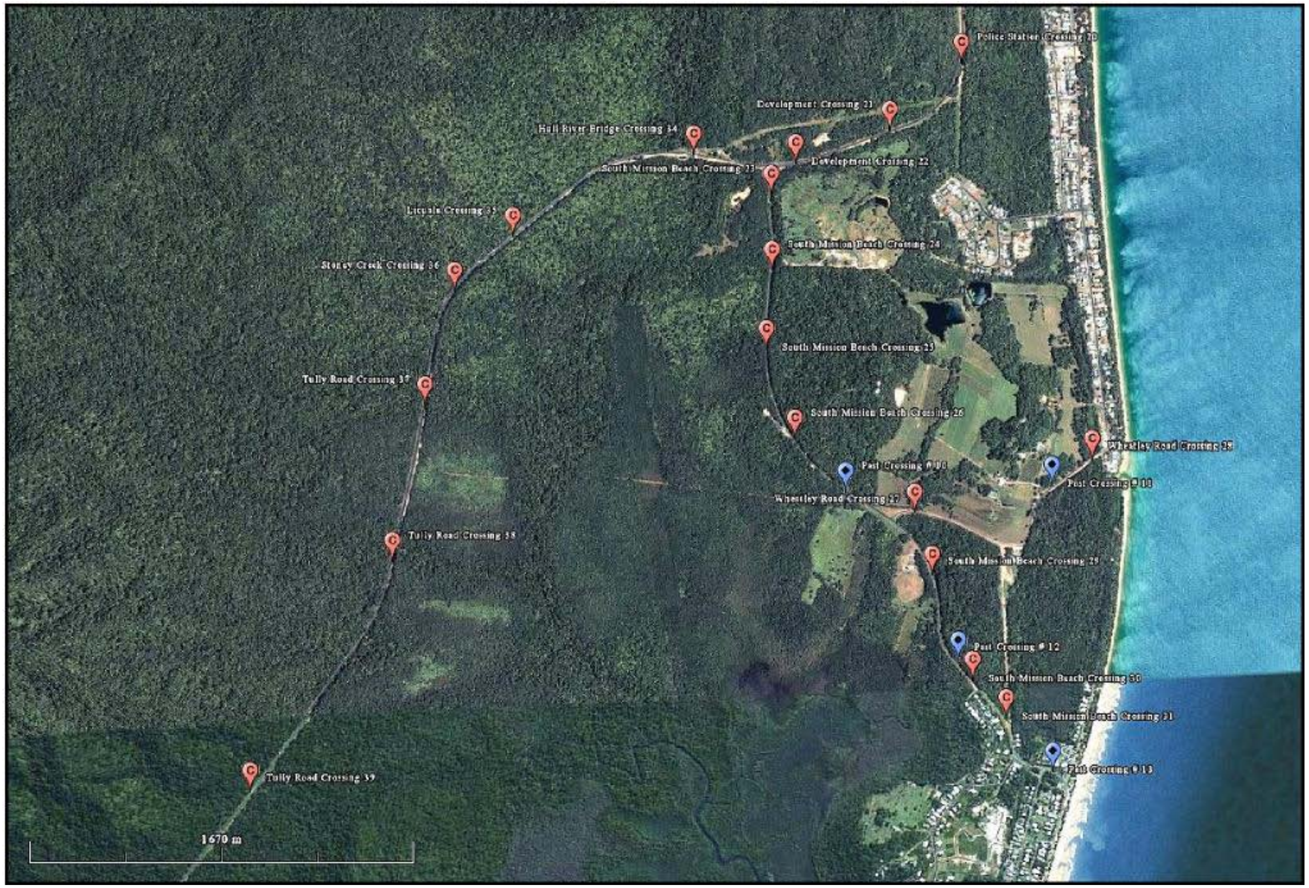
Overview of Mission Beach cassowary road crossing locations (N=80)



Red icons = active crossings Blue icons = past crossings Green icons = past sighting
Icons often represent a zone of crossings rather than exact points

Figure 2.10

An example of the detailed mapping of crossing locations (South Mission Beach Road and Licuala).

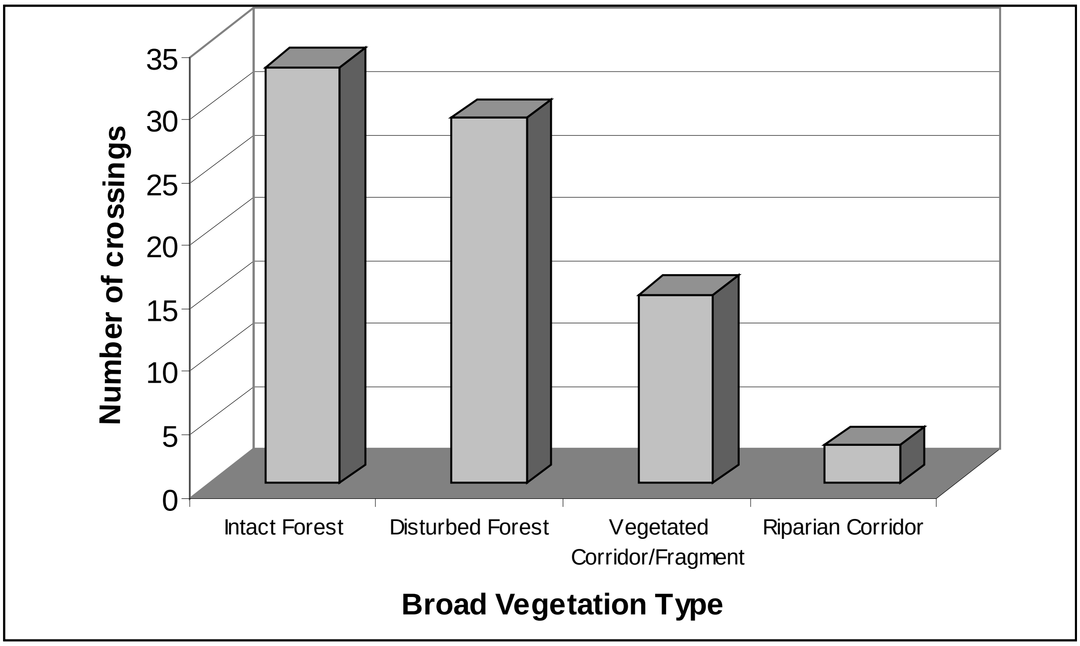


Red icons = active crossings   Blue icons = past crossings from previous studies
Icons generally represent a zone of crossings rather than exact points

2.3.1.1 Crossing Habitat Types

Twenty of the previous cassowary road crossings were photographed in 1998 and again in 2008 (Appendix 2). Most of the crossings show a widening of the road corridor (canopy to canopy) due to road upgrades and damage caused by Cyclone Larry in 2006. Figure 2.11 shows the number of road crossings which occur in each of the four major landscape categories. Most road crossings occur in areas of intact or disturbed forest, although vegetated corridors and fragments contain a substantial number of crossing areas. It should be remembered that lengths of road in intact and disturbed forest are much greater than those in remnants and riparian areas.

Figure 2.11
Number of Cassowary Road Crossings in each of the four major habitat categories



Two of the identified road sections have >50% of their length with contiguous forest on both sides of the road (Table 2.6). The El Arish – Mission Beach Road between the Bingil Bay Road turnoff and Cassowary Drive turnoff (Lacey Creek section) has 72.6% of its length with contiguous forest. The Tully-Mission Beach Road between the South Mission Beach turnoff and the Bruce Highway at East Feluga has 78.9% of its length with contiguous forest either side. These two roads also contain approximately 44% of all the identified road crossings in the region. Both roads, particularly the Tully-Mission Beach Road are designed for high vehicle speeds. The South Mission Beach Road also has substantial lengths of contiguous forest on either side (~46%) and vehicles travel along this road at high speeds also. Contiguous forest on either side comprises 65% of the short length of forested ‘corridor’ along the Bruce Highway at Smith’s Gap. However, other barriers are also present in the form of the railway. The remaining five road sections are council-controlled and traverse mainly cleared or modified habitat, although some sections around Garner’s Beach and Bingil Bay provide short areas of contiguous habitat.

Table 2.6
Habitat adjoining known cassowary road crossings

Road No.	***Road location***	***Length of road (km)***	***Vegetation both sides (km)***	***% crossing habitat***
1	El Arish – Bingil Bay Road turnoff	5.41	0.25	4.6
2	Bingil Bay Road – Garners Beach Road turnoff	5.01	0.3	6.0
3	Garners Beach and Bingil Bay area	2.81	0.57	20.0
4	Alexander Drive – Cassowary Drive	6.54	0.38	6.0
5	El Arish-Mission Beach Road from Bingil Bay Road turnoff – Cassowary Drive (Lacey Ck)	8.16	5.92	72.6
6	Cassowary Drive – South Mission Beach Road	5.17	1.4	27.1
7	South Mission Beach Road	3.35	1.53	45.7
8	Tully-Mission Beach Road from South Mission Beach Road turnoff – Bruce Highway	14	11.05	78.9
9	Bruce Highway - Smiths Gap	3.89	2.54	65.3

2.3.2 Cassowary Road Crossings

2.3.2.1 Annual means of visitation to Mission Beach

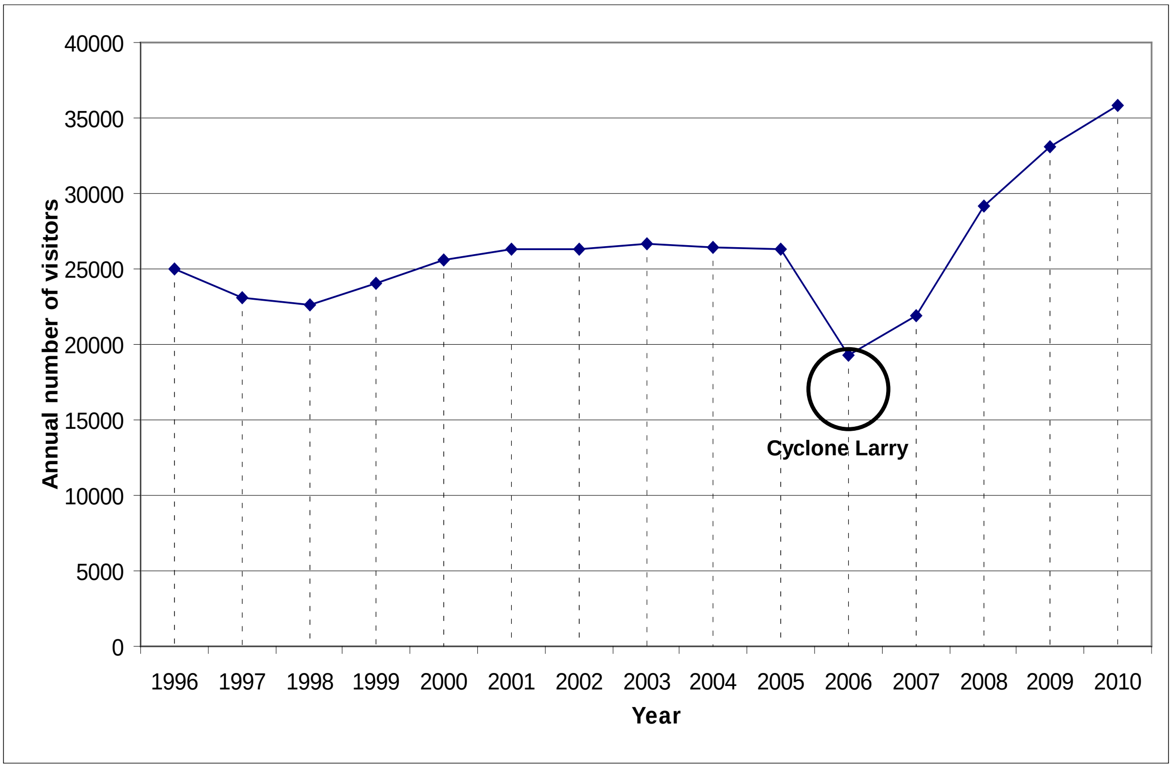
Mean visitation in the years between 1997 and 2010 were 26,097 ± 1102 (SE) people. Figure 2.12 shows that annual visitor numbers to Mission Beach were relatively stable apart from two divergences. The first obvious deviation from the mean followed the arrival of Cyclone Larry in 2006 (19,258 visitors) and the downturn continued in 2007 (21,907 visitors). Since then, visitor numbers have been climbing steadily (Figure 2.12).

2.3.2.2 Monthly means of visitation to Mission Beach

The annual visitor numbers were pooled to obtain monthly means (Figure 2.13). There was a background level of approximately 1000 visitors per month in January to March, and again in December.

Visitor numbers quickly rise from April, reaching a peak in July (~4400) before gradually decreasing from August to November. Figures indicating the relative proportion of national and international visitors are not available.

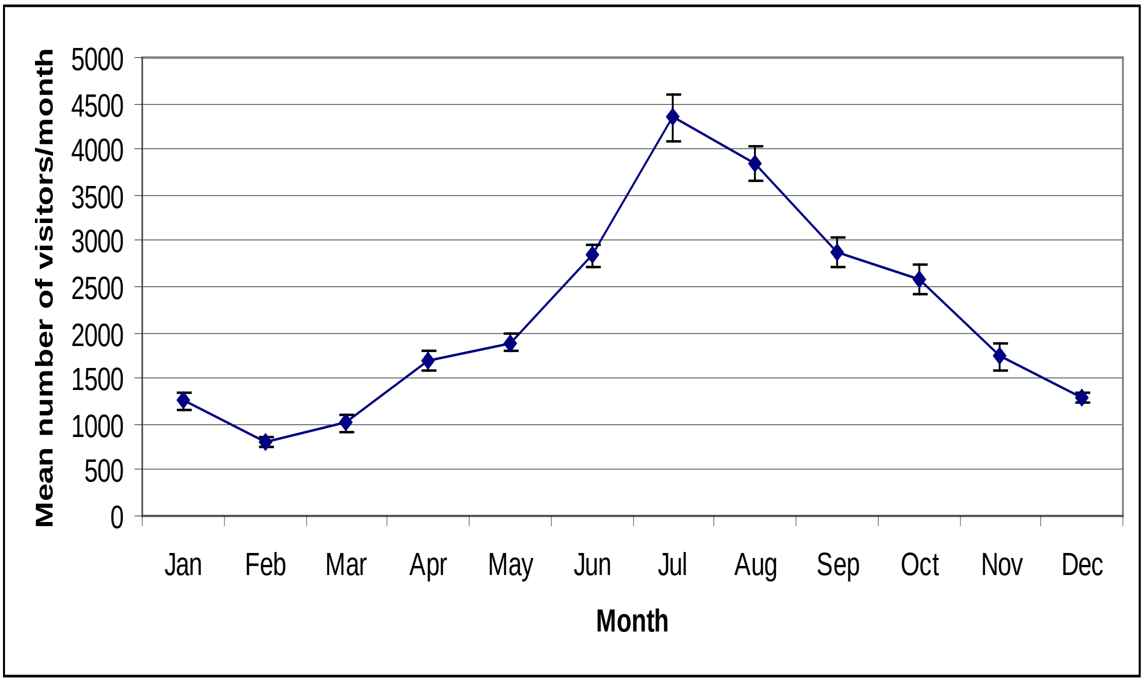
Figure 2.12
Annual visitor numbers at Mission Beach 1996-2010*



*Visitor numbers for 2010 did not include December so the average for December 1997-2010 was included; this is likely to be an underestimate.

Note: Decreased visitation coincides with major events

Figure 2.13
Mean (SE) monthly visitor numbers (1997-2010)



2.3.2.3 Mean Annual Cassowary Road Crossings 1997 - 2008

A total of 2400 cassowary road crossings were recorded, by visitors filling out C4 sighting sheets from 1997 to 2008. As birds frequently cross outside the sight of observers, this figure represents the minimum number of road crossings made by cassowaries in the 12 year period (Table 2.7). To illustrate this point, while monitoring activity at a crossing point near Lacey Creek (June 2008), an adult female cassowary was observed to cross the road three times in nine hours, unseen by tourists in the nearby car park or by passing drivers (this bird was subsequently killed on the road).

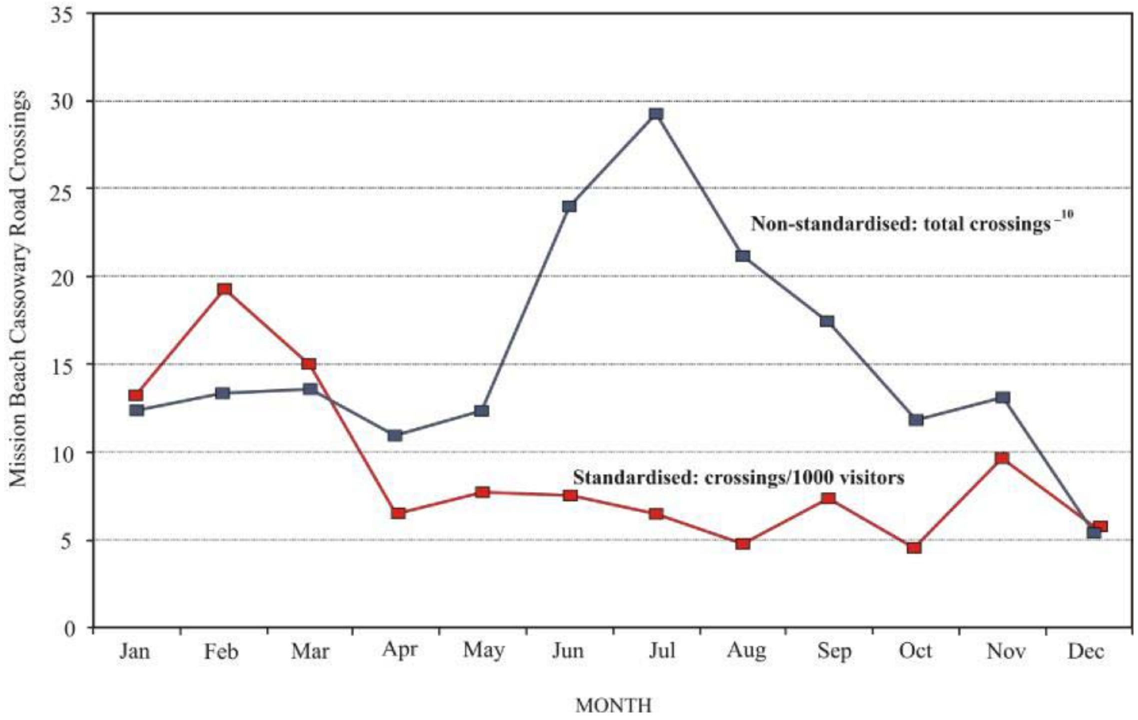
Cassowary road crossings recorded on the C4 sightings sheets prior to Cyclone Larry ranged from a low of 138 crossings in 1998-1999 to a high of 233 crossings in 2005-2006 (unadjusted for visitor numbers) (Table 2.7). Mean annual crossings for the nine years pre-cyclone (1997–2005) was 186.3 ± 10.3 crossings per year. Annual road crossings decreased in the three years post-Cyclone Larry (2006-2008) to only 46 ± 21.52 crossings per year, a decrease of approximately 75%.

Approximately 90% of the records in the cassowary sighting database were submitted to C4 by visitors. Because visitor numbers peak between May and October, there is more opportunity for road crossings by cassowaries to be recorded in the C4 sightings sheets in those months. Similarly, in years when there are fewer visitors, there are likely to be fewer records. This creates a significant bias in the sightings records. Accordingly, the crossing data was standardised to the number of cassowary sightings per 1000 visitors per month and year. Figure 2.14 shows the monthly non-standardised sighting data together with the standardised figures. Although the raw data indicates a peak in cassowary crossings from May to October during the peak visitor season, the adjusted figures show that cassowary roads crossings are actually more frequent between January and March. All subsequent analyses have been conducted on standardised crossing data.

Table 2.7
Annual cassowary road crossings - April to April

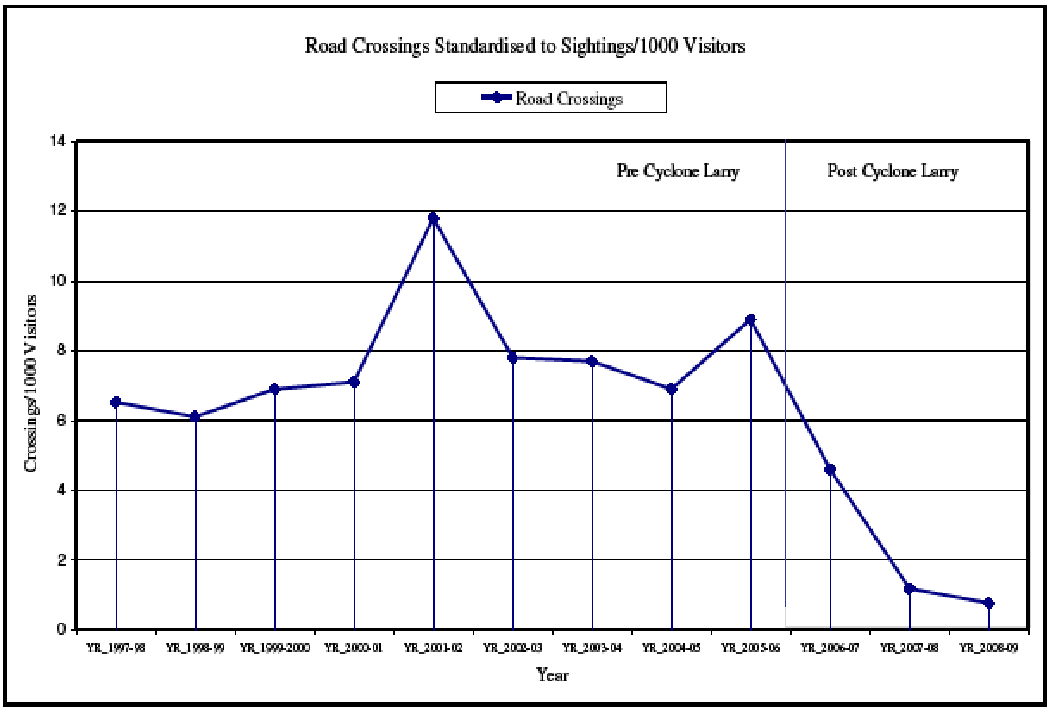
Year	Cassowary Road Crossings
1997-98	151
1998-99	138
1999-2000	166
2000-01	181
2001-02	213
2002-03	206
2003-04	206
2004-05	182
2005-06	233
2006-07	89
2007-08	26
2008-09	23

Figure 2.14
Non-standardised and standardised monthly cassowary road crossings



Once cassowary road crossings per year were standardised to 1000 visitors over years and months, around 6-8 crossings per 1000 visitors were recorded per year. The exceptions were 2003 (a high of 12 crossings/1000 visitors) and 2006-2008 after the cyclone when numbers of crossings recorded in the sightings record dropped (Figure 2.15).

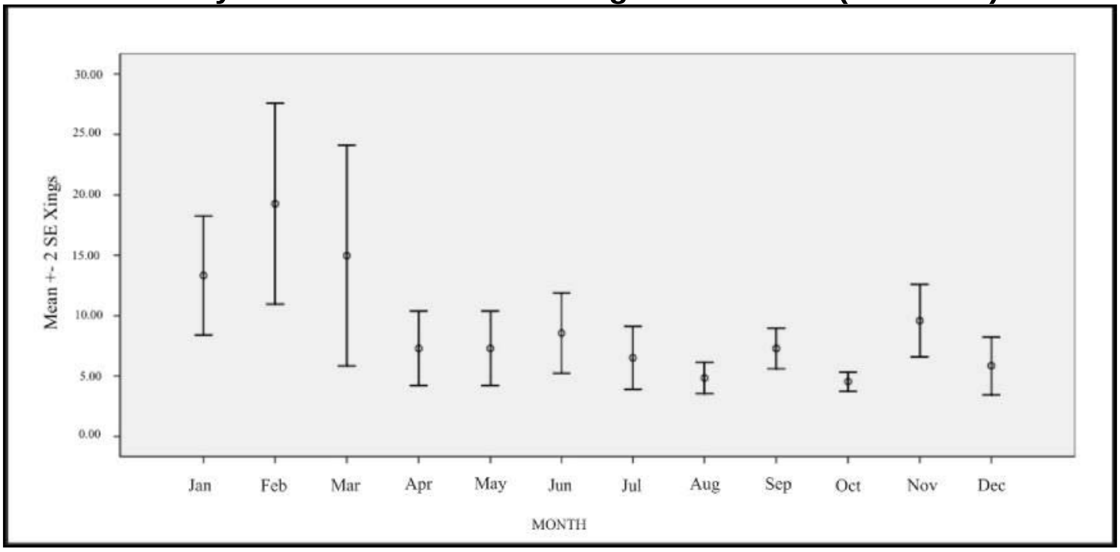
Figure 2.15
Annual Mission Beach cassowary road crossings/1000 visitors 1997-2008



2.3.2.4 Mean Monthly Cassowary Road Crossings 1997 - 2005

Monthly crossing means were obtained by grouping all cassowary road crossings between 1997 and 2005 prior to Cyclone Larry into monthly totals and standardising to the number of crossings per 1000 visitors (Figure 2.16). Analysis of variance confirmed significant differences in crossing frequency between months ($F_{1,11} = 4.151$, $P = 0.001$).

Figure 2.16
Monthly mean & se of road crossings/1000 visitors (2001-2005)



2.3.2.5 Temporal distribution of cassowary road crossing

Cassowaries are diurnal but can begin moving from their sleeping sites at dawn. To determine whether cassowaries cross roads more at certain times of the day, road crossings with definite time observations (N=579) were grouped into hourly time periods beginning at 05:00 hrs and finishing at 19:00 hrs**.** Observed crossings were relatively evenly distributed throughout the day, other than in the early morning (05:00 - 07:00) and late in the evening (18:00 – 19:00), when recorded crossings were low. The lower number of observations in those time periods probably relates to less road traffic and visitors at that time of day, together with later dawn and earlier dusk in the winter months. No cassowary crossings were recorded at night.

2.3.2.6 Demography of cassowary road crossings

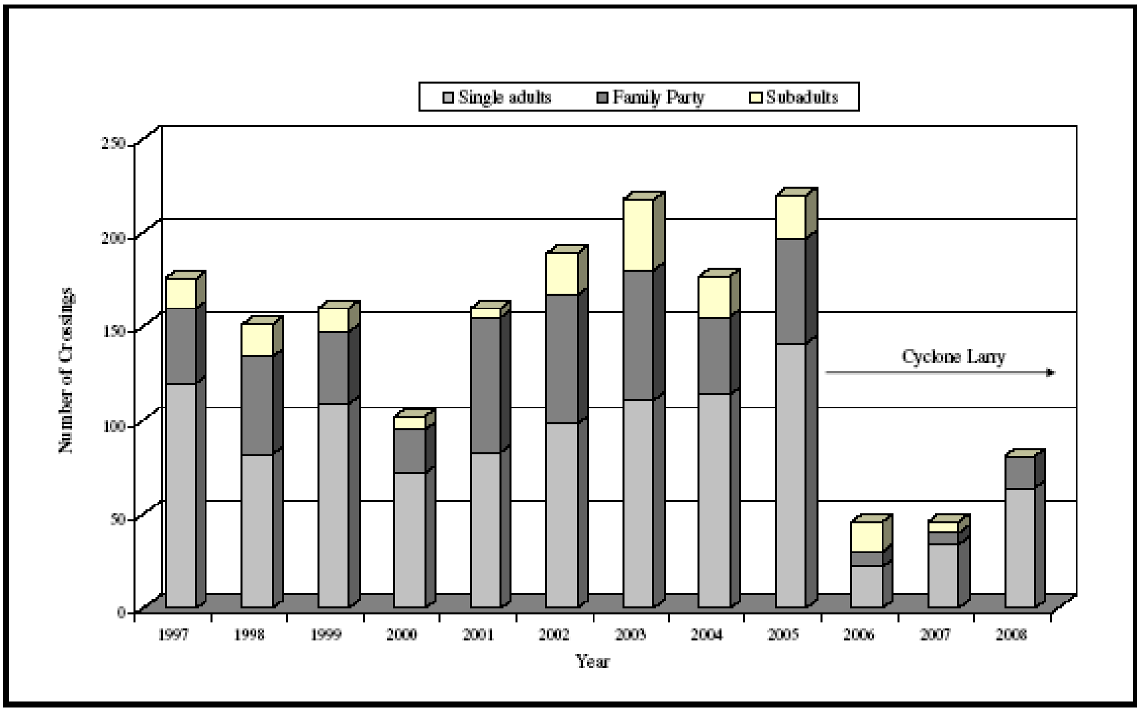
A total of 2213 road crossings by cassowaries were divided into three cohort classes: single or paired adults, family parties, and subadults. Sightings where the age of the cassowary was uncertain were omitted from this analysis. Annual proportions of each class were determined and an overall annual mean for cohort class was calculated over the twelve years of crossing data. This showed that adults crossed more frequently (61%, s.e 2.63) than family parties (28%, s.e 2.60), or subadults (11%, s.e. 1.31).

Figure 2.18 shows the annual demographics of cassowary road crossings from 1997-2008. There was a 49% increase in the mean number of family party sightings in 2001-2003 (mean 25.37, s.e. 1.86) compared to previous and following years (mean 37.73, s.e. 3.89). It is postulated this increased breeding may have been the result of the above-average rainfall that occurred in the preceding years of 1998-2000 (Table 2.8). It is interesting to observe, however, that this apparent high reproductive rate in 2001–2003 was not reflected in significant increases in subadult sightings in subsequent years.

Table 2.8
Annual rainfall (mm) 1997-2007 (Tully)

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
4153	5086	5913	5947	3845	2256	2939	4199	2725	4271	4176

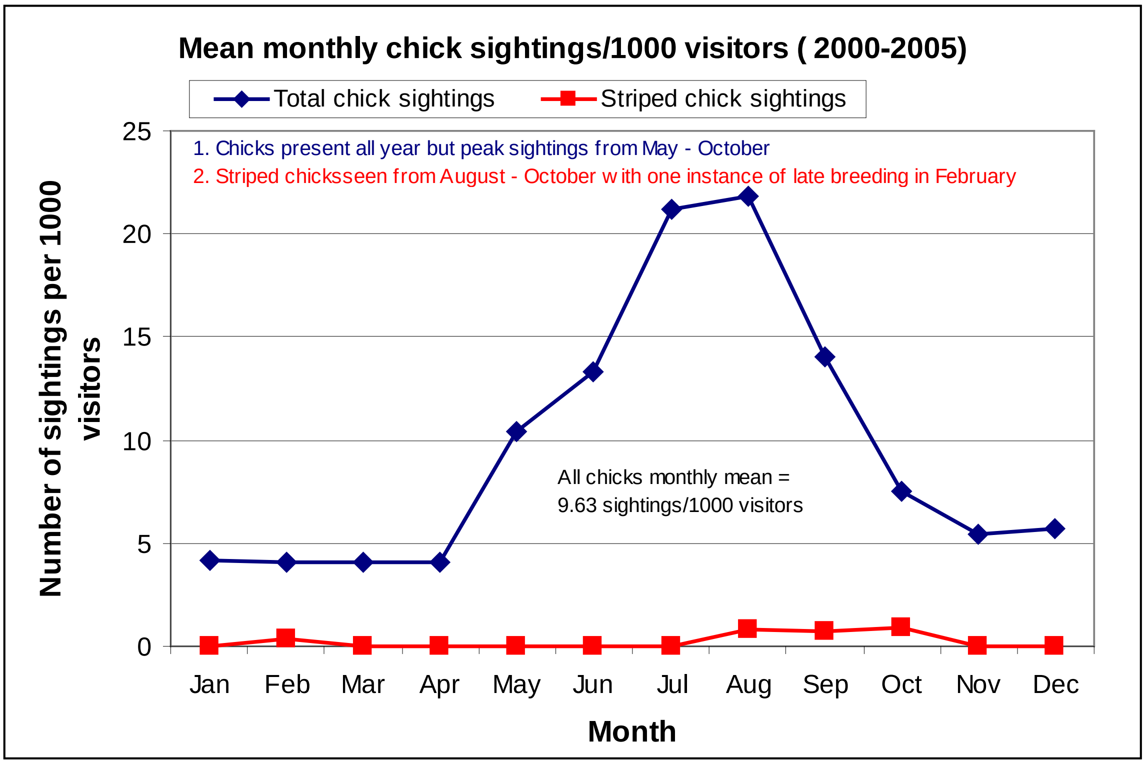
Figure 2.18
Annual demography of cassowary road crossings 1997-2008



2.3.2.7 Is there a defined breeding season at Mission Beach?

Although brown juveniles in the company of the male parent are observed in all months of the year, sightings peak from May to October. In this study, the breeding season has been defined as the calculated time of first egg-laying until the absence of striped chicks in the population. The onset and cessation of nesting is considered to be the 52 days before the first sighting of striped young until the last sighting of striped young (Figure 2.19). In an analysis of 1050 family party sightings, the earliest record of striped young occurred in August and the last sighting in October. As the incubation period is approximately 52 days (Crome and Moore 1990, HANZAB 1990, Bentrupperbaumer 1998) the first eggs of the year would have been laid in early June, with laying continuing to approximately mid-August.

Figure 2.19
Mean monthly sightings of striped and brown cassowary chicks



The occasional sighting of striped chicks in February indicates egg-laying can occur as late as December. However, the absence of striped chicks indicates that breeding is probably rare at other times of the year. One of the intriguing facets of the life history strategy of the cassowary is that adult males do not all breed in the same year. This is clearly illustrated by the presence of chicks from one to nine months old in the population. It is unknown whether females exhibit the same reproductive pattern or if they mate with unaccompanied males and produce eggs every year.

2.3.2.8 Do cassowaries cross the road at regular locations?

Previous cassowary studies at Mission Beach (Bentrupperbäumer 1992, Moore and Moore 1998, Moore 1999 - 2007) indicated that cassowaries regularly used the same crossing locations over a number of years. For example, 86% of the crossings identified by Moore and Moore (1998) on the three major roads of El Arish-Mission, Cassowary Drive, and Tully-Mission Beach Roads remain active a decade later. However, road crossings away from 'traditional' crossing locations also occur. In areas that have been partly cleared, road crossing points are usually restricted to remnant vegetation lines which allow the cassowaries sheltered access to the road. The reason behind the choice of crossing areas is not as clear within continuous forest, with individual home range requirements, social systems, landscape constraints, and preferential use of habitat all playing a role in crossing selection (Mack 1995, Moore and Moore 1998, Moore 1999-2007).

2.3.3 How do cassowaries cross the road?

There is little data on cassowary road crossing behaviour. Observed crossing behaviour falls into the following broad categories:

- running across without previous indication (uncommon);
- sighted by the roadside before running across the road (common);
- sighted standing by or walking along the road verge before walking across (frequent);
- walking down the centre of the road pavement (uncommon);
- watching traffic by the roadside before returning to the forest without crossing (frequent).

2.3.3.1 *Observed Road Crossing Behaviour*

The crossing behaviour of cassowaries was observed in sixty-one cassowary road crossings along the El Arish to Mission Beach Road during this study (2008-2009):

- 41 walked across after standing by the roadside or within the vegetation line;
- 5 stood by the roadside until a break in traffic then crossed;
- 3 ran across in front of approaching cars;
- 5 were sighted in the middle of the road in the act of crossing;
- 7 stood by the roadside but moved back into the forest without crossing.

Constant background vehicle noise does not appear to trouble cassowaries when they are preparing to cross the road. However, loud and irregular sounds, such as that made by large trucks or cars with trailers, will always frighten birds and it is unpredictable whether they will run cross the road in front of the vehicle or retreat back into the forest. Figure 2.20 shows a subadult cassowary at Nonda Street (Mission Beach) frightened away from the road by the arrival of a large truck.

Figure 2.20
Series of photos showing a subadult cassowary being frightened from crossing the road by a large truck (Photographs: Ms Liz Gallie)

Some cassowaries become habituated to roads and will calmly attempt to cross between passing vehicles (Figure 2.21). If sighted early, most drivers will slow or stop to let the bird cross safely. However, a crossing cassowary can be easily concealed from view by a first vehicle, subsequently colliding with the following vehicle that was unsighted.

The majority of cassowary road deaths occur on high speed roads. One such road is the Lacey Creek section of the El Arish to Mission Beach Road. Although this road has a posted speed limit of 80 kph, vehicles have been timed at 164 kph along parts of its length (Goosem pers. comm.). This speed gives drivers little time to slow down adequately to avoid a cassowary crossing the road. Figures 2.22 and 2.23 show two separate crossings made by an adult female cassowary (June-July 2008) whose territory extended both sides of the road and encapsulated the Lacey Creek and Licuala walking trails. Figure 2.22 shows how difficult it is to detect a cassowary on a dark road surface against a varied coloured background of rainforest. Monitoring from April – August 2008 showed this bird frequently crossed the road 3-4 times each day.

Figure 2.21
Adult cassowary crossing the road between passing vehicles (Photo: M. Prociv)

Figure 2.22
Cassowaries crossing the road in open areas can be difficult to detect

Figure 2.23 shows the adult female cassowary had just crossed the road when a vehicle travelling in excess of 100 kph passed. This cassowary, which had been identified ten years ago in the 1998 field survey, was subsequently killed at this location in September 2008.

Figure 2.23
Vehicles travelling fast are more likely to collide with cassowaries

2.3.3.2 Most common road crossing behaviour:

The behaviour of the majority of crossing birds (41/61 crossings) was similar but may have been influenced by the proximity of an observer:

1. Birds planning to cross the road stood just inside or on the edge of the vegetation line;
2. On deciding to cross the road birds came out of the forest and hesitated briefly on the road verge (2-5 seconds);
3. Crossing birds moved across the road pavement without stopping;
4. Individuals often stood briefly on the opposite road verge looking back along the road before entering the forest;
5. Four birds stopped midway across the road and ran off when startled by approaching cars.

2.3.3.3 Mean length of time to cross the road:

The mean time taken to cross the road in the 61 observed crossings was 13.5 secs.

2.3.3.4 Range of possible road crossing times

A simple calculation of the expected time to cross the road (Langevelde and Jaarsma 2004) can be used to determine the variation between walking and running pace, as several birds were observed to run across (see 2.3.3.1).

The formula calculates the time (C) in seconds for an individual to cross the road:

$$C = (B + L)/V$$

Where *B* = pavement width (metres):
L = average body length of the species (metres snout – tail tip);
V = crossing speed (metres/sec) (Langevelde and Jaarsma 2004).

Cassowary walking speed is estimated at 60 metres/minute i.e 1 metre/sec
Cassowary running speed is estimated at 250 metres/minute i.e. 4.167 metres/sec

At walking speed it would therefore take a cassowary 9.5 seconds to cross;

At running speed it would take the cassowary 2.3 seconds to cross;

Assuming that a) the body length, *L*, for a cassowary is 1.5 metres
b) the pavement width averages 8.0 metres
c) birds cross the road without any waiting time
d) birds cross the road at right angles to the road surface
e) birds cross the road at a constant speed.

Therefore the expected time to cross the road pavement ranges between 2.3 and 9.5 seconds if a bird crosses perpendicularly without waiting.

If we modify the Langevelde and Jaarsma (2004) formula to take into account the fact that the bird is on the road from the moment its beak crosses the pavement, to the moment its tail leaves the pavement (D. Westcott, pers. comm.), the formula becomes

$$C = (B + 2*L)/V$$

and the expected times to cross at walking and running speed become 11 seconds and 2.6 seconds respectively.

As the mean crossing time recorded was 13.5 seconds, 4 or 2.5 seconds slower than calculated for walking speed, all of the assumptions must not be met in the majority of cases.

Observations suggest that much of the extra time spent on the road by cassowaries involved standing on or near the road pavement prior to crossing. Birds also often stopped while still on the opposite edge of the road pavement to look along the road, presumably for approaching vehicles. Additionally all birds do not cross at right angles in a straight line.

2.3.4 Scenarios of cassowary deaths on the two major entry roads to Mission Beach

Single crossing event:

Scenarios were developed that allow comparison of the likelihood of cassowary road death on the two major entry roads into Mission Beach i.e. the Tully–Mission Beach Road between the Bruce Highway and the South Mission Beach Road turnoff, and the El Arish–Mission Beach Road between the Bingil Bay Road turnoff and the Cassowary Drive turnoff.

Models were derived from the predictive model of Hels and Buchwald (2001) which was developed for estimating wildlife-vehicle collisions for a specific road. The model incorporates species-specific information on the rate of a species' movement while crossing a road, the known traffic volume, and the approximate size of the impact zone. A simplified version of the equation is:

Probability of road mortality (P_{killed}) = 1 - ($e^{-Na/v}$)
Where
N = vehicles per minute
a = width of kill zone (metres)
v = velocity of animal moving through kill zone (metres/min).

Similar to previous calculations, assumptions of this model include:
a) Animals cross perpendicular to the direction of traffic:
b) All collisions are fatal.

This model does not include the role of driver and animal behaviour in attempting to avoid a collision or the potential for habituation of animals to vehicles enabling them to learn avoidance behaviour. Similarly the potential for the crossing speed of the animal to affect the ability of a driver to avoid a collision is not included. Therefore the model only provides an indication of potential for road death in a simplified situation.

However, the model does present an opportunity to compare scenarios from different Mission Beach roads of the likelihood of a simplified potential road crossing by a cassowary resulting in death at the speeds, traffic volumes and road widths that are known to occur on the Mission Beach entry roads (Chapter 4).

In the following scenarios, models were developed in collaboration with statisticians Dr Mick O'Reilly (Director, Sstat Pty Ltd) and Dr Walter Robb (Director, Analyse Australia Pty Ltd).

In the Mission Beach scenarios, the following assumptions were made:
a) the kill zone of cassowaries was calculated as the average width of a vehicle (2 m);
b) any collision causes severe injury or death;
c) road pavement width is 8 metres;
d) cassowary body length is 1.5 metres.

Three velocities for road crossing cassowaries were used:
1) approximate rate of normal movement when walking (60 metres/minute or 3.6 km/h);
2) mean observed crossing speed (42 metres/minute or 2.5 km/h);
3) approximate running speed (250 metres/minute or 15 km/hr).

Three vehicle frequencies were modelled:
1) June- September AADT of the El Arish–Mission Beach Road: 119 vehicles/hour during daylight hours (1.98 vehicles/minute);
2) June – September AADT of the Tully-Mission Beach Road: 208.7 vehicles/hour during daylight hours (3.48 vehicles/minute)
3) Williams *et al.* 2009: Tully–Mission Beach Road: 257 vehicles/hour (4.3 vehicles/ minute).

The results of the three scenarios are shown in Figure 2.24 and the first two are presented in Table 2.9 omitting the third traffic figure as it was higher than observed in Chapter 4. However, it is likely that these traffic figures come from Cassowary Drive so do represent a level of traffic observed on roads at Mission Beach (Tully–Mission Beach Road where it passes through Wongaling).

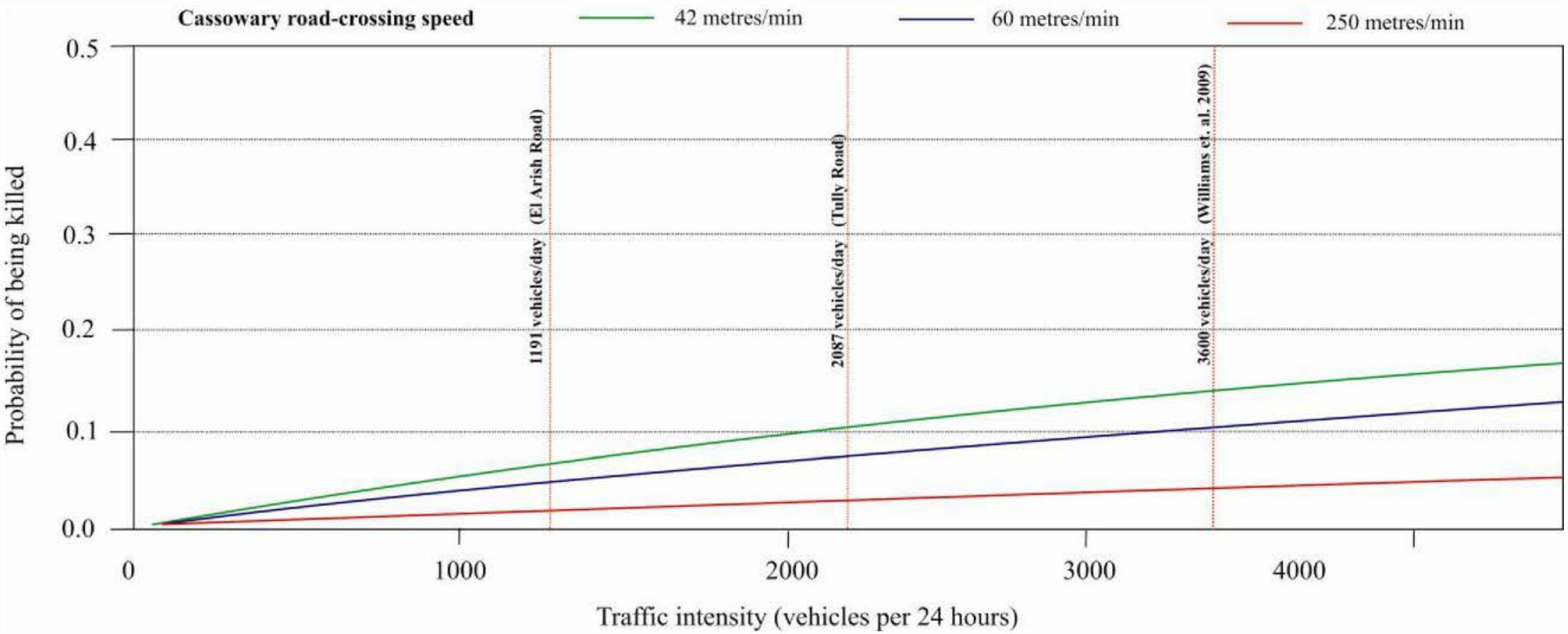
The scenarios predicted that cassowaries have approximately 60% greater likelihood of being killed crossing the Tully–Mission Beach Road at current measured traffic flows than when crossing sections of the El Arish-Mission Beach Road with similar design parameters. The difference is a direct function of the greater traffic volumes on the Tully–Mission Beach Road. As traffic volumes increase probabilities will increase also.

These scenarios do not take into consideration the higher traffic speeds observed on the Tully–Mission Beach road. This would be expected to increase the risk of injury and reduce potential avoidance time. Similarly they do not take into account the distance from which the driver has the opportunity to observe a bird crossing (line of sight) or from which the bird can see an approaching vehicle to allow either to take evasive action, reducing potential avoidance time on curved or hilly road sections.

Table 2.9
Estimates of the probability of a cassowary being hit by a car in a single crossing event (road data from Goosem 2009)

Crossing velocity	***Lacey Creek***	***Licuala***
Walking speed (60m/min) averaged over all angles of crossing	P = 0.047	P = 0.075
Walking speed (60m/min) perpendicular crossing relative to road	P = 0.014	P = 0.024
Running speed (250m/min) averaged over all crossing angles	P = 0.014	P = 0.025
Running speed (250m/min) perpendicular crossing angle	P = 0.003	P = 0.006
Observed speed (42m/min) averaged over all angles of crossing	P = 0.063	P = 0.098
Observed speed (42m/min) perpendicular crossing relative to road	P = 0.019	P = 0.034

Figure 2.24
Three scenarios with estimates of the likelihood of cassowary road death in a single crossing event



The models estimated a range of probabilities of cassowary mortality during a single crossing event of the El Arish–Mission Beach road for a variety of crossing angles and crossing speeds that ranged between 0.014 – 0.063 (1 – 7%). For the Tully – Mission Beach Road the corresponding estimates ranged between 0.034 and 0.098 (3 – 10%).

Using a modification of the Hels and Buchwald (2001) models by Litvaitis and Taish (2008), multiple crossings increase these scenario estimates many times (Table 2.10). The methodology for these estimates is provided in Moore (2009). Again these estimates do not consider the potential of both birds and drivers for avoiding collisions and any ability to learn evasion tactics. However, they do emphasise the potential for multiple crossings to increase the likelihood of mortality.. The model scenarios presented here are not reality because of the many assumptions made and can only be considered as providing comparisons between the roads rather than absolute results. However, the comparative scenarios for the two major roads do provide an indication of potential road sections on which to focus mitigatory efforts.

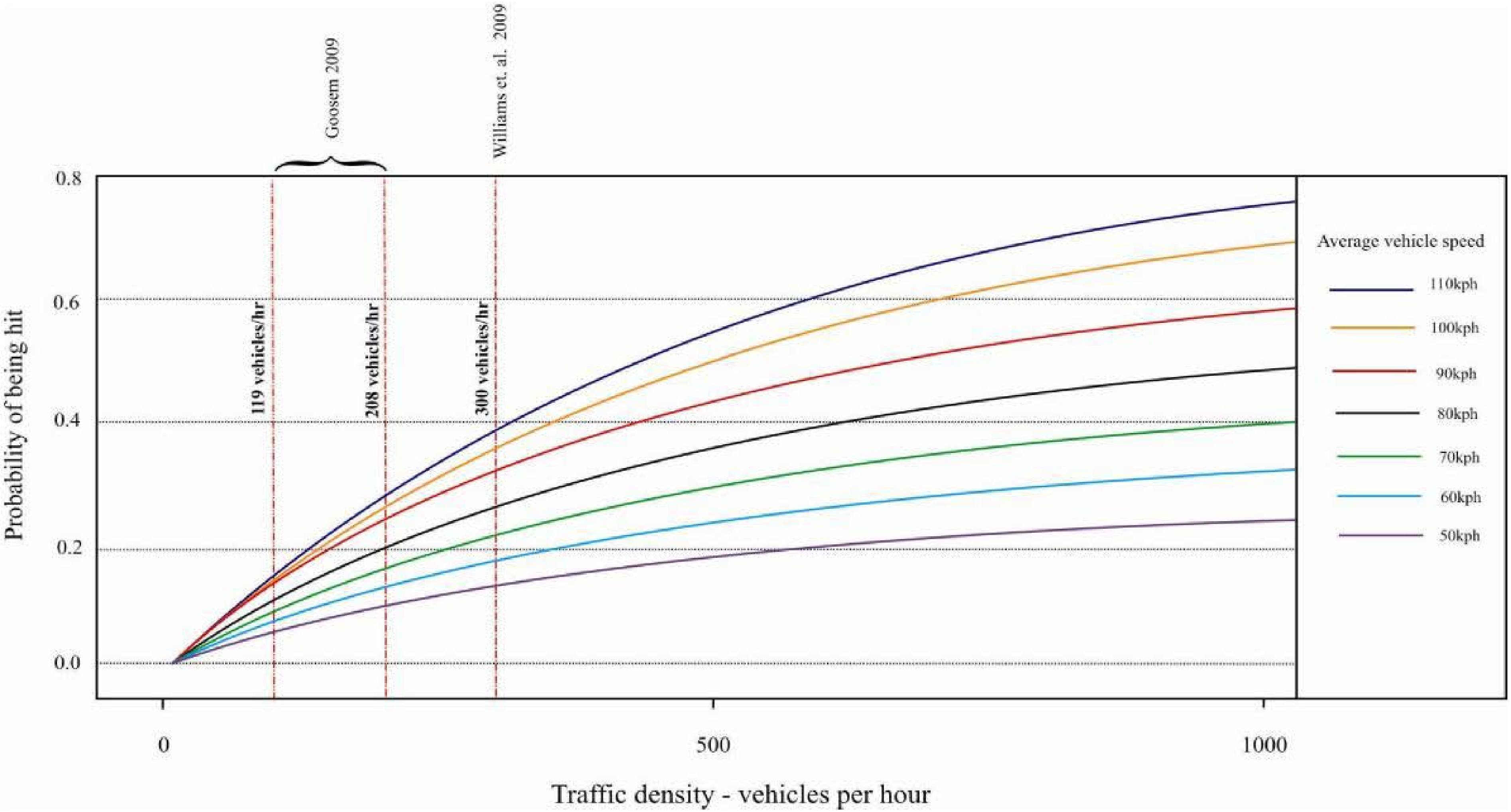
Table 2.10
Estimates of the probability of cassowary road death at Lacey Creek with multiple road crossings

AADT = 1191 vehicles/day	***Number of crossings***		
Crossing velocity	**P=0.50**	**P=0.75**	**P=0.90**
Walking speed (60m/min) averaged over all angles of crossing	12	23	>35
Running speed (250m/min) averaged over all crossing angles	30	-	-
Observed speed (42m/min) averaged over all angles of crossing	8	15	25

2.3.5 Effect of vehicle speeds

Extending the model scenarios to traffic speeds and volumes experienced on the Mission Beach entry roads (Chapter 4, Williams *et al*. 2009) allows comparison of the effects of vehicle speeds on the likelihood of collision (Figure 2.25). Again, the assumptions in the model mean that these figures are useful for comparison only, rather than representing reality. However, given these caveats, they suggest that increasing speed from 60 to 80 km/h at the traffic volumes experienced on the Tully-Mission Beach Road, might increase the likelihood of collision with a cassowary crossing the road at walking speed by about 50%, while increasing speeds from 60 to 100 km/h may almost double the likelihood of collisions. As these models do not take the potential for evasive action by driver or cassowary into account, it is possible that increasing speeds may actually have a larger comparative effect, as the potential for evasive action also becomes less with higher speeds.

Figure 2.25 Model scenarios of the likelihood of collision with a cassowary crossing the road at walking speed (60 metres/min) at a variety of traffic speeds and traffic densities, showing those measured on the Mission Beach Roads.



A study on the distribution and abundance of road kill on Tasmanian highways by Hobday and Minstrell (2008) also provides valuable insight into how speed may influence the number of wildlife road kills in an area. Although the study is focussed on small animals and the behaviour and ecology of each species is different, it was found that relatively more road kills occurred at higher vehicle speeds than lower speeds. Speed was correlated to the density of roadkills. Hobday and Minstrell (2008) postulated that a 20% reduction in vehicle speed from 100 km/h to 80 km/h through known wildlife mortality areas could theoretically result in a reduction in road kill of up to 50%.

Reductions in vehicle speed in the Mission Beach region may also theoretically produce reductions in road kill. Estimates using Hobday and Minstrell's Tasmanian data, rather than Mission Beach data (which was unavailable), applied to vehicle speeds experienced on the Mission Beach entry roads, suggest that reducing speeds from a mean of 90 km/h to 60 km/h could reduce road mortality by 45% for similar small animals as those discussed in the Tasmanian scenarios.

2.3.5.1 Application of speed reduction in vulnerable areas (crossing areas)

Hobday and Minstrell (2008) concluded that a reduction of 20% in speed through sections of road where most wildlife was killed could significantly reduce the risk of wildlife mortality while adding very little to the overall time to complete the vehicle journey. This line of reasoning can be considered for Mission Beach for the two major roads connecting Mission Beach to Tully and El Arish. Average vehicle speed was assumed to be approximately 90 km/h (see Chapter 4).

El Arish to Mission Beach Road

The distance from Cassowary Drive to the junction of the El Arish Road with the Bruce Highway is approximately 14 kilometres. The forested section of road from the western edge of Tam O'Shanter National Park (Lacey Creek) to Clump Mountain Cooperative Society is a known hotspot for cassowary road kill, and is approximately 5.2 km in length (37% of total road length). Theoretically the time it would take to drive the 14 km of road at 90 km/h is approximately 9.55 mins. Reducing the traffic speed to 60 km/h through the crossing hotspot adds 1.57 minutes to the travel time.

Tully to Mission Beach Road

The distance from the South Mission Beach Road to the junction of the Bruce Highway is approximately 18 kilometres. This distance includes approximately 7.4 km of known hotspots for cassowary road kill (41% of total road length): the Licuala section (5 km) and either side of Sugarcane Creek (2.4 km). Theoretically, the time to drive the 18 km section of road at 90 km/h is 14.47 minutes. Reducing the traffic speed to 60 km/h through the crossings hotspots adds 2.78 minutes to the total travel time (Table 2.11).

Table 2.11
Differences in travel times when reduced speeds are driven through cassowary crossing 'hotspots'

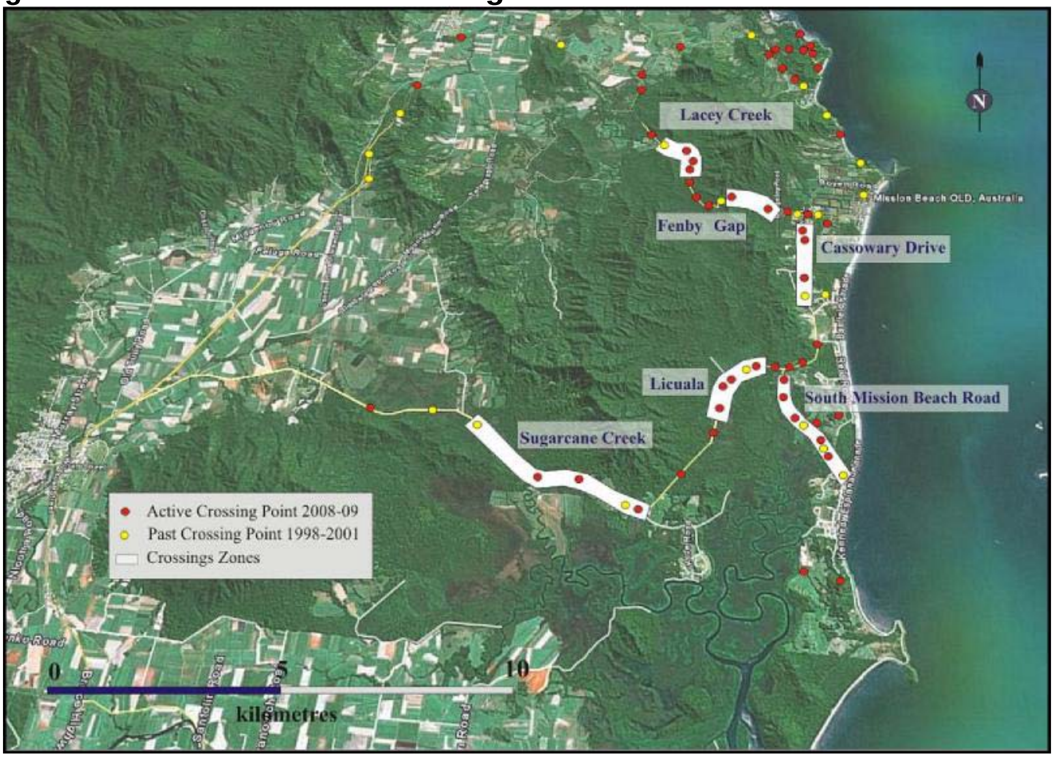
Road section	Road section length (km)	Journey time -- posted speed (min)	Length cassowary crossing 'hotspot' (km)	Journey time - reduced speed through crossings	Increased travel time (min)
Tully-SMB Road	18	12 (90kph)	7.4	14.78 (60kph)	2.78
El Arish - Cassowary Drive	14	9.55 (90kph)	5.2	11.12 (60kph)	1.57

2.3.6 Cassowary Use of Individual Road Crossing Zones

By grouping observations, sufficient data were obtained from 1997-2008 to explore the annual and monthly cassowary use of six major crossing zones: Lacey Creek, Fenby Gap, Cassowary Drive, South Mission Beach, Licuala and Sugarcane Creek (Figure 2.25). These are similar to those in the historical data, showing that patterns of crossings have not changed a great deal over the last two decades (see section 2.1.3). Individual crossings were included in each zone based on their representation of a discrete area or section of road. Figure 2.26 shows the road crossing zones used in the following analyses.

Road crossings made prior to March 2006 were analysed for pre-cyclone patterns. Where data were sufficient, similar analyses were applied to the three years of post-cyclone data and an evaluation made of changes in crossing use by cassowaries.

Figure 2.26 Location of road crossing zones at Mission Beach



2.3.6.1 Lacey Creek

The Lacey Creek Interpretation Centre and adjoining forest walk are located within the Tam O'Shanter National Park on the El Arish to Mission Beach Road (Figure 2.27). The area is popular with tourists and local residents, and is the site of many cassowary road deaths. Due to its high visitation rate, the probability of birds being seen is higher than elsewhere and crossing patterns may possibly be influenced by visitors spending more time in the roadside car park.

Figure 2.27 Lacey Creek cassowary crossing zone

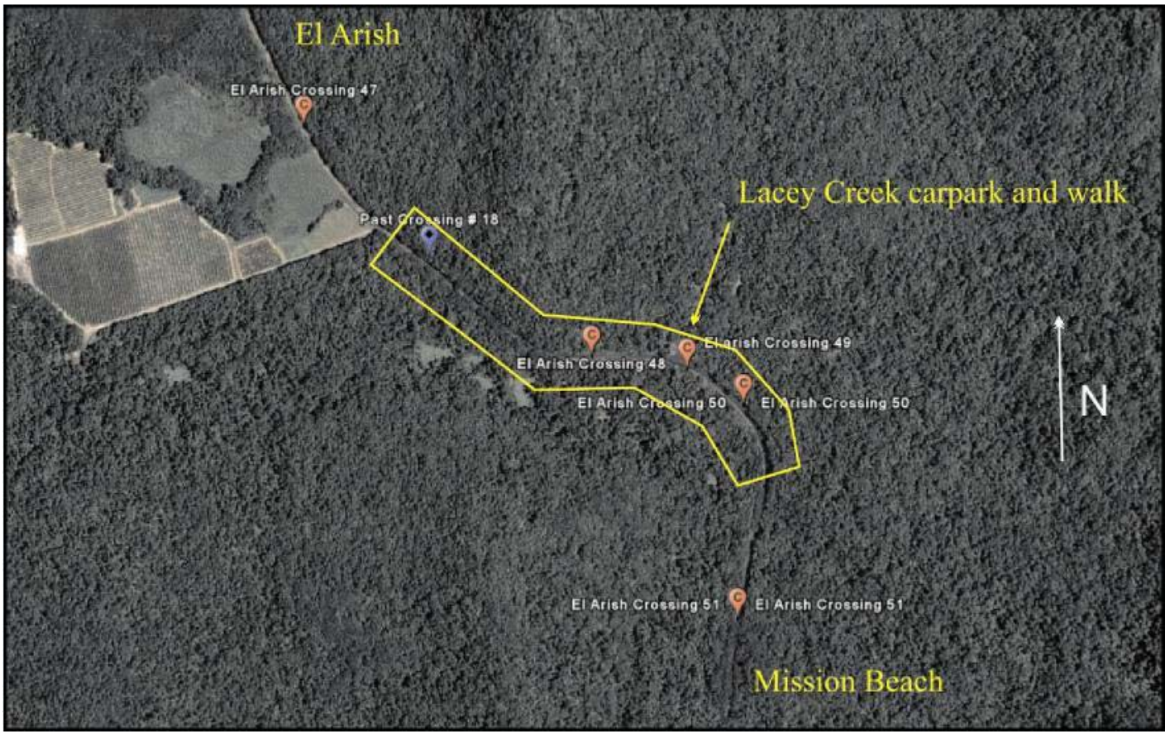


Figure 2.28 shows the data standardised to crossings per 1000 visitors for the birds crossing the road at Lacey Creek each year from 1997 to 2008. Total sightings (n=388) comprised 76% adult birds, 14% family parties and 10% subadults crossing. One-way ANOVA showed significantly fewer road crossings were observed at Lacey Creek in the three years following Cyclone Larry ($F_{1,11}$ = 26.798, P = 0.001).

Seasonal crossing patterns are shown in Figure 2.29 as monthly mean crossings per 1000 visitors between 1997 to 2005 (the pre-cyclone years). Although an annual pattern is discernible and broadly reflects that found for the grouped Mission Beach crossings, ANOVA indicated that monthly differences were not significant (P=0.88). Figure 2.30 presents the annual demography of road crossings at Lacey Creek showing that family parties crossed in all months, and comprised 8-20% of all sightings. Subadult sightings were few or absent in the months of December to March, but comprised 10-20% of all sightings over the remaining eight months. Adult numbers stayed relatively static, ranging from 70-90% of all sightings.

Figure 2.28 Lacey Creek annual cassoway road crossings/1000 visitors 1997-2008

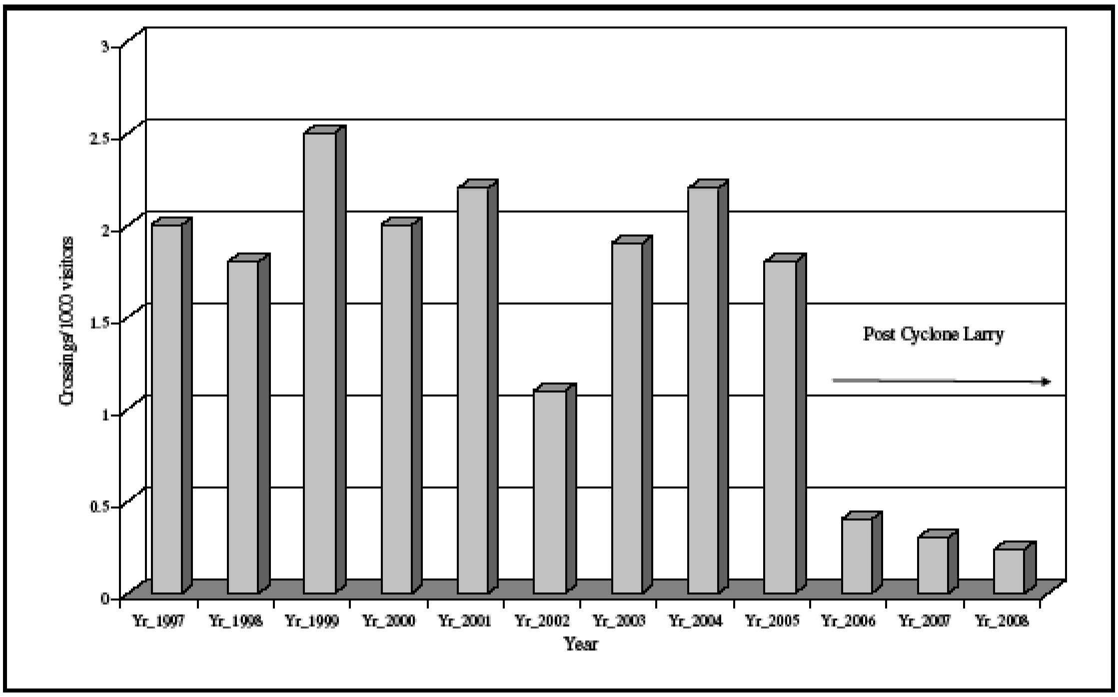


Figure 2.29 Lacey Creek mean monthly cassowary road crossings / 1000 visitors

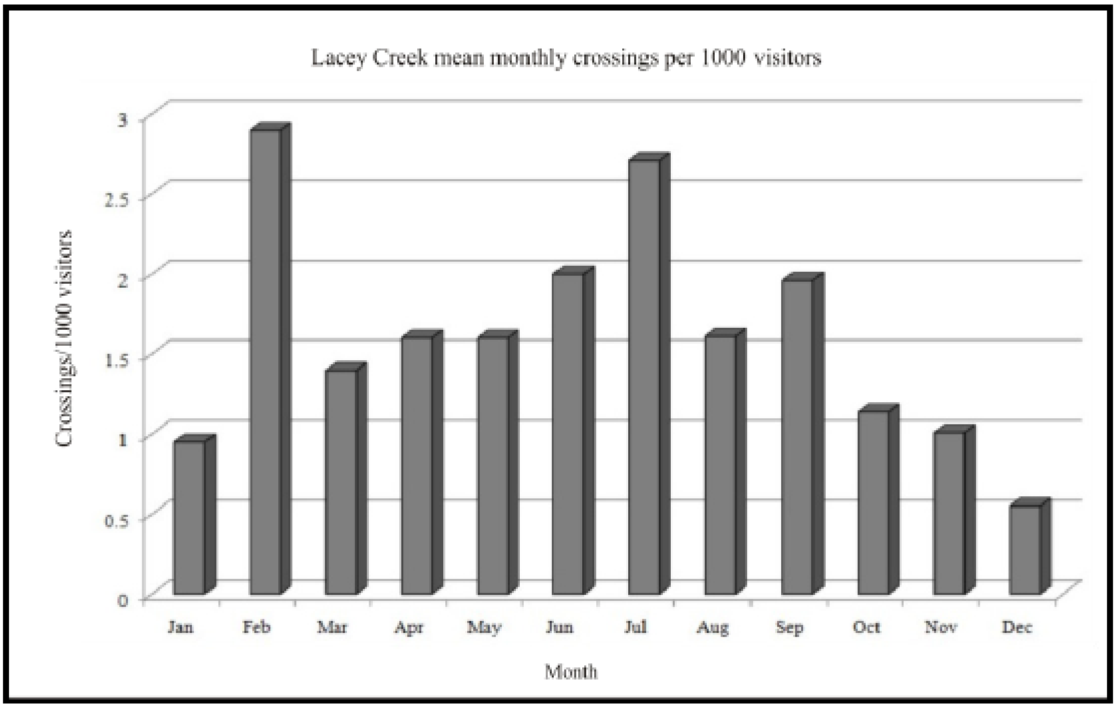
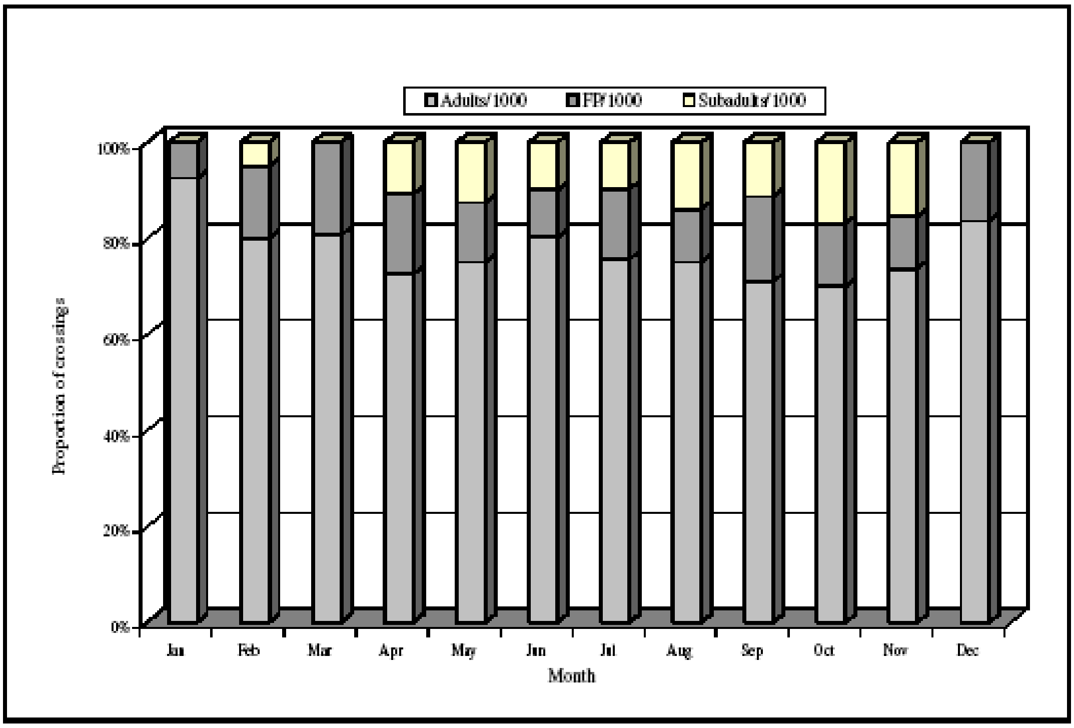


Figure 2.30 Lacey Creek annual demography of cassowary crossings / 1000 visitors 1997-2008



2.3.6.2 Fenby Gap

Fenby Gap is the name given to the saddle across Luff Hill Range east of the Bean Tree Track which connects with Licuala to the south (Figure 2.31). The crossings used in this analysis extend eastward from the top ridge.

Total sightings (n=91) comprised 81.3% adult birds, 14.3% family parties, and 4.4% subadult crossings.

Figure 2.32 shows the annual totals for cassowary road crossings in the Fenby Gap area between 1997 and 2008. To identify seasonal crossing patterns, the data for the pre-cyclone years 1997-2005 were pooled and monthly mean crossings per 1000 visitors calculated (Figure 2.33). Fenby Gap was used seasonally by cassowaries (predominantly in February) with occasional crossings made throughout the remaining months of the year (Figure 2.34). Adult cassowaries made most use of this crossing point (81% of all sightings). Crossing data are too few to discuss demography further.

Figure 2.31 Fenby Gap crossing zone

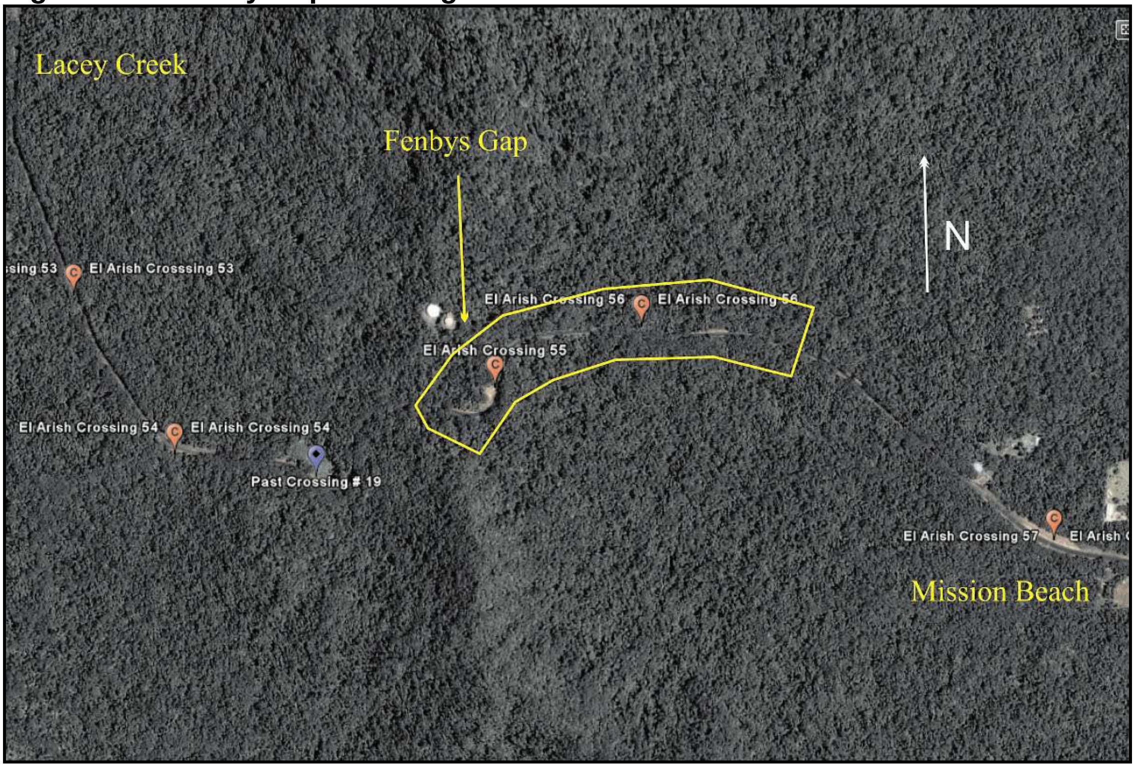


Figure 2.32 Fenby Gap cassowary road crossings/1000 visitors 1997-2008

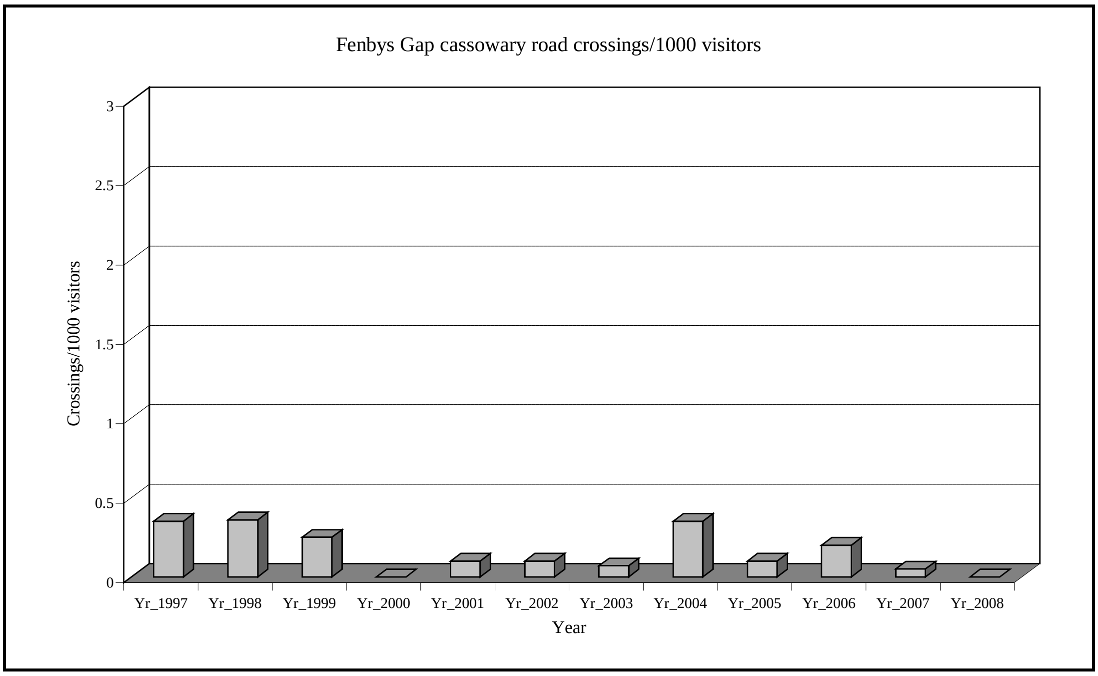


Figure 2.33 Fenby Gap mean monthly cassowary crossings/1000 visitors

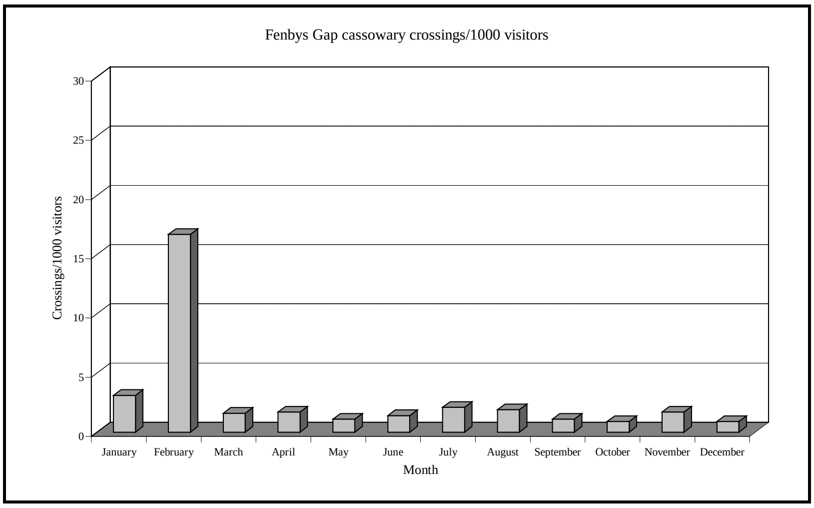
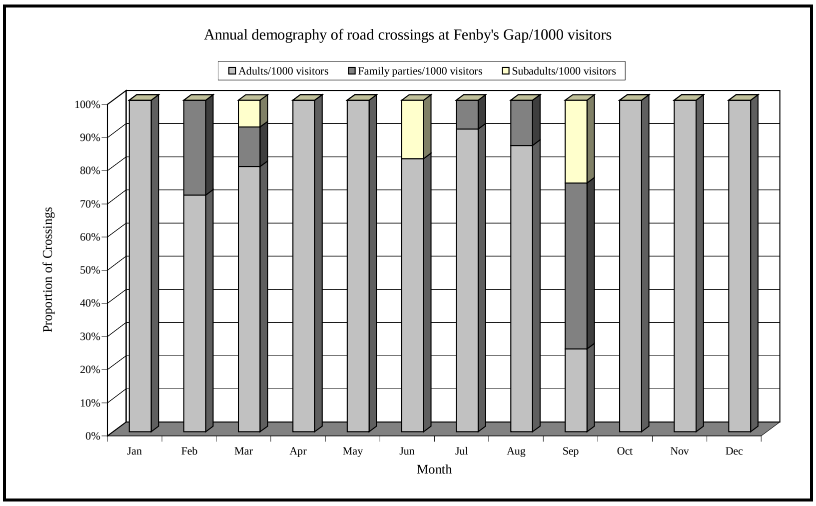


Figure 2.34 Fenby Gap annual cassowary road crossing demography 1997-2008



2.3.6.3 Cassowary Drive

(Tully-Mission Beach Road between El Arish-Mission Beach Road and South Mission Beach Road – i.e. Wongaling section)

This crossing zone extends from the junction of Cassowary Drive and El Arish Road to approximately 500 metres south of Webb Road (Figure 2.35).

Total sightings comprised 62% adult birds, 23% family parties, and 15% subadult crossings. The data were standardised to crossings per 1000 visitors (Figure 2.36). ANOVA showed there were no significant difference between the number of cassowary road crossings observed along Cassowary Drive after Cyclone Larry ($F_{1,11}$ = 0.064, P = 0.850). Seasonal crossing patterns were not evident along this road when the data for the pre-cyclone years 2000-2005 were pooled and monthly mean crossings calculated (Figure 2.37).

Figure 2.35 Cassowary Drive cassowary road crossing zone

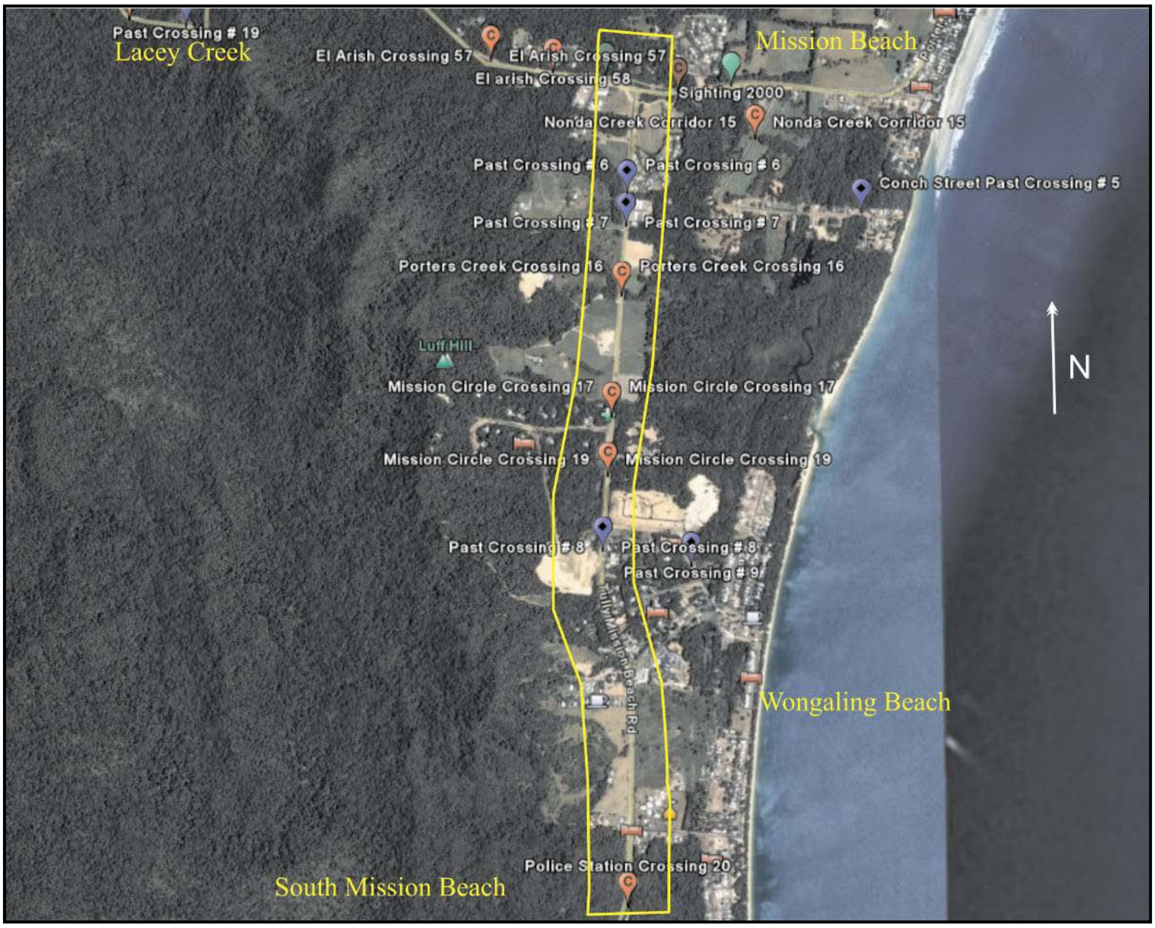


Figure 2.36 Cassowary Drive cassowary road crossings/1000 visitors 1997-2008

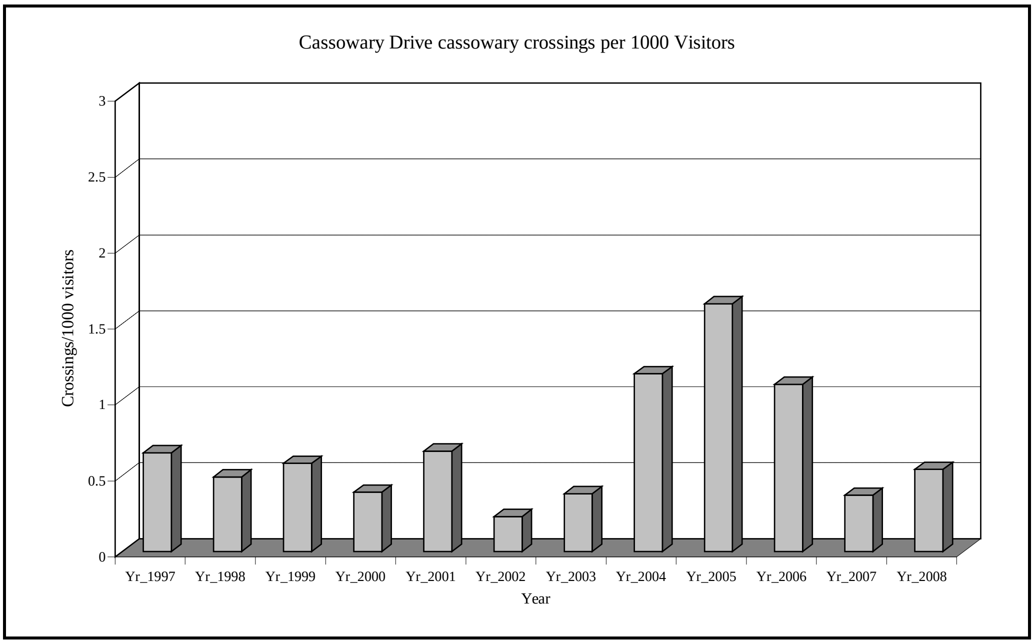
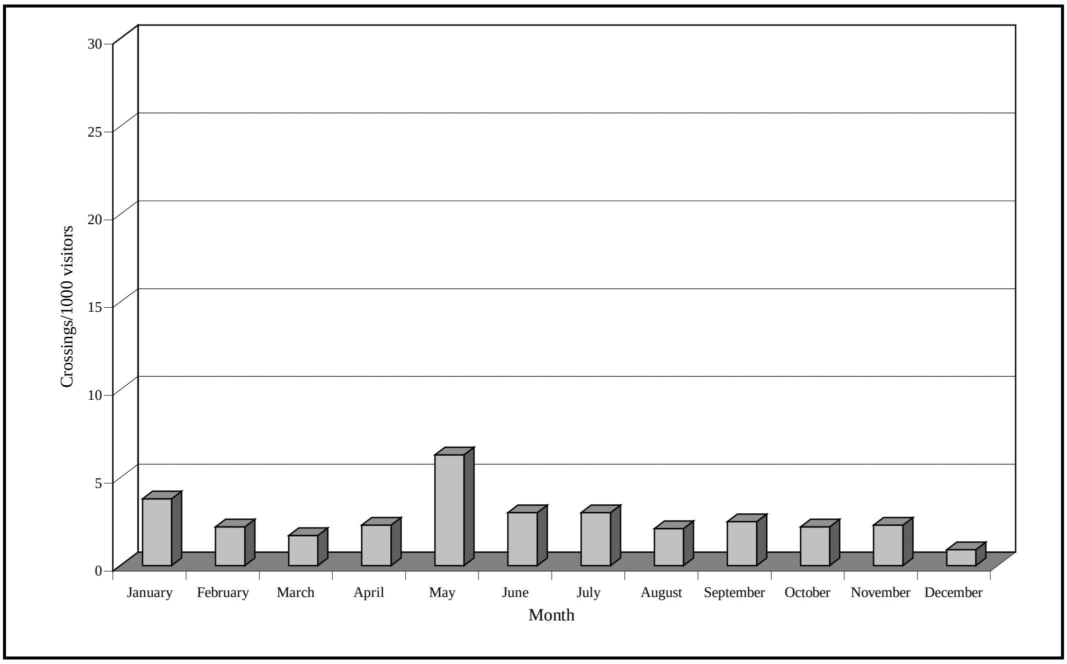


Figure 2.37 Cassowary Drive mean monthly cassowary road crossings/1000 visitors



2.3.6.4 South Mission Beach Road

This crossing zone extends from the junction of South Mission Beach and Tully-Mission Beach Roads south to the South Mission Beach Esplanade (Figure 2.38).

Total sightings comprised 52% adult birds, 34% family parties, and 14% subadult crossings. The data were standardised to crossings per 1000 visitors (Figure 2.39). There was no significant difference between the number of cassowary road crossings observed along South Mission Beach Road before and after Cyclone Larry ($F_{1,11}$ = 0.751, P=0.418). The data for 1997-2005 were pooled and monthly mean crossings calculated (Figure 2.40). The differences between months was significant (ANOVA $F_{3,8}$ = 9.509, P=0.005) and broadly reflects that found for the grouped Mission Beach crossings and Lacey Creek. Family parties crossed the road in all months, comprising 12-80% of all observed crossing cassowaries (Figure 2.41).

Figure 2.38 South Mission Beach road crossing zone

Figure 2.39 South Mission Beach cassowary road crossings/1000 visitors 1997-2008

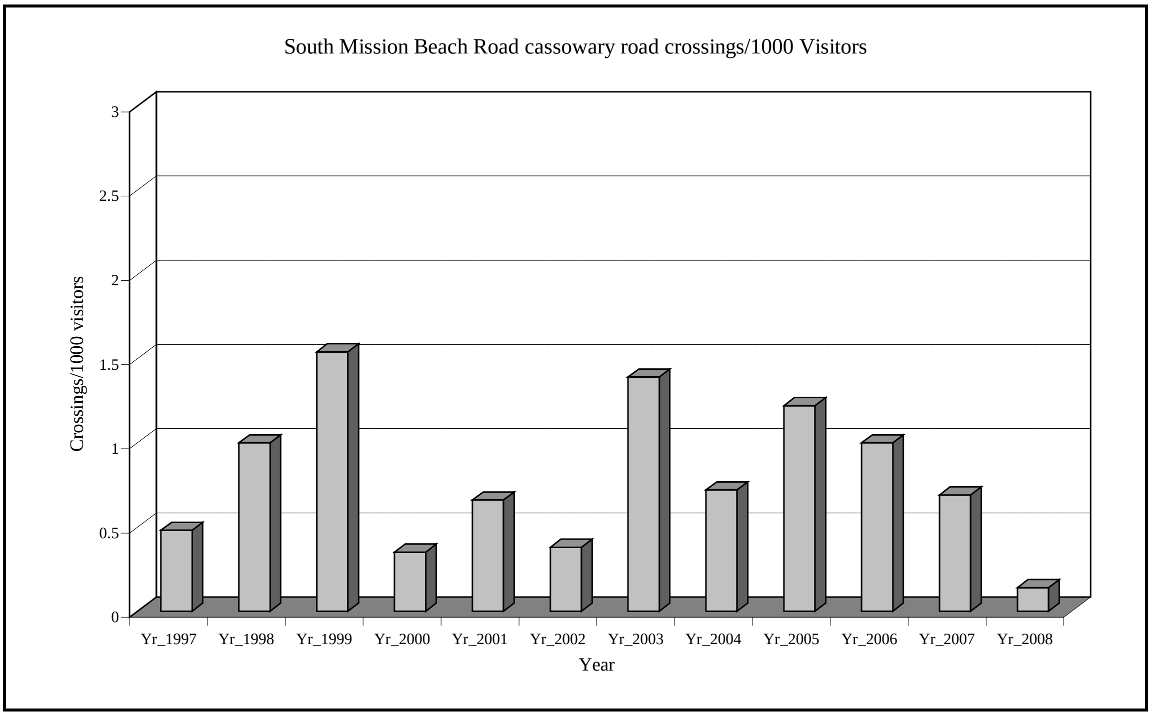


Figure 2.40 South Mission Beach mean monthly cassowary road crossings/1000 visitors

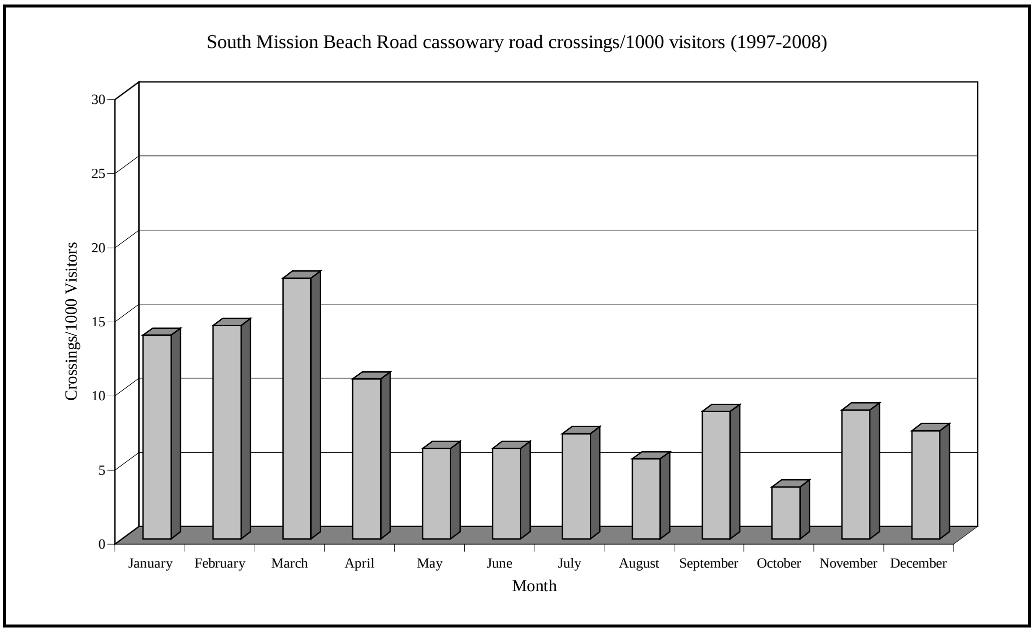
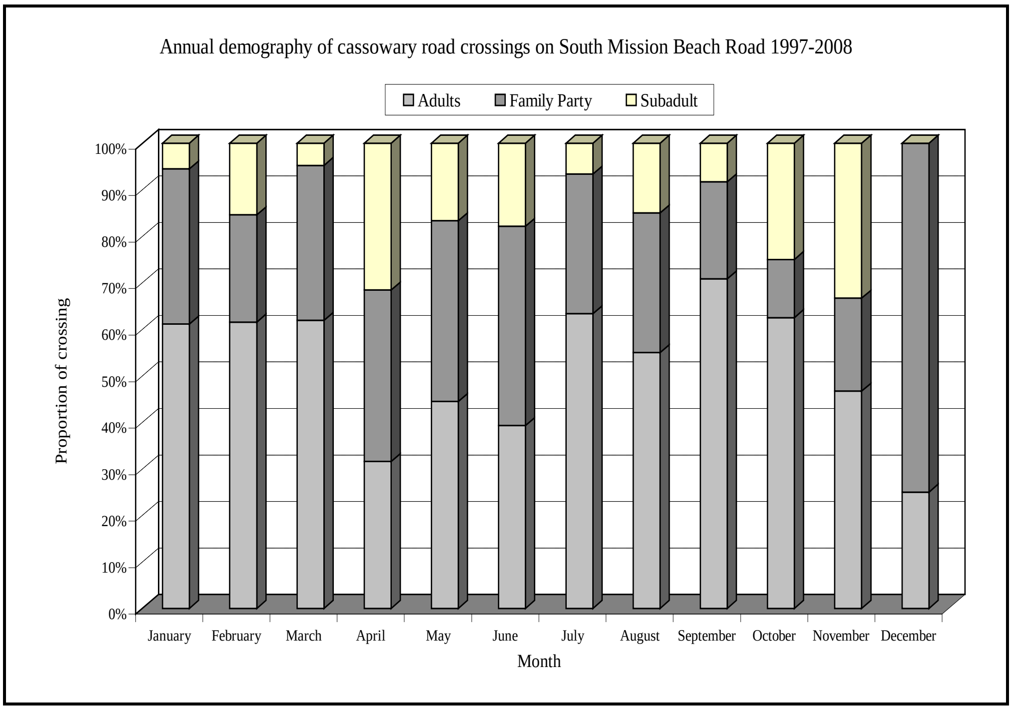


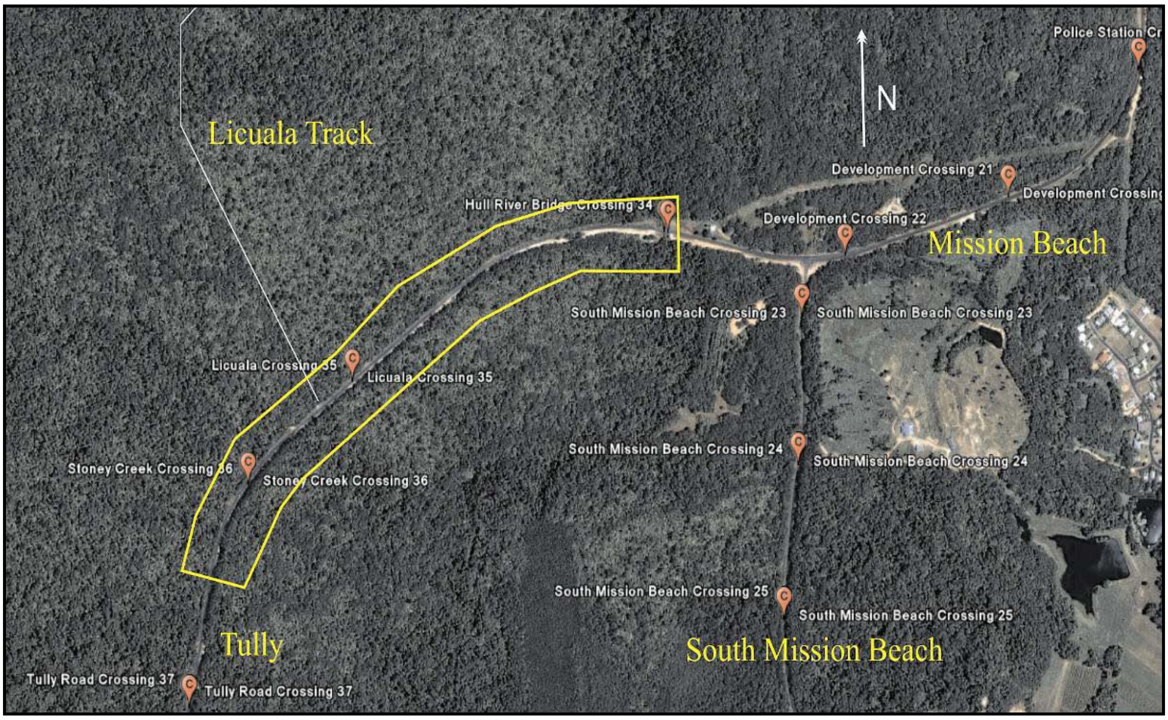
Figure 2.41 South Mission Beach annual demography of cassowary road crossings



2.3.6.5 Licuala area – Tully- Mission Beach Road

The crossing area designated as 'Licuala' extends from the Hull River Bridge eastwards to Stoney Creek and incorporates the road either side of the entrance to the heavily visited Licuala walking track (Figure 2.42).

Figure 2.42
Licuala crossing zone



Road crossings (257) comprised 60.3% adult birds, 27.6% family parties, and 12.1% subadult crossings.

The data were standardised to crossings per 1000 visitors (Figure 2.43). A two-tailed t-test found no significant difference in crossing numbers before and after Cyclone Larry ($t_{1,\ 11}$ = 1.981, P=0.76). There was a substantial peak in crossing frequency in 2001 and 2002 following two above average rainfall years (1998-1999).

Licuala had significantly fewer cassowary crossings per 1000 visitors than Lacey Creek (ANOVA: $F_{1,11}$ = 4.998, P=0.036). The data for 1997-2008 were pooled and monthly mean crossings per 1000 visitors calculated (Figure 2.44). Family parties comprised 10%-50% of all crossings per month (mean=32%) (Figure 2.45). A two-tailed t-test confirmed there were significantly more cassowary family parties crossing the road at Licuala than Lacey Creek ($t_{2,22}$ =-3.201, P= 0.004).

Figure 2.43 Licuala annual cassowary road crossings per 1000 visitors 1997-2008

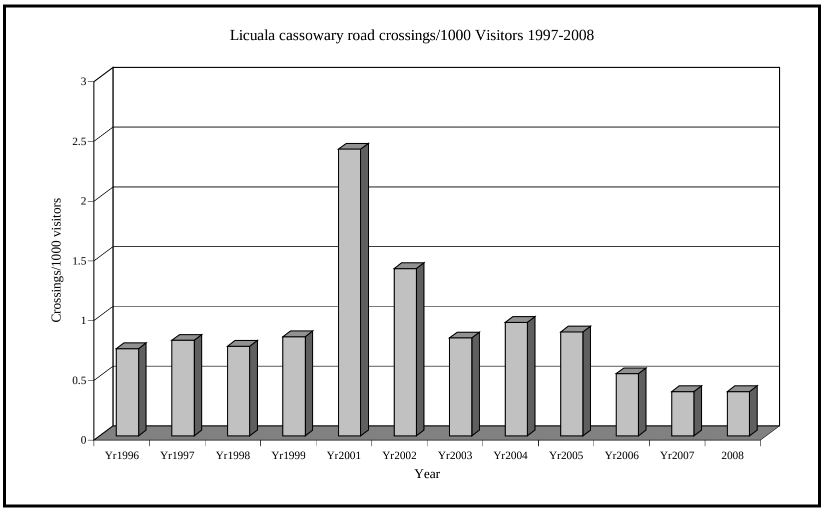


Figure 2.44 Licuala mean monthly cassowary road crossings/1000 visitors 1997-2008

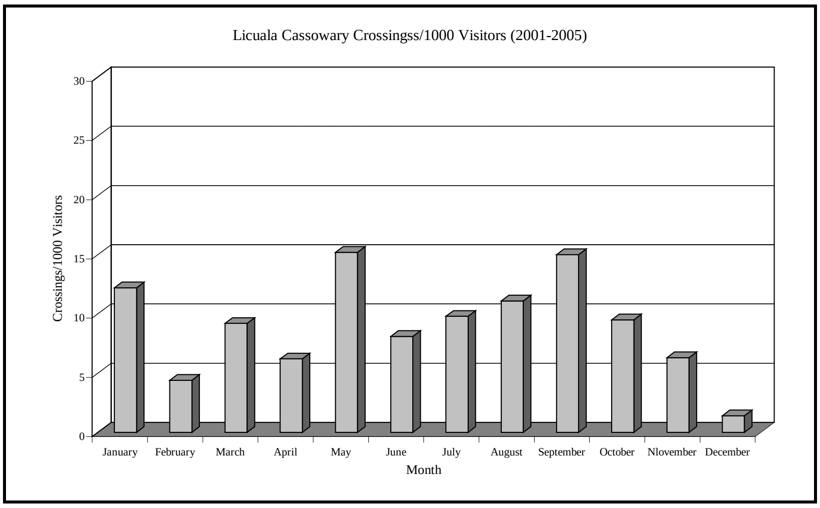
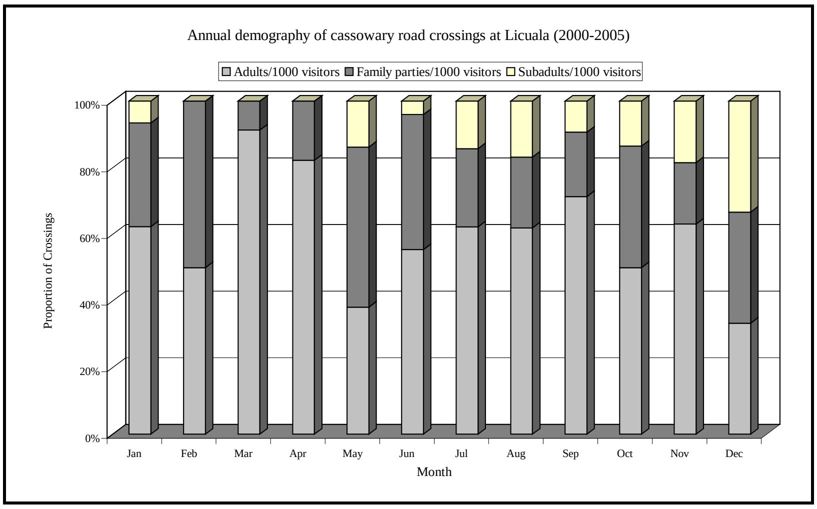


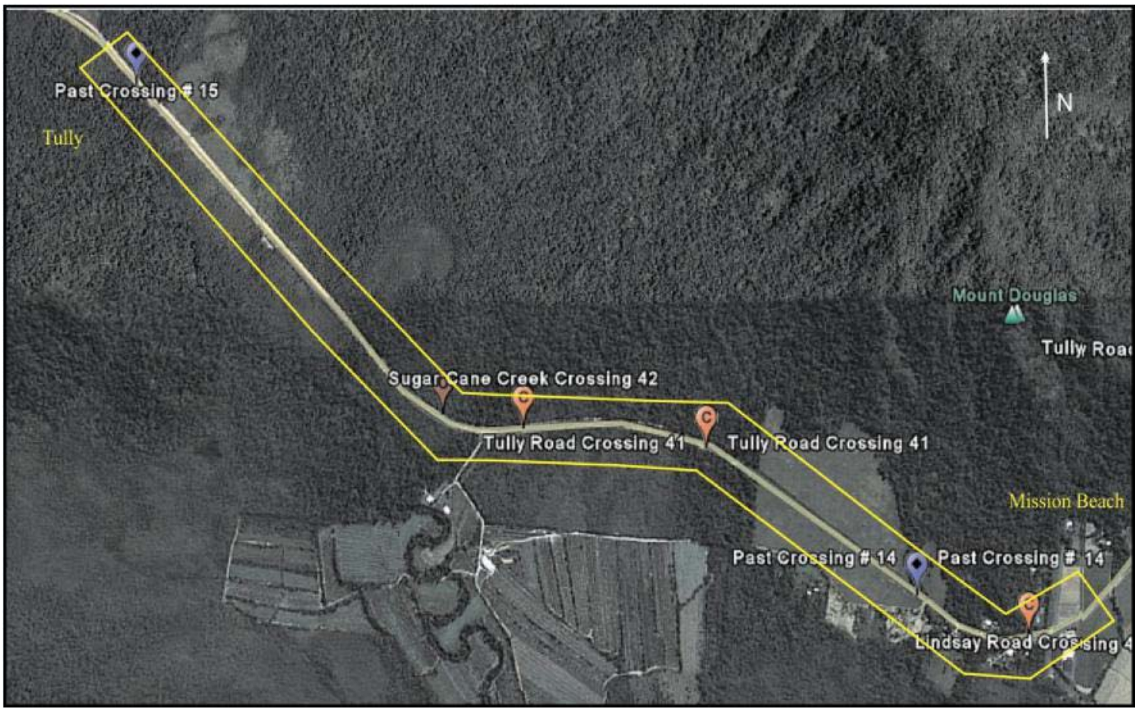
Figure 2.45 Licuala annual cassowary crossing demography 1997-2008



2.3.6.6 Sugarcane Creek area – Tully- Mission Beach Road

The crossing area designated as 'Sugarcane Creek' extends from Lindsay Road on the Tully-Mission Beach Road west to East Feluga Road (Figure 2.46).

Figure 2.46
Sugarcane Creek cassowary road crossing zone



Road crossings (278) comprised 52.4% adult birds, 36.1% family parties, and 11.5% subadult crossings.

Figure 2.47 shows the annual totals for cassowary road crossings for the Sugarcane Creek crossing zone from 1997-2008, standardised to crossings/1000 visitors. A two-tailed t-test found no significant difference in crossing numbers after Cyclone Larry ($t_{1,11}$ =1.586, P=0.144).

To identify any seasonal crossing patterns, the data for 1997-2005 were pooled and monthly mean crossings calculated (Figure 2.48). An annual pattern is discernible and broadly reflects that found for the grouped Mission Beach crossings, Lacey Creek, and South Mission Beach Road. ANOVA indicated that January to March had significantly more road crossings than at other times of the year ($F_{3,8}$ = 4.79, P=0.03).

The annual demography of cassowary road crossings at Sugarcane Creek showed that family parties crossed the road in all months (Figure 2.49). Males with chicks comprised 15-60% of all observed crossing cassowaries (mean=31%), with the greatest numbers occurring in February. Subadults were most common in July, possibly becoming independent because the male parent was courting/breeding again, but subadults were absent in November and December.

Figure 2.47 Sugarcane Creek cassowary road crossings/1000 visitors 1997-2008

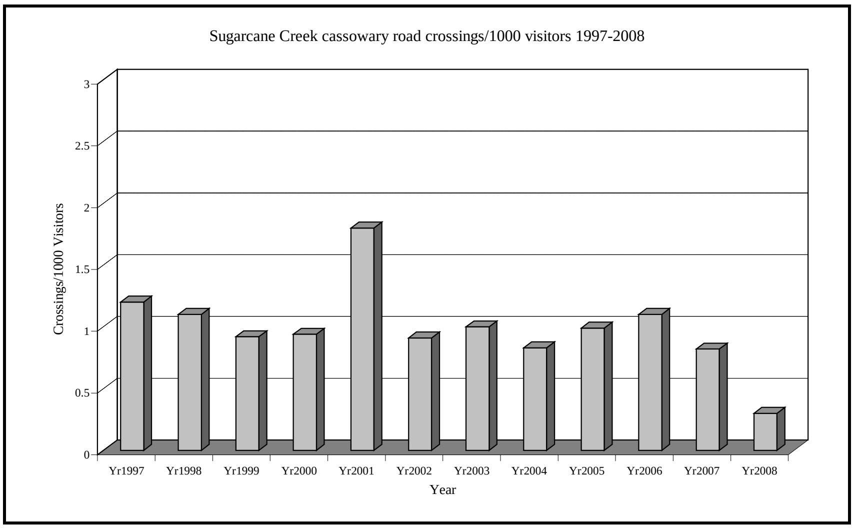


Figure 2.48 Sugarcane Creek mean monthly cassowary road crossings/1000 visitors

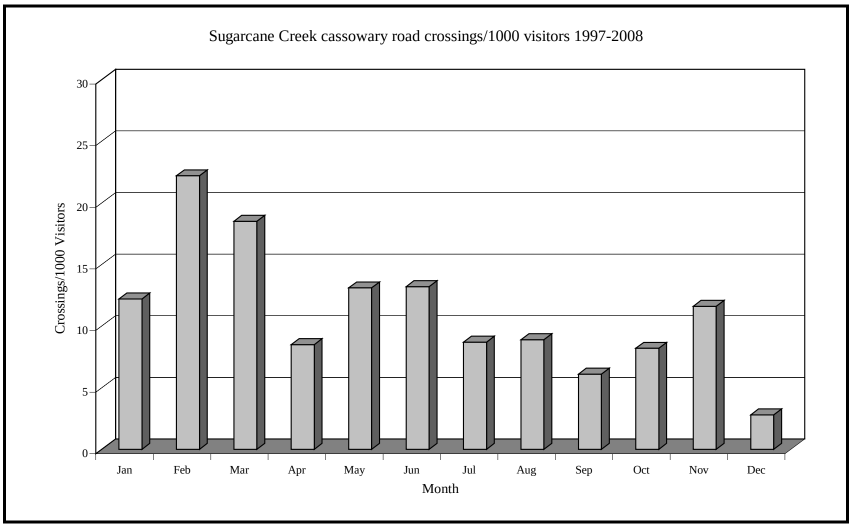
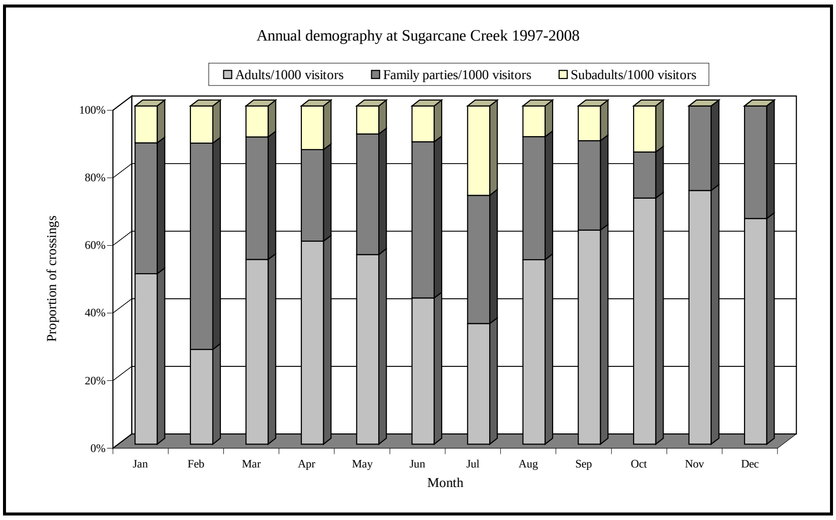


Figure 2.49 Sugarcane Creek annual cassowary crossing demography 1997-2008



2.3.6.7 Comparison of Crossing Frequencies at selected Cassowary Crossing Zones

Figure 2.50 presents a comparison of crossing frequency for the six road crossing zones. Over the 12 years (1997-2008) the zones of Lacey Creek, Licuala, and Sugarcane Creek had significantly greater numbers of cassowary road crossings than the remaining three zones.

Two-tailed t-tests showed that significantly more cassowary road crossings were observed at Lacey Creek than at Licuala (P=0.035) and Sugarcane Creek (P=0.044), whereas there was no significant difference in cassowary crossings between Licuala and Sugarcane Creek (P=0.618).

Road crossings at Lacey's Creek were relatively constant with approximately 2 crossings/1000 visitors over the nine years prior to the 2006 cyclone; but decreased 80-88% in the following three years. Although there were annual variations in the number of observed cassowary crossings at each crossing zone, fewer crossings were observed in several major zones after the cyclone. The use of Fenby Gap as a crossing location appeared to cease following the post-cyclone death of the two adults known to make use of the crossing area, although this area has recently been in use. Figure 2.50 shows an increase in crossings on Cassowary Drive after Cyclone Larry, possibly due to birds moving out of the forest to feed in urban areas.

2.3.6.8 Comparison of Family Party Road Crossings Frequencies at selected Cassowary Crossing Zones

The sightings data were pooled for the period 1997-2005 and monthly mean crossings of family parties (adult males with dependent chicks) calculated for four of the six crossing zones (Figure 2.51). These zones comprised two crossing zones on the El Arish to Mission Beach Road (Lacey Creek and Fenby Gap) and two crossing zones on the Tully to Mission Beach Road (Licuala and Sugarcane Creek). Sightings along the remaining two crossing zones, Cassowary Drive and South Mission Beach Road, are influenced by local traffic activity and not included in this analysis.

ANOVA showed a significant difference in the number of family party road crossings between the two major access roads ($F_{2,33}$ = 3.617, P=0.038). Post-hoc tests showed that although Licuala and Sugarcane Creek were not significantly different from each other (P=0.249), both crossing zones had significantly more family party road crossings than Lacey Creek and Fenby Gap (P=0.034).

Overall, there were more cassowary road crossings observed at Lacey Creek. However, model estimates of the likelihood of a cassowary being hit by a vehicle on the El Arish-Mission Beach Road are less than on the Tully-Mission Beach Road because of the greater traffic volumes on that road (Table 2.9). Higher speeds increase the risk.

The concentration of family party sightings (males with chicks) in the two crossing zones along the Tully-Mission Beach Road, particularly in the Sugarcane Creek/ Lindsay Road area between April and October and the high road mortality observed in the area (Figure 2.4, Table 2.1) has significant implications for the viability of the Mission Beach cassowary population.

Figure 2.50 Crossing frequency for selected cassowary crossing zones - crossings per 1000 visitors 1997-2008

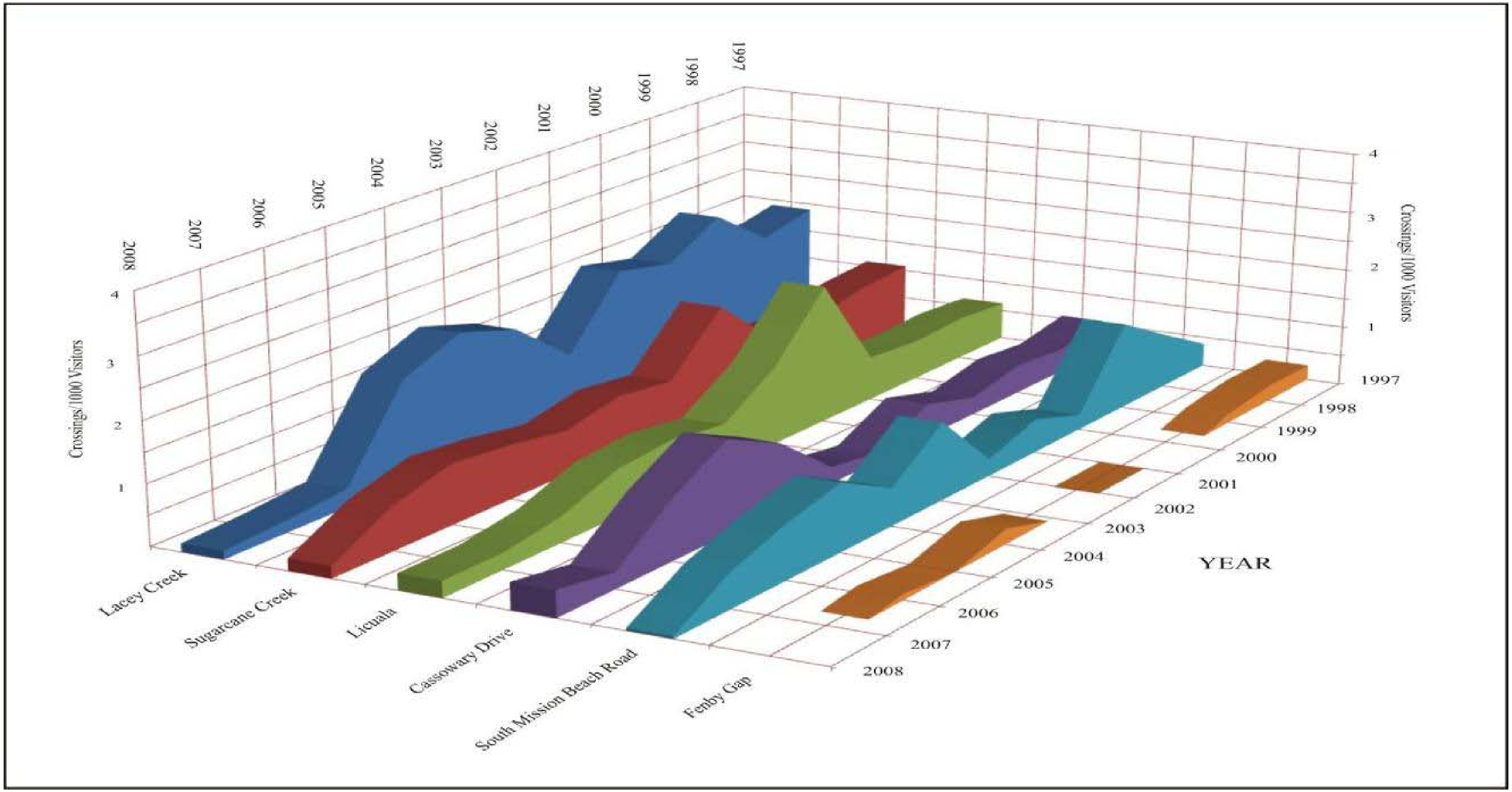
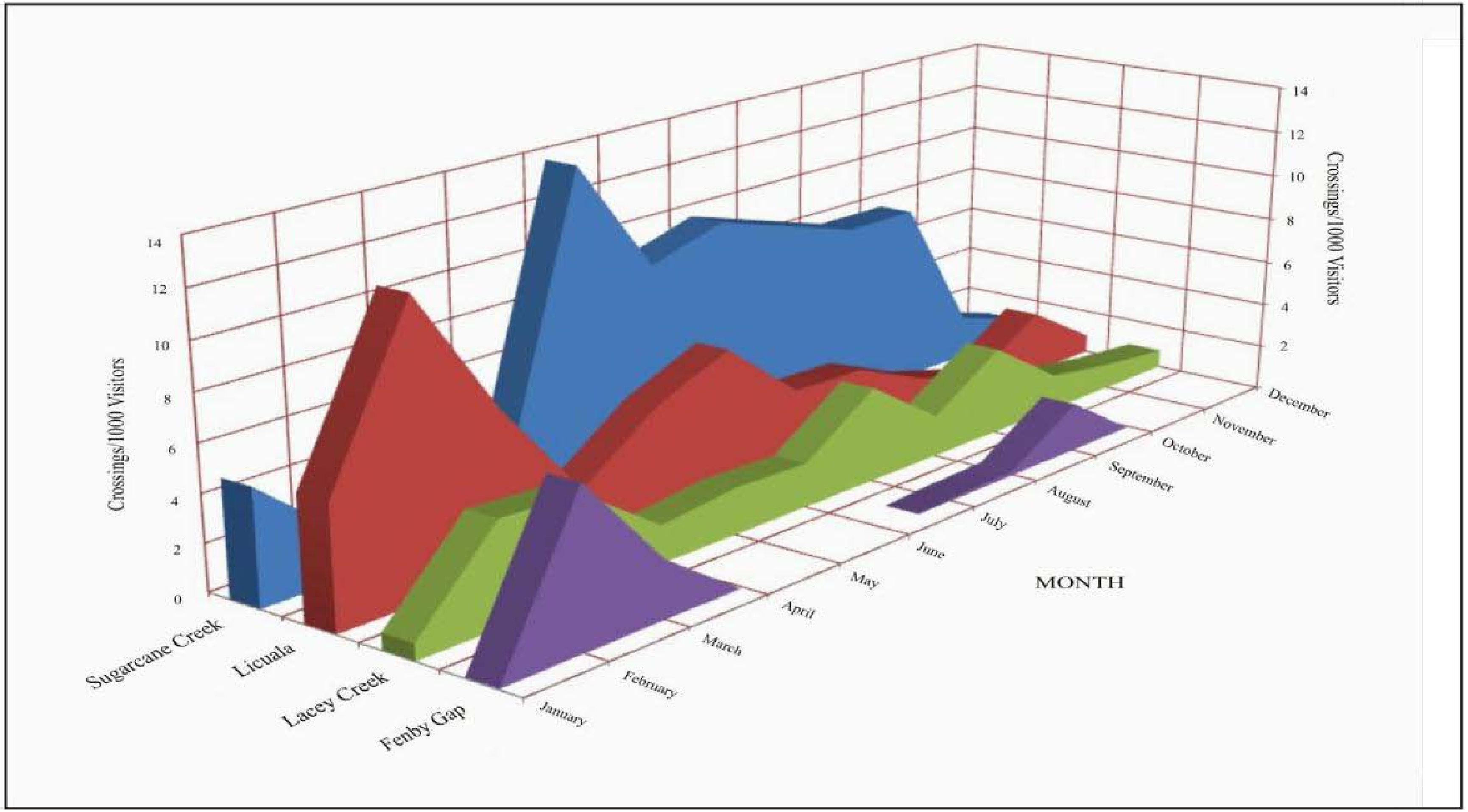


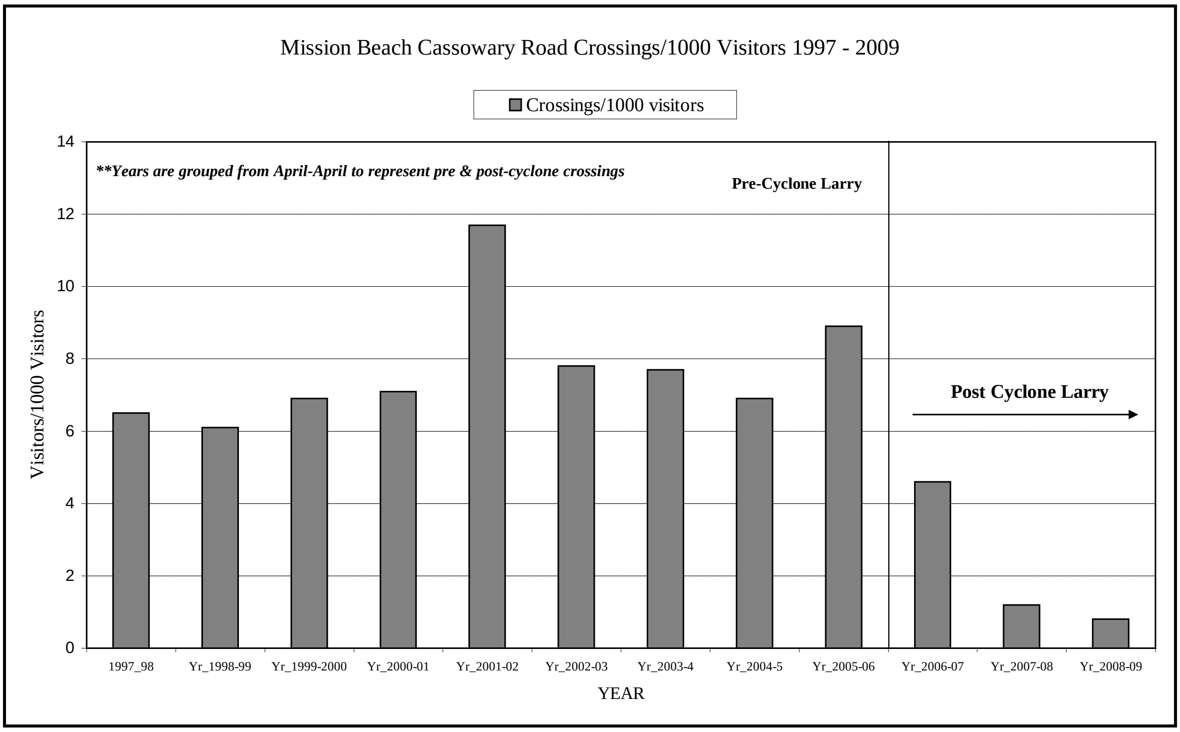
Figure 2.51 Mean monthly number of family parties (1997-2008) observed crossing each Crossing Zone (excluding Cassowary Drive and South Mission Beach)



2.3.6.9 The Effect of Cyclone Larry on Cassowary Road Crossings

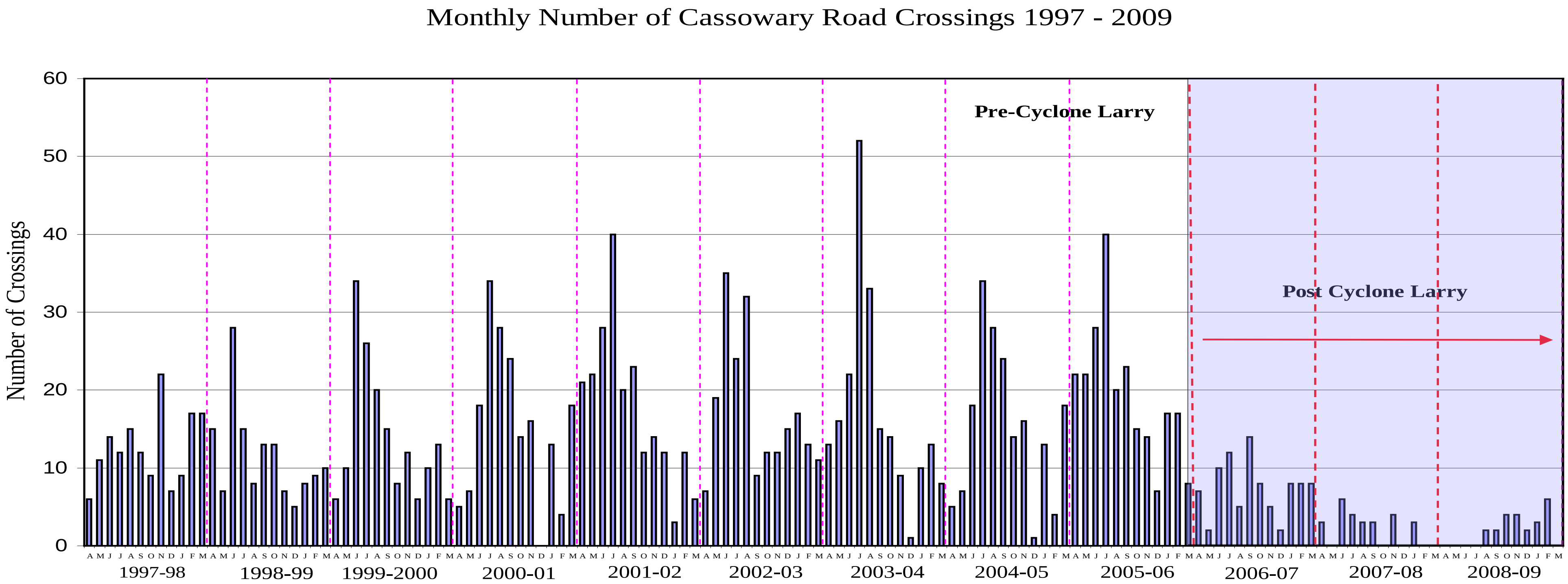
Establishing the effect of severe cyclones on the Mission Beach cassowary population is important in the development of effective road mitigation strategies. Figure 2.52 shows the monthly cassowary road crossings observed at Mission Beach from 1997-2009 (non-standardised). To remove bias associated with increases or decreases in sightings due to visitor numbers, the road crossing data was standardised to the number of observed crossings per 1000 visitors (Figure 2.53). The monthly sightings have been grouped in a yearly pattern of April to April. This allows for a direct comparison of pre and post-cyclone road crossing frequencies. Sightings in the 12 months following Cyclone Larry are not reliable as C4 was closed a great deal during this period, reducing the opportunity for visitors to record sightings (Ms Liz Gallie, C4, pers. comm. 2009).

Figure 2.53 Mission Beach cassowary road crossings/1000 visitors 1997-2009



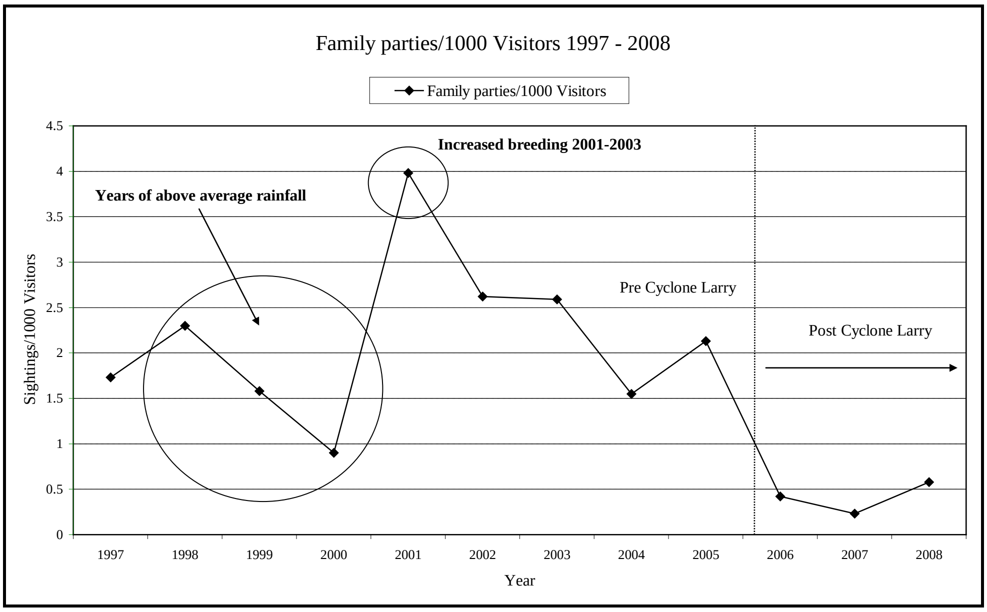
A paired-samples t-test confirmed the highly significant differences in the number of road crossings per 1000 visitors (t_6 = 4.060; P=0.007) with significantly fewer road crossings being made by cassowaries post-Cyclone Larry. This decrease may be due to behavioural changes in the cassowary population which has resulted in fewer road crossings. Reasons for this could be the siting of feed stations away from the roads for 18 months until forest fruiting recommenced, or disturbance from vegetation removal activities. However, the continued decrease in numbers through 2008/09 suggests that a more likely explanation is that the cassowary population near roads decreased significantly following the 2006 cyclone.

Figure 2.52
Total cassowary road crossings (not standardised for visitor numbers) 1997-2008



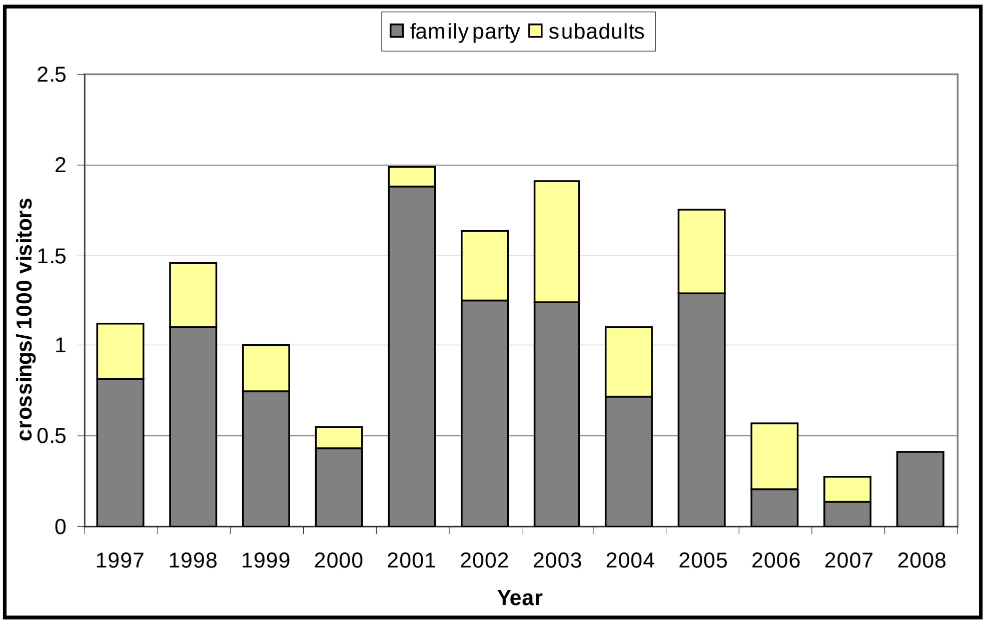
Annual totals of road crossings by cassowary family parties were standardised to crossings per 1000 visitors (Figure 2.54). Sightings of family parties decreased significantly (F = 13.176, P=0.005) It appears that few family parties survived the cyclone in 2006, and little breeding occurred in 2007. There appears to have been a small increase in breeding in 2008, two years after the cyclone.

Figure 2.54 Mission Beach road crossing family parties/1000 visitors 1997-2008



The ratio of subadults to family parties of previous years provides a coarse indication of subadult survival and, by inference, potential recruitment into the adult population. Crossing data indicated that some subadults survived the cyclone (Figure 2.55) but their numbers decreased sharply in 2007. Although subadults were sighted in the forest and suburbs around Mission Beach in 2008, none were sighted crossing the roads.

Figure 2.55 Yearly demography of cassowary crossings / 1000 visitors 1997-2008



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MISSION BEACH ROAD IMPACTS ON CASSOWARIES AND OTHER VERTEBRATES

SECTION 3:

ROAD MORTALITY OF OTHER VERTEBRATES AND USE OF POTENTIAL UNDERPASSES

3. ROAD MORTALITY OF OTHER VERTEBRATES AND USE OF POTENTIAL UNDERPASSES

Marina Gibson and Miriam Goosem

Summary.

This study examined road mortality of fauna on four transects chosen along the El Arish – Mission Beach Road and the Tully Mission Beach Road between April and July 2008. Additionally, faunal use of three potential underpasses at the Hull River bridge, Laceys Creek culvert and Stony Creek retrofitted culvert was recorded during the same period using sand tracks. Opportunistic monitoring of sand tracks and camera traps occurred during fieldwork for other projects for several months afterward.

Road mortality of fauna was recorded on two 0.5 kilometre transects on the El Arish – Mission Beach Road where it traverses Tam O'Shanter National Park for a five day period of each month (4 surveys of one week) and compared with that on two similar transects on the Tully – Mission Beach Road where it passes through Licuala National Park. Road mortality was examined with respect to road clearing width, road design features and traffic volume and speed.

Mean road mortality was 81.8 specimens per kilometre per day, with Cane Toads (*Bufo marinus,* 458) being most common. A variety of invertebrates, particularly insects, were also recorded (14 orders). Native vertebrates were much less common as roadkill statistics, with White-lipped Tree Frog (*Litoria infrafrenata*, 10), Dainty Green Tree Frog (*Litoria gracilenta,* 8), Long-nosed Bandicoot (*Perameles nasuta*, 4) and a skink (*Carlia rubrigularis*, 4) recorded most often. However, a large proportion (nearly one third) of the road mortality fell into an 'unidentifiable' category a large proportion of which was likely to be amphibians other than toads, as recognisable amphibian characteristics are quickly obliterated. We found ten species of amphibian, five reptile species, three species of birds and five species of mammal that could be identified to species. There were significant monthly effects in rate of roadkill of all species, with June road mortality being greatest and significantly greater than April and July, the month of least road mortality. Vertebrate road mortality peaked in April due to large numbers of Cane Toads at the end of the wet season. Cassowary fencing, road marking, rumble strips and warning signage did not impact on vertebrate road mortality, with the highest toll occurring near a cassowary awareness sign. Transect location was an important factor, with significantly less roadkill occurring on the 500 metre transect west of the Bean Tree Track (the walking track from the El Arish – Mission Beach road through to the Licuala day use area) than the 500 metres in the vicinity of Lacey's Creek, although both occur on the El Arish – Mission Beach Road. Tully – Mission Beach Road transects had intermediate levels of road mortality and were similar in numbers. Although data were insufficient to analyse road microtopographic and habitat information with respect to mortality, it appeared that greater roadkill rates occurred near creeks.

Long-nosed Bandicoot (*Perameles nasuta*) were the most frequent users of the underpasses as determined by sand tracks and scats (36). Eighty-four tracks and signs were recorded during the four month intensive data collection. Other vertebrates in order of most to least common included *Rattus* spp. (likely to be Cape York and/or Bush Rat, 13), Water Rat (*Hydromys chrysogaster,* 11), Southern Cassowary (*Casuarius casuarius johnsonii,* 6), Cane Toad (*Bufo marinus,* 3), Fawn-footed Melomys (*Melomys cervinipes,* 2), Red-legged Pademelon (*Thylogale stigmatica*, 1) and Giant White-tailed Rat (*Uromys caudimaculatus,*

1*)*, with several tracks of unidentified reptiles and smaller birds. The majority of these tracks were found under the North Hull River bridge (63) and this was the only place that Southern Cassowary tracks were observed. No Southern Cassowary tracks or traces were observed in either of the culverts at Lacey's Creek or Stony Creek.

We recommend that alternative means of road mortality mitigation be trialled, and especially legislated speed limit reduction in forested areas. We also suggest that the Stoney Creek retrofitted underpass and accompanying Cassowary fencing could be upgraded to encourage more faunal usage of the underpass. Similar inclusions of cover, ensuring that vegetation reaches underpass entrances and provision of dry passage could be included at Laceys Creek. However, it appears unlikely that these underpasses will be used to any great extent by Cassowaries. Rather, the large bridge-style underpasses such as at the North Hull River provide opportunities for Cassowary utilisation. Further research is required to ascertain the efficacy of these measures.

3.1 INTRODUCTION

3.1.1 Road Impacts and Zone of Effects

The fragmentation of habitats by roads can contribute to inbreeding, unnatural community composition (Forman *et al.* 2003; Goosem 2004), reduced movement (Goosem *et al.* 2001) and reduced reproduction (Klocker *et al.* 2006). Species that are small may be affected to a greater extent due to their lesser mobility. For example, a small population of geckos died out in Western Australia, partly due to an inability to disperse across a landscape fragmented by roads (Driscoll 2004). Road mortality can also increase extinction risk. In Tasmania, populations of quolls and Tasmanian devils decreased or disappeared after the sealing of a road into a National Park (Jones 2000). However, slowing of the traffic resulted in the populations recolonising the area when road kill was reduced (Jones 2000).

Impacts of roads can extend well beyond the actual road surface (Forman *et al.* 2003; Chapter 1) – the 'road zone' effect. Road zone impacts include edge and barrier effects, and penetration by noise, lights, and pollution (Goosem and Turton 2000; Wilson and Goosem 2007; Dawe and Goosem 2008). To mitigate against these impacts a holistic assessment of the effect of a particular road is required. For example, a winding road may cause a larger area of disturbance than a straight one in terms of penetration of noise and lights and the ingress of weeds and pest animals, whereas the presence of guardrails, fences and culverts may influence road kill rate (Jaeger 2007; Finke *et al.* 2008).

3.1.2 Road Impacts affect many species

Although at Mission Beach the focus of concern with respect to road impacts has mainly been on the endangered southern cassowary, many other species are likely to suffer road mortality and fragmentation effects. Impacts on other species have never previously been investigated in the Mission Beach region. The southern cassowary is considered a keystone species, and therefore it is often considered that protection of habitat for the cassowary and mitigation of anthropogenic impacts on the species will result in general 'umbrella' protection of other species. However, it is likely that other species will be affected by roads in different ways – for example a smaller rainforest-dependent species may find the road clearing a greater psychological barrier than the large, mobile cassowary, causing it to avoid crossing and resulting in much greater fragmentation impacts and less severe impacts from road kill than experienced by the cassowary. Therefore, although conservation of the cassowary provides many benefits, differences between species will also result in different impacts from roads and consideration needs to be given to these differences during design of mitigation measures for road impacts.

Collisions of vehicles with fauna are an obvious sign of road impacts, at least in the case of larger species. However, the impact on smaller species is often not realised. For example, a weekly roadkill survey of 2 km on the Kuranda Range section of the Kennedy Highway behind Cairns found more than 4000 casualties within a 3 year period (Goosem 2000): 3000 amphibians, 500 reptiles, 500 mammals and 100 birds. Of these, the majority were too small to be observed from a moving vehicle – possibly about one-third of the mammals and reptiles, about 10% of the birds and amphibians could be noticed when driving. So the road toll is generally much larger than those of which drivers are aware. Many smaller species are rare, vulnerable and endangered under conservation legislation.

3.1.3 Fauna Sensitive Road Design

Fauna Sensitive Road Design is a means of mitigating road impacts on a variety of species. However, addressing these issues can be complex in an environment of conflicting government legislation at various levels (van der Ree *et al*. 2007). Recently, attempts to alleviate these problems have been made, primarily through devolution of responsibility to lower government levels, but confusion can still be caused by the numerous levels of agencies engaged in flora and fauna protection: federal, state and local government protected areas, resulting in a number of government agencies and private, community-based and Traditional Owner organisations becoming involved in conservation and design of mitigation strategies. All of these bodies need information to achieve their goals.

Fauna Sensitive Road Design theory suggests several methods of **mitigation against fauna-vehicle collisions.** These include road markings, wildlife awareness signage, guide fencing and underpasses and are discussed in detail in Chapter 5. Options that were not considered here because of absence in the Mission Beach area include scent markings, inclusion of strategic verge and island vegetation and rope overpasses (QDMR 2002; QTMR 2010) but are considered in Chapter 5.

Road Markings include transverse, peripheral herringbone, checked pattern and raised pavement markings. These are easy and economical to install and may produce a short-term effect without drivers being aware of the change. However local drivers are less likely to alter behaviour and tend to habituate to the markings (Deller 2005).

Wildlife Awareness Signage is used extensively worldwide, generally depicting the animal concerned or providing information to raise awareness. Signage is also economical to install and educative, but also tends to be ineffective without other mitigation measures, particularly for local drivers. Recent innovations include fibre optic signs which become illuminated when wildlife encroach onto roadsides – these are used throughout France (Bank *et al.* 2002).

Guide Fencing does not rely on human behaviour for effectiveness, unlike road markings and wildlife signage. Like signage and road markings, however, fencing must be used with other measures to be effective. Initially, fencing was designed to keep fauna off the road, thereby increasing the fragmentation effects of roads by dividing roadside faunal populations. More recently there has been a shift away from this approach with more emphasis on guiding fauna off roads and towards crossing structures (QDMR 2002, QTMR 2010). Research suggests that guide fencing has significantly reduced fauna-vehicle collisions (Goosem et al. 2004); however this may come at a cost of fragmentation of populations if insufficient crossing structures are provided. Guide fencing is installed to guide fauna off roads and into habitat or underpasses, but 'returns' must be provided for animals that become trapped within the road corridor. These can take the shape of gaps in the fencing strategically angled to ensure fauna only enter from the road, rather than adjacent habitat, or ramps up to the top of the fence from the road side only. Guide fencing is different for each target species or group. For example, when frogs are the primary concern the fence is low and constructed to prevent hopping over, whereas escape poles from the road side of the fence might be provided for climbing animals to return into adjacent habitat beyond the fence (Goosem 2003). Slippery sheeting can be installed to prevent climbing animals reaching easily-climbed fence materials (Goosem 2003; Caneris and Jones 2004). Whichever is used, fencing can be an expensive option in terms of maintenance because vegetation must be kept clear of the fence and holes in the fence must be mended immediately.

Fencing specifically for cassowaries has been constructed at one site on the Tully Mission Beach Road, and another in habitat adjacent to the El Arish Mission Beach Road. However its effectiveness has not been previously assessed. The experience of cassowary researchers indicates that fencing for cassowaries must not be constructed of wire mesh because birds will continue to attempt to move through it and thereby injure themselves (Bentrüpperbaumer and Goosem 2005). Instead shade mesh should prevent cassowaries observing habitat on the other side of the road and guide them to safer crossing areas (Goosem *et al.* 2004).

Underpasses are defined as 'a crossing structure allowing animals to pass under traffic' and can be further categorised into 'bridges' and 'culverts' (Wildlife Crossings Toolkit, USDA 2005; van der Ree *et al.* 2007). The North Hull River bridge is a "multi-span bridge' as it has one or more intermediate support columns between abutments (USDA 2005). Culverts are 'a conduit covered with embankment around the entire perimeter' which 'may or may not convey water' (USDA 2005). The culverts at Lacey Creek and Stoney Creek are 'box culverts' as they have 'four sides, including bottom' (USDA 2005).

The benefits of providing corridors and connectivity are generally agreed (Laurance et al. 2008) and underpasses and other crossing structures form part of the provision of landscape connectivity. Benefits of connectivity include increasing diversity through genetic exchange, maintenance of faunal population and community structure and decreasing competition for food resources (Goosem *et al.* 2006; Bond and Jones 2008; Bissonette and Adair 2008; Laurance *et al.* 2009).

Although installation of underpasses is popular, there are great uncertainties regarding optimum distance between underpasses, the number of animals required to cross each year to ensure effective genetic dispersal; and the species that will use underpasses and therefore how to provide effective connectivity (Forman *et al*. 2003; Bissonette and Adair 2008). These uncertainties arise because of the need to integrate several factors into underpass design.

Design factors to be considered include:
a) corridors in the form of continuous habitat leading to the structures that provide food plants to entice fauna;
b) furniture within underpasses,
c) dry and wet pathways for different species groups and
d) differences in underpass size requirements by different species groups (Forman *et al*. 2003; Goosem 2003; Goosem *et al.* 2006; Bond and Jones 2008).

Vegetation requirements also differ between species. For example, most macropods prefer simple vegetation structure while many rainforest species prefer much more complex vegetation. Research shows that the further away vegetation is from the underpass, the more likely that use of the underpass will be less (Goosem *et al*. 2006). On the other hand, excessive vegetation which hinders external or internal views of apertures can decrease use of underpasses by open habitat species (Forman *et al.* 2003; Barnes 2007). Vegetation can also assist in limiting penetration of noise and headlight glare, both of which may reduce underpass use (Goosem *et al.* 2006).

Underpass use can be encouraged, habituation time decreased and use increased by the provision of furniture which includes leaf litter, soil and rocks (Goosem *et al.* 2005; Wilson 2006; Bond and Jones 2008). Goosem and Weston (2002) described successful furniture at a particular site that included escape poles for climbing animals to avoid ground predators and rocks and logs to provide connectivity, refuge and dry passage for small mammals, amphibians and reptiles (Goosem *et al.* 2004). Provision of dry passage is important because many underpasses serve a dual purpose, acting simultaneously as water channels and crossing structures. Dry passage can be ensured by using pipes and culverts at varying heights (Barnes 2007), ledges and logs within culverts. Underpasses need to provide dry and wet passage throughout all seasons to encourage use by all species groups (Goosem *et al.* 2004; QDMR 2004; Barnes 2007; Swanson and Hershfeld 2007) and prevent terrestrial fauna from crossing over the road surface when underpasses are wet, thereby increasing roadkill rate (Baker *et al.* 2004).

Underpass efficacy is also affected by underpass size. In general, wildlife use of underpasses increases with an increase in structural dimensions (Goosem *et al.* 2001). Structures with greatest use have heights at least equal to their width and apertures that allow unobstructed view of habitat (Goosem and Weston 2002). However, size needs to be considered in terms of local fauna and targeted species. For example, small mammals tend to use smaller underpasses although furniture, vegetation and shelving in large underpasses may encourage their use (Bond and Jones 2008).

Underpass design and implementation must be addressed holistically to provide the greatest chance of success (Goosem *et al*. 2004). It is the integration of design guidelines with site-specific requirements and knowledge of the target species or group that encourages success (Jaeger 2007). An effective crossing structure is defined as one which enhances or re-establishes genetic exchange and connectivity (Bond and Jones 2008) and maintains population and community structure on either side of a road (Weston *et al.* 2011). Success may be encouraged by installing several culverts in one location to reduce competition between individuals, predator attraction, travel time to a safe crossing and habituation time (Barnes 2007) and incrementally increase connectivity (Jaeger 2007). Success can also be increased by installing culverts that can be utilised by a large number of species (Bissonette and Adair 2008), by connecting larger areas before smaller ones (Jaeger 2007) and by undertaking research prior to installation that establishes local fauna pathways and behaviour (Forman *et al.* 2003; Taylor and Goldingay 2009).

However, even though all these considerations may be taken into account, success can never be assured due to animal behaviour. For example, in Tasmania, purpose-built platypus culverts were ignored and high levels of roadkill continued (Magnus *et al.* 2004). Specialist species may also be more difficult to encourage; generalists such as bandicoots and rats tend to be frequent users (Taylor and Goldingay 2003; Magnus *et al*. 2004; Goosem *et al.* 2006). Prey funnelling has often been considered a disadvantage of crossing structures, but thus far has not been observed for a variety of structures in the Wet Tropics (Goosem *et al.* 2006; Weston *et al*. 2011), although occasionally observed elsewhere (Hunt *et al.* 1987; Brock and Kelt 2004).

This study aimed to examine the two major access roads to Mission Beach in relation to roadkill rates, including both small and larger species. Road design and efficacy of underpasses and cassowary fencing were also examined using sand tracking in underpasses and adjacent to fencing.

Several research questions were considered:
a) What was the wildlife mortality rate on the El Arish - Mission Beach Road and the Tully - Mission Beach Road over four months?
b) What was the effect of traffic volume and speed on roadkill rate?
c) Were there temporal variations in roadkill rate?
d) Did cassowary fencing influence roadkill rate?
e) Were fauna crossing roads via road underpasses such as culverts and a bridge?
f) Did road design affect roadkill rate?

3.2 METHODS

3.2.1 Road Mortality Surveys

Four roadkill surveys were conducted between April and July 2008.

Study transects
Study sites were located between 17.5^{o}S and 17.52^{o}S and approximately 146.45^{o}E along the Tully - Mission Beach Road and the El Arish - Mission Beach Road. Two transects of 0.5 km in length separated by approximately 5 km were surveyed on each road by walking along either side of the road. All transects were relatively flat, although some areas on each transect included dips and curves and road surfaces were of similar width (approximately 6.6. m from edge line to edge, although there were some narrower and wider sections in each transect. Each transect had grassy road verges which varied in width and elevation before rainforest edge and each contained at least one watercourse. Tree sizes and ages varied along each transect with some revegetation along some sections and others with mature trees. Transect 1 commenced near the Bean Tree track on the El Arish – Mission Beach Road and finished 0.5 km from there towards El Arish. Transect 3 commenced at commenced at Lacey's Creek and continued for 0.5 km towards El Arish. Transect 2 on the Tully – Mission Beach Road included 0.5 km in the vicinity of Stoney Creek, whilst Transect 4 was situated about 1 km towards Mission Beach from Sellar's banana farm.

Each transect was surveyed for road design factors including adjacent microtopography, habitat, road surface width and total road clearing width. Transects were divided into 20-30 m intervals marked with flagging tape.

Roadkill surveys occurred each day in a continuous 5 day period (Monday to Friday) once a month from April 2008 till July 2008 (4 field trips and 20 days). The position of each road kill on the road surface and adjacent verge was noted while walking along either side of the road. Specimens were removed from the road and those that could not be identified *in situ* were stored in plastic bags and identified under the microscope in the laboratory. Surveys commenced at dawn and the initial transect surveyed was varied throughout the field trip so biases in time of survey in terms of identifiability and scavenging by other fauna were avoided.

3.2.2 Underpass Use Surveys

Sand plots were constructed during the April roadkill survey. They were placed at either end of the Stoney Creek culvert on the Tully – Mission Beach Road, one on either side of the road under the cassowary fencing at Stoney Ck on the Tully – Mission Beach Road; two at either end of Lacey's Creek culvert on the El Arish – Mission Beach Road; and another under the North Hull River bridge on the Tully – Mission Beach Road. All sand plots were 1.5 m x 1.5 m in size, except at the North Hull River which was 1.5 m wide and 3 m in length to encompass the entire accessible width under the western side of the bridge which was not under water.

Sand plots were checked each day of the roadkill surveys (May, June, July) for prints, tracks and scats, with photographs taken and direction of travel and features of the print recorded including number of toes and size of print. Sand plots were then smoothed for examination the next day. After July, opportunistic examination of sand plots was undertaken during field work for other projects between August and October 2008.

3.2.3 Data analysis

Data were presented graphically using Microsoft Excel 2003 and analysed statistically where sufficient data existed using Analysis of Variance (ANOVA) and Least Significant Difference (LSD) in SPSS Version 17.0. Analysis of variance examined the effects of time (four months: April, May, June, July) and location (4 transects) on roadkill for species groups: remnants, invertebrates; reptiles and amphibians. There was insufficient data for analysis of mammals and birds.

3.3 RESULTS

3.3.1 Road Mortality Surveys

Over the study period of surveys along 2 km of transects 5 times in April, May, June and July 2008, 1983 roadkill specimens were documented, of which 1355 were identifiable to a faunal group (Figure 3.1), while the remaining 628 specimens were remnants comprising small mixed pieces of bone or chitin. Cane toads (*Bufo marinus*) had the highest roadkill rate of all species with 457 specimens recorded, or nearly a quarter of all roadkill. Fourteen groups of invertebrates were found (Table 3.1, Figure 3.2), as well as a general insect group for specimens that could not be identified further. Table 3.2 and Figure 3.3 show the vertebrate species recorded: nine species of amphibians, and two general groups (unidentifiable Hylid frogs, unidentifiable amphibians); four species of reptiles, and a group of unidentifiable snakes and lizards; three species of birds and an unidentifiable group; and six species of mammals, birds and bats were identified and six species of mammals and two groups that could not be identified to species (unidentifiable Chiropterid bats, unidentifiable mammals).

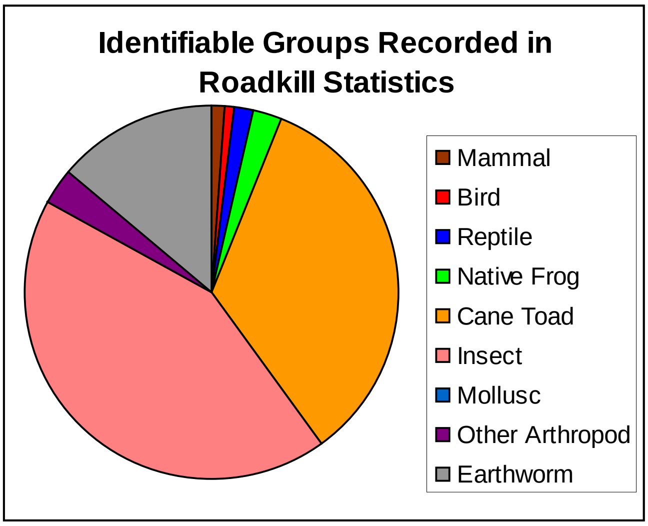

Figure 3.1 General groups of road kill victims on 2 km surveyed from April – July 2008

Table 3.1 Invertebrate specimens recorded in road mortality statistics

Specimen	**Common name**	**April**	**May**	**June**	**July**	**Total**
Insects						
Lepidoptera	Moths and butterflies	24	81	170	77	352
Papilio aegeus aegeus	Orchard butterfly	1	0	0	0	1
Coleoptora	Beetles and Weevils	17	32	52	7	108
Odonata	Dragonflies and Damselflies	27	25	15	12	79
Caelifera	Grasshoppers	12	2	4	1	19
Ensifera	Crickets and Katydids	0	8	6	1	15
Hymenoptera	Wasps, Bees, Ants, Sawflies	0	2	1	2	5
Phasmotodea	Stick insects	1	0	0	0	1
Diptera	Flies	1	0	0	0	1
Unid Insects		0	2	0	0	2
Other Arthropods						**43**
Diplopoda	Millipedes	0	4	3	4	11
Chilopoda	Centipedes	0	2	5	2	9
Aranaea	Spiders	5	4	13	1	23
Molluscs						**1**
Gastropoda	Snails and Slugs	0	1	0	0	1
Earthworms						**187**
Opisthopora	Earthworms	6	56	63	62	187

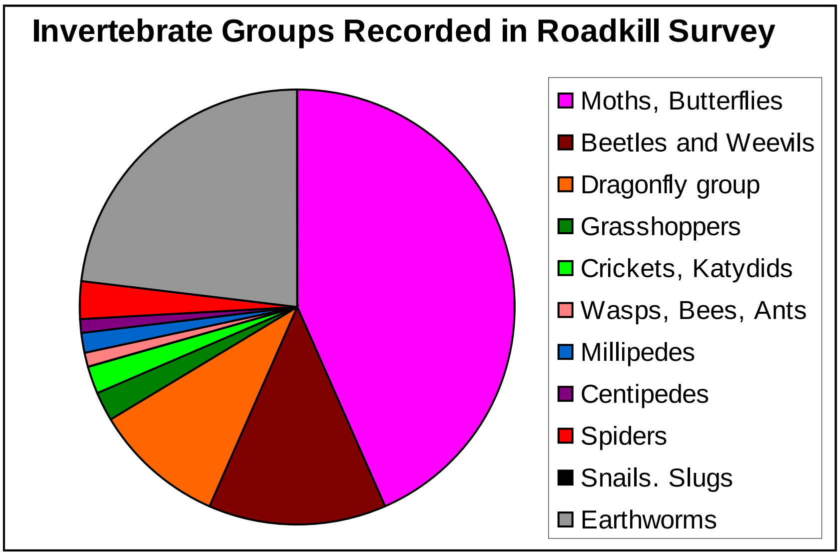

Figure 3.2 General invertebrate groups recorded in the road kill survey.

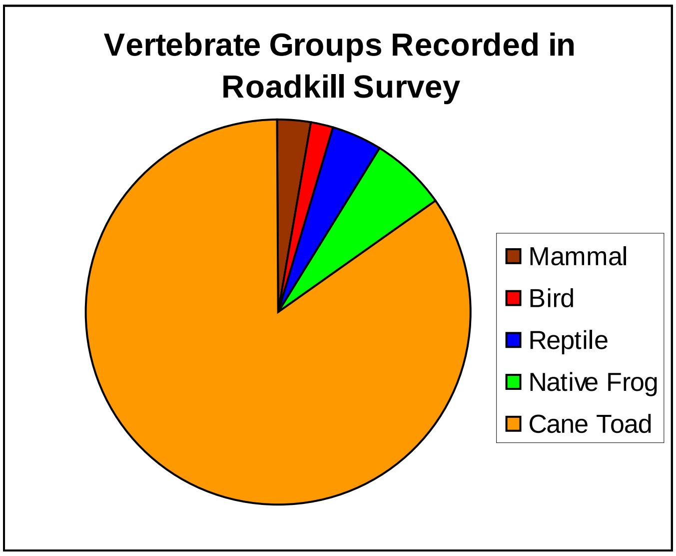

Figure 3.3 General vertebrate groups recorded in the road kill survey. The feral Cane Toad has been separated from the remainder of amphibian (native frog) casualties.

Table 3.2. Vertebrate specimens recorded in road mortality statistics

Specimen	Common name	April	May	June	July	Total
Amphibians						**492**
Bufo marinus	Cane Toad	147	86	110	115	458
Litoria infrafrenata	Giant White-lipped Tree Frog	7	3	0	0	10
Litoria gracilenta	Dainty Green Tree Frog	7	1	0	0	8
Limnodynastes convexiusculus/ peronii	Marbled Marsh Frog/ Striped Marsh Frog	3	0	0	0	3
Litoria rubella	Desert Tree Frog	0	0	2	0	2
Litoria bicolor/ fallax	Northern Dwarf Tree Frog/ Eastern Dwarf Tree Frog	0	1	1	0	2
Litoria nigrofrenata	Bridled Frog	2	0	0	0	2
Litoria genimaculata	Green-eyed Tree Frog	2	0	0	0	2
Litoria lesueuri/ jungguy	Stony Creek Frog	0	1	2	0	3
Nyctimystes dayi/ Litoria rheocola		0	0	1	0	1
Unid hylid frog		1	0	0	0	1
Reptiles						**23**
Carlia rubrigularis	Skink	2	0	1	1	4
Gehyra dubia	Gecko	1	0	0	0	1
Cacophis churchilli	Snake	1	0	0	0	1
Dendrelaphis calligastra	Northern Green Tree Snake	0	1	0	0	1
Cryptophis nigrescens	Small-eyed Snake	0	1	0	0	1
Unid snake/ skink		8	2	3	3	16
Birds						**10**
Rhipidura rufifrons	Rufous Fantail	0	1	0	0	1
Chalcophaps indica	Emerald Dove	1	0	0	0	1
Monarcha trivirgatus	Spectacled Monarch Flycatcher	0	0	0	1	1
Unid birds		2	0	4	1	7
Mammals						**15**
Perameles nasuta	Long-nosed Bandicoot	1	1	1	1	4
Rattus leucopus/ fuscipes	Cape York Rat/ Bush Rat	1	0	0	0	1
Melomys cervinipes	Fawn-footed Melomys	1	0	0	0	1
Uromys caudimaculatus	Giant White-tailed Rat	1	0	0	0	1
Miniopterus schreibersii	Common Bent-wing Bat	1	0	0	0	1
Miniopteris australis	Little Bent-wing Bat	1	0	0	0	1
Unid. Chiropterid	Unidentified microbat	1	1	0	1	3
Unid. Mammal	Unidentifiable fur, bone	1	1	0	1	3

3.3.1.1 Seasonal Effects

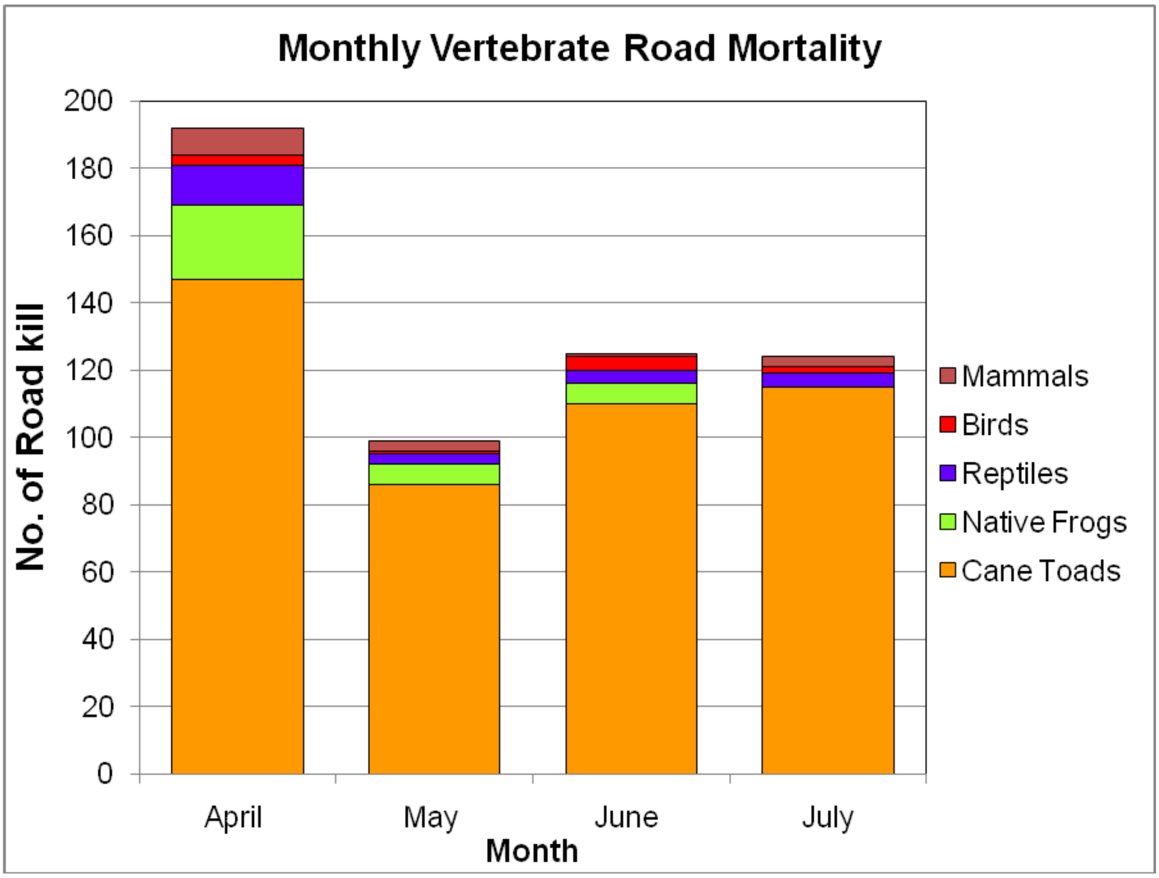

Figure 3.4 Total monthly roadkill of vertebrates.

The greatest amount of roadkill overall was recorded in June, due to high numbers of invertebrates, particularly moths, being killed. June was significantly different from the other three months (ANOVA: Months, F=5.3, df=3, P=0.010; species group*months, F=0.005, df=6, P=0.005). The interaction between months and species groups was due to the increased numbers of amphibians and reptiles in April and May compared with June and July, whilst invertebrates had significantly higher numbers in June.

In contrast, greatest road mortality of vertebrates occurred in April due to larger numbers of cane toads and native frogs being killed at the end of the wet season (Figure 3.4).

3.3.1.2 Location Effects

Over the entire survey period, the transect on the El Arish – Mission Beach Road that includes Lacey Creek had the highest roadkill rate of vertebrates and invertebrates (>950 specimens), although road mortality on the Tully – Mission Beach Road at both Stoney Creek and one kilometre towards Mission Beach from Sellar's banana farm was also very high (~640 specimens). The 0.5 km towards El Arish commencing at the Bean Tree Track (which leads from the El Arish – Mission Beach Road to Licuala picnic area and walks) had the least numbers of animals killed (~280 specimens, 41 vertebrates, 9 native species but including an endangered frog species). Cane toads formed the majority of vertebrate road statistics on all transects, although there were few toads near the Bean Tree Track. Native frog kill was similar across all transects except near the Bean Tree Track where there were lower numbers recorded (3 vs 10-15). The numbers of birds and mammals were very low on all transects.

There was significantly less roadkill overall (including unidentifiable remnants) recorded on the transect near the Bean Tree Track (T1) on the El Arish – Mission Beach Road than on the other three transects whereas road mortality on the Lacey Creek transect (T3) was significantly higher than the other 3 transects on (ANOVA: F=13.6, df=3, P=0.001; LSD = 27.2: T1=38.5, T2=82.7; T3 = 124.2; T4 = 81.2). Both transects on the Tully – Mission Beach Road recorded similar road kill rates (T2, T4). The relatively low levels of road mortality near the Bean Tree track compared to other transects was also apparent for native amphibians (2 specimens vs 12, 17 and 12 on transects 2, 3 and 4 respectively) but bird and mammal mortality was relatively even (6-8 casualties), other than on the Lacey Creek transect where 20 birds and mammals were recorded. These data of native vertebrate mortality recorded in the four months were insufficient for statistical analysis. Longer term surveys would be required to confirm any differences between transects.

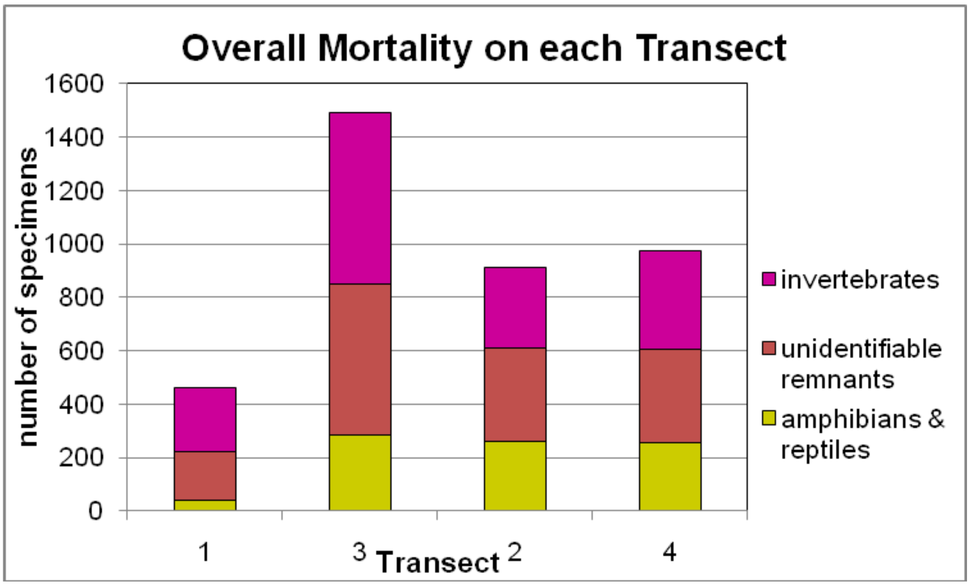

Figure 3.5 Overall mortality on each transect for invertebrates, amphibians and reptiles and unidentifiable remnants

3.3.1.3 Species of Conservation Concern

Only two species of conservation concern were recorded in the road mortality statistics. There were the Green-eyed Tree Frog (*Litoria genimaculata*) and a specimen in a state which made identification difficult but which was narrowed down to either *Nyctimystes dayi* or *Litoria rheocola*, based on the features remaining. Not surprisingly, these stream-dwelling frogs were found near water. *Litoria genimaculata* was found in April on the Stoney Creek transect near a fast-flowing creek, whilst the other endangered specimen was found in June near a creek culvert. Additionally the Southern Cassowary (*Casuarius casuarius johnsonii*) was encountered crossing the road during road kill surveys, particularly on the transect near the Bean Tree Track.

3.3.1.4 Road Design Features associated with High Road Mortality

Features of areas recording high road kill rates overall, included an area on the Bean Tree Track transect where a creek flows parallel to the road, although this was not the area of highest native vertebrate mortality which generally occurred near culverts for smaller creeks.

On the transect incorporating Stoney Creek, highest road mortality again occurred near a small creek with two culverts, however highest vertebrate mortality and native vertebrate mortality occurred at Stoney Creek itself. Highest roadkill rates were also associated with a creek on the transect 1 km from Sellar's banana plantation, although creeks were not the focus of roadkill on the transect incorporating Lacey Creek. Low levels of vertebrate road mortality appeared to be associated with cuttings and steep slopes in several places, although insufficient data were collected to analyse road design features statistically.

3.3.2 Surveys of Underpass Use

On the total of seven sand plots installed in this study, 84 tracks and scats were found between April and October 2008 in underpasses and one print and one scat were observed on the plots adjacent to the cassowary fencing. The majority of tracks and scats (68) were found under the North Hull River bridge (Figure 3.7). Scats of *Rattus* spp. (probably *leucopus* or *fuscipes* i.e. Cape York or Bush Rat) were recorded most often (9), whilst tracks of bandicoots (most likely to be *Perameles nasuta,* Long-nosed Bandicoot) were the most common (35 of 71 tracks). Southern Cassowary (*Casuarius casuarius johnsonii*) tracks (6) were only found under the North Hull River bridge (Figure 3.6). Other species with tracks and/or scats observed included 10 tracks and 1 scat of Water Rat (*Hydromys chrysogaster*), 1 track of Red-legged Pademelon (*Thylogale stigmatica*), 2 tracks of small rodent likely to be Fawn-footed Melomys (*Melomys cervinipes*), 1 track of Giant White-tailed Rat (*Uromys caudimaculatus*), 1 track and 2 scats from Cane Toad (*Bufo marinus*), three tracks of birds, and three of reptiles (probably goanna or dragon lizard).

Figure 3.6 Variety of tracks including Southern Cassowary found in the sand trap under North Hull River bridge on 25/09/2008.

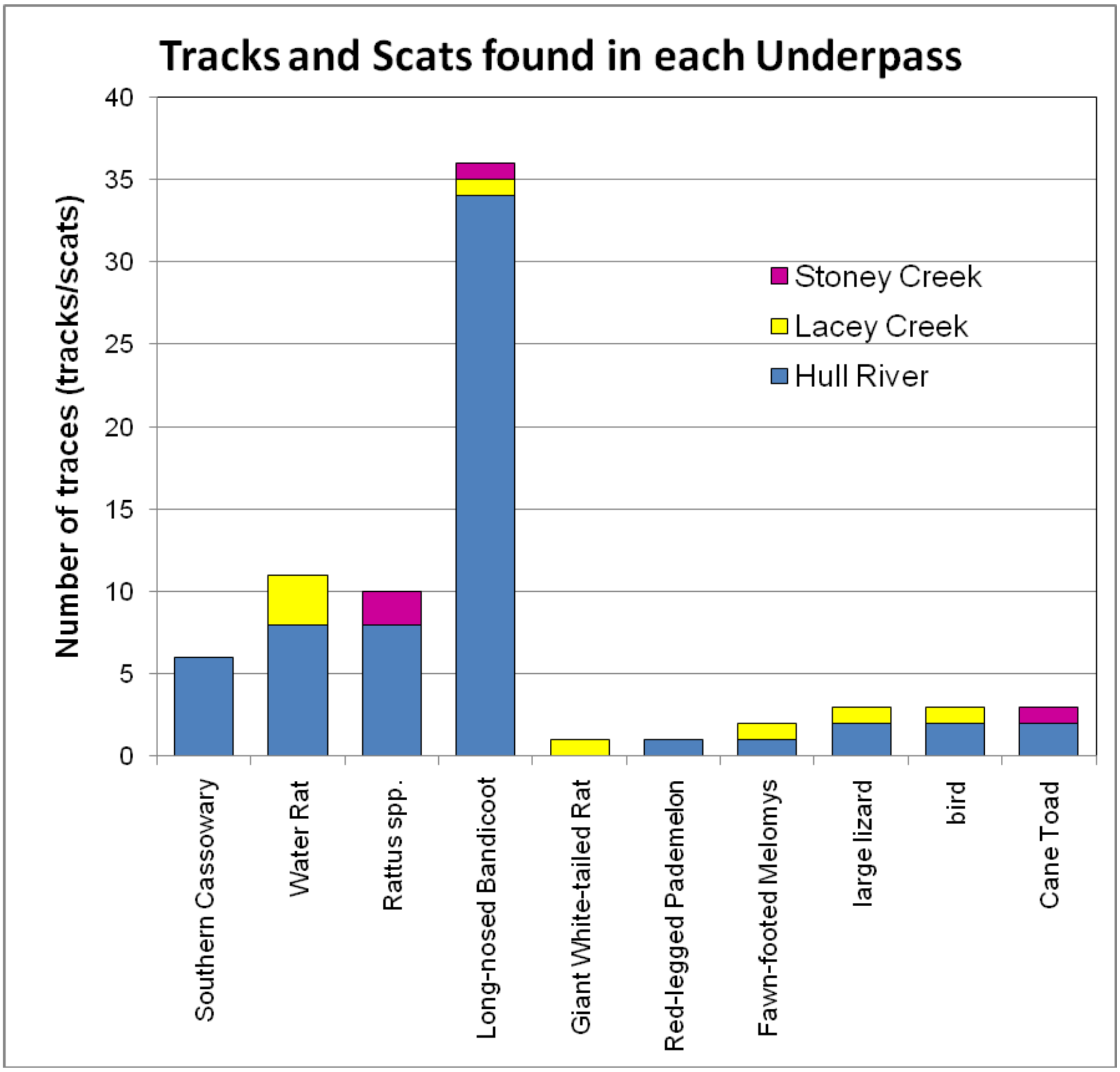

Figure 3.7 Underpass use by vertebrates recorded between April and October 2008.

Most tracks and scats were recorded in July, otherwise numbers recorded were relatively consistent over the four months of consistent monitoring (May – August).

Additionally, several photographs were obtained using infra-red triggered wildlife cameras of animals using the Lacey Creek underpass. Unfortunately, cameras in the Stoney Creek underpass were not successfully deployed prior to flooding, when sensors were washed away and it was not possible to install cameras safely that would cover the large area under the Hull River bridge (Figure 3.8).

Figure 3.8 Long-nosed Bandicoot and Snake photographed inside the Lacey Creek culvert.

3.4 DISCUSSION

3.4.1 Road mortality

We found greatest roadkill rates on the half kilometre transect near Lacey's Creek, although this was a function of greater Cane Toad, invertebrate and unidentifiable remnant numbers, rather than native vertebrates. In fact, over all transects, native vertebrate road mortality was fairly evenly distributed (25-34), other than for the transect near the Bean Tree Track (10) which had much lower numbers of all types of road kill. It is not clear what the reason for this may be. The road has several dips and crests which may possibly reduce driver speed, together with the requirement to reduce speed to negotiate the curves of Fenby Gap nearby. Cassowaries were observed crossing in this area twice during the survey (and crossings were common in other sections of this study), so it is possible that drivers were being "Casso-Wary". The lower numbers are certainly not a function of traffic volume, because traffic density on the El Arish – Mission Beach Road is significantly less than on the Tully – Mission Beach Road (Chapter 4) and the two transects with highest and lowest road mortality occur on the same road. A concurrent study found that highest levels of roadside rubbish, particularly food, were found near Lacey's Creek, so it is possible that animals such as Cane Toad and insects are attracted to this resource. The presence of the Lacey's Creek culvert does not appear to have any impact on road mortality rate, although it would not be expected to function as an underpass for the majority of the invertebrate fauna or for Cane Toads which prefer open areas.

An interesting point is that the lowest level of road mortality of all groups was observed on the transect with the smallest average verge width (2m wide on either side and grassy) compared with 6-10 m wide on the Tully – Mission Beach Road and about 4 m on the Lacey Creek transect). It therefore appears that wider verges do not provide greater protection from road mortality for a variety of fauna.

Seasonal variation did have an effect on mortality rate of amphibians and invertebrates but data were insufficient to analyse this for other groups. There was an apparent increase in road mortality in the vicinity of creeks of varying sizes, but again we did not have enough data to determine whether this was significant statistically.

Neither the cassowary fencing at Stoney Creek nor the road markings in the Stoney Creek area of the Tully – Mission Beach Road nor the rumble strips in the vicinity of Lacey Creek on the El Arish – Mission Beach Road nor potential underpasses at Stoney Creek and Lacey's Creek nor signage on the transects appeared to have a significant effect on road mortality rate. In fact the lowest mortality rate was recorded on the transect that had almost none of these "Fauna Sensitive Road Design" solutions. There are several reasons for this lack of effectiveness:

1) All the species found as road kill could easily have passed under the cassowary fencing – even an animal as large as a wallaby was found as a carcass in October 2008. However, there was evidence of cassowary use near the fencing in the form of droppings which suggested that the alignment of the fence did not encourage cassowaries to move onto the road surface, at least in that area.
2) On the Lacey's Creek transect, the highest rate of road mortality occurred nearly 500 m from the creek culvert at the area of the sign stating "Cassowaries utilise this area. Please do not feed cassowaries', demonstrating that that particular sign has little effect on mortality of other fauna. Studies have found that local drivers tend to become habituated to signage unless it has a novel flavour and is moved often,
3) The road markings at Stoney Creek were not particularly obvious and again habituation can be a factor. Evidence suggested that when transverse lines were placed at short distances across the road near the Hull River Bridge that traffic did tend to slow somewhat, however, the likelihood of precipitating illness in some members of the travelling public necessitated removal of closely-spaced lines.
4) The rumble strips in the vicinity of Lacey Creek are not very obvious and, even though recently refurbished, still do not tend to be noticed by many drivers.
5) Both potential underpasses have problems and are unlikely to function effectively (see Underpass Usage below).

3.4.2 Underpass Usage

Although cane toads were most frequent in the road mortality statistics they did not use the underpasses. The reverse was true for bandicoots, which were the highest users of underpasses recorded on sand plots but seldom appeared as road kill.

Of all the areas with potential to function as underpasses, under the North Hull River Bridge was the most used. Revegetation along the side of the river where fauna can enter the underpass has been successful. Cassowaries appear to use the area commonly at least at certain times of the year – there were at least two different size of footprints recorded, suggesting a family party and another single adult. There could be several reasons for this use of the North Hull River bridge by Cassowaries:

1) It is almost always relatively dry;
2) It is wide and high which generally will encourage use by larger fauna; and
3) It is well vegetated.

Overall this underpass provides an option for Cassowary movement which avoids crossing the road surface. However, this is only likely to be effective in the vicinity of the bridge, as Cassowaries commonly cross the road surface near the South Mission Beach Road turnoff and are occasionally recorded crossing the road surface only several hundred metres away from the bridge towards the Licuala turnoff. To increase the use of this underpass a large amount of purpose-designed cassowary fencing would be necessary, which could also have the effect of

1) Preventing movements across the road by other fauna which do not range as widely, thereby fragmenting populations;
2) Disrupting Cassowary movements and potentially bringing them into territorial disputes with others of the same species at the area where the fencing ended;
3) Affecting the aesthetics of the road for drivers including tourists;
4) Trapping Cassowaries that enter the road beyond the fencing on the road surface;
5) Requirements for a lot of maintenance of the fencing.

In comparison, the Stoney Creek purpose-designed retrofitted underpass received minimal use and there it was not used by Cassowaries during the study period. There are several possible reasons for this also:

1) It is often wet, allowing no use during those times;
2) At one end, there is a pool of water which would prevent most small fauna from moving into the adjacent habitat from the dry ledge (i.e. there is no dry passageway all the way through the culvert), this may also discourage cassowaries;
3) It has no furniture for cover;
4) Vegetative cover at entrance and exit is affected by the creek, providing little protection;
5) It has a relatively small height and width for its length.

In the past there has been evidence of at least one family party of Cassowaries occasionally using the Stoney Creek culvert (DERM ranger, pers. comm.), but this only appeared to be during one time of one year and it certainly was not occurring in 2008.

Similarly, the culvert at Lacey's Creek was not used for passage by Cassowaries during the study period and there is little evidence that it has ever been used as a road crossing route. In the past a Cassowary was observed heading towards the culvert but it turned back. Meanwhile the road surface at the Lacey Creek carpark and walking track on the other side of the road is commonly crossed by Cassowaries (Chapter 2) and one bird was killed there during the Chapter 2 study. The Lacey Creek culvert was also not used a great deal by other fauna, although photographs were taken of a snake and bandicoot passing through and smaller rodents did appear to use it. Possible reasons for this are

1) A lack of dry passageway at wetter times of the year;
2) Disturbance by visitors using the picnic area and swimming in the creek.
3) These culverts have a relatively low height and width in comparison to length.

3.5 CONCLUSIONS AND RECOMMENDATIONS

Unfortunately the toll from road mortality was not affected by "Fauna Sensitive Road Design" that included cassowary fencing, road markings to reduce the apparent road surface width, warning signage, rumble strips and potential underpasses. We found that higher traffic volume is not necessarily a cause of increasing road mortality of fauna other than Cassowaries. Seasonal variation did have an effect on amphibian and invertebrate road mortality rates, but there were insufficient data to examine this for other groups. It is possible that greater road mortality occurs near streams but analysis was impossible.

Underpass usage showed that a variety of fauna will use these structures, and, in particular, the higher, wider and well-vegetation Hull River bridge underpass was well used. Cassowaries only used this underpass, and did not venture into the lower, narrow Lacey's Creek or Stoney Creek culverts.

Several recommendations can be made from this study:

1) The Stoney Creek underpass needs refurbishment to include:
   a) dry passage at either end;
   b) more vegetative cover at either entrance;
   c) some cover within the culvert, which, in the case of this culvert which also carries water, could take the form of rocks that are cemented in but still provide refuge for small fauna underneath them:
   d) Refurbishment is unlikely to encourage much use by Cassowaries due to the dimensions of the culvert and the ease of crossing over the road surface unless much greater attention is paid to fencing which can then cause other problems.

2) The Cassowary fencing needs upgrade to reduce the gap at the bottom of the fence to a much smaller gap that will exclude fauna the size of Cassowary chicks from passing under. This was always the intention of the design, but unfortunately did not get translated exactly into practice.

3) Road mortality did not appear to be affected by traffic volume or by design features such as rumble strips, signage and road markings that aim to reduce traffic speed. It appears that much stronger measures are needed to reduce speed. The smaller numbers of victims appearing on a transect that tends to require drivers to drive more slowly due to dips and crests, suggests that speed reduction could be effective in reducing mortality. Reduced speed may give drivers greater opportunity to sight fauna and fauna more chance of avoiding vehicles. We suggest that a lowered legislated speed limit along the forested sections of the Mission Beach entry roads could contribute to less road mortality.

4) It may be possible to encourage use of the Lacey's Creek underpass by fauna other than Cassowaries by undertaking similar retrofitting as suggested for the Stoney Creek underpass above. However it is unlikely that this will encourage use by Cassowaries to any great extent due to the dimensions of the culverts.

5) Further research into speed reduction mechanisms, road mortality and underpass usage is required, particularly to determine impact of mortality on local populations and community composition and establish requirements of crossing structures that provide genetic and demographic connectivity.

6) Trial of other forms of signage rather than the sedentary signs currently in situ is needed to determine whether habituation of motorists to signage can be reduced by novel means.

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MISSION BEACH ROAD IMPACTS ON CASSOWARIES AND OTHER VERTEBRATES

SECTION 4:

TRAFFIC LEVELS AND SPEEDS ON TULLY – MISSION BEACH ROAD AND EL ARISH – MISSION BEACH ROAD

4. TRAFFIC LEVELS AND SPEEDS ON TULLY – MISSION BEACH ROAD AND EL ARISH – MISSION BEACH ROAD

Peter Byrnes and Miriam Goosem

Summary.

Traffic volume and speed are important determinants of many road impacts. Foremost among these is road mortality, with many species including the iconic, endangered southern cassowary (*Casuarius casuarius johnsonii*) suffering dramatic losses. This study aimed to determine the defining characteristics and patterns of traffic volume and speed along two roads leading to Mission Beach, one from El Arish in the north (EAMB Rd) and the other from Tully (TMB Rd) in the south.

We placed traffic counters at three sites on each road, all in important cassowary habitat, and with different types of psychological traffic calming. We recorded vehicle characteristics and speed over a four year period. Results showed that both traffic volume and speed were greater on the Tully Mission Beach Road (TMB Rd: mean numbers = 2177 vehicles/day, mean car speed = 85.2 km/h; EAMB Rd: 1214 vehicles/day, 78.7 km/h), while traffic on both roads showed distinct patterns at annual, weekly and daily scales. Annual patterns of traffic flow, where evident, coincided with the seasons, with peak numbers on the road during the dry season (June-October) when Mission Beach receives its tourist influx, and less traffic during the wet season (December-April). Highest traffic volumes occurred on weekdays, with Friday consistently the busiest day and Sunday the least busy. Daily patterns showed directional variability in traffic volume, reflecting the movement of workers and students to and from Mission Beach in the morning and afternoon.

Annual patterns were not evident in average vehicle speeds. However speeds were generally greater on weekdays than weekends and showed strong daily patterns. In particular, vehicle speeds were highest during early morning (0000 hrs - 0700 hrs) and lowest during later daylight hours when traffic volume was greatest and police presence increased. Average monthly speeds along the Tully Mission Beach Road generally exceeded the speed limit of 80 km/h (car 83.8-87.6 km/h, buses and medium-sized trucks 86.7-89.7 km/h).and were consistently greater than along the El Arish Mission Beach Road (car 77.1-82.4 km/h, buses and medium-sized trucks 77.8-83.5 km/h). Maximum speeds on both roads exceeded the 80 km/h limit by up to 120 km/h (EAMB Rd cars 180 km/h, buses and medium-sized trucks 164.5 km/h; TMB Rd: cars 199.6 km/h, buses and medium-sized trucks 199.8km/h).

Psychological traffic calming along the Tully Mission Beach Road, in the form of lines painted to create an appearance of a narrower carriageway at Stoney Creek and lines perpendicular to the road at Hull River, appear to have little effect on traffic speeds, as speeds were greatest at the Hull River. At Lacey's Creek there is a reduction in speeds to an average of 73.7 km/h, but it is difficult to assess whether this is due to the rumble strips installed on either approach or to the winding nature of the road in that area. The large cassowary road accident signs in the vicinity may also have some small effect, in that tourists often slow to take photographs. Similarly vehicles move slowly when entering or leaving the car park at Lacey's Creek and these could also affect the average traffic speeds in the vicinity. The potential impacts of these findings on cassowary populations are discussed.

4.1 INTRODUCTION.

Roads are a major cause of population decline for many important animal species both locally and globally. Causes include edge effects, competition for resources with introduced and native intruders and road mortality (Goosem 2007). The most visible cause of this decline, and therefore the one which gains most attention in the popular media, is road mortality. Within the Wet Tropics World Heritage Area, collision with motor vehicles is a major cause of mortality for iconic species such as the southern cassowary (*Casuarius casuarius johnsonii*) and Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*). Road mortality accounted for 55% of all cassowary deaths recorded in northeast Queensland by Kofron and Chapman (2006) while Newell (1999) estimated that a dozen or more individual *D. lumholtzi* are killed on roads on the Atherton Tablelands each year, with the majority being juvenile or sub-adult males dispersing to new territories. In Tasmania, road mortality also threatens iconic species, including eastern quolls and Tasmanian devils (Jones 2000). This is not a problem restricted to Australia. International examples of animals significantly affected by road mortality include brown frogs in Denmark (Hels and Buchwald 2001) and the endangered Florida panther and key deer in Florida, USA (Forman and Alexander 1998). Vehicle speed and traffic volume are important determinants in the extent and severity of these impacts.

The speed at which a vehicle is travelling determines its ability to stop and the time available for both the driver and animal to react, and therefore avoid a collision (van Langevelde and Jaarsma 2004). It is also directly related to the mortality rate, so slower moving vehicles are less likely to cause fatal injuries to an animal (Gucinski, *et al.* 2001). As such, roadkill is often greater where speed limits are higher. In Tasmania, roadkill representing 54 taxa was found to be greatest where speed limits were greater than 80km/h, while relatively few roadkills were observed in lower speed zones (Hobday and Minstrell 2008). When speed limits were reduced, populations of eastern quolls and Tasmanian devils recovered, although they were previously threatened by road mortality (Jones 2000).

The factor of road design and operation that has been studied most often in relation to road impacts is traffic volume. The common finding in many of these studies is a positive correlation between road impacts and traffic volume. This is also the case for road mortality (Forman and Alexander 1998) at any given speed, because with greater traffic volumes, there are fewer gaps between vehicles for animals to safely traverse the road surface. These higher capacity roads are typically wider and have a higher speed limit (Forman and Alexander 1998; van Langevelde and Jaarsma 2004), increasing the crossing risk further.

Traffic calming is one approach aimed at mitigating negative impacts, such as road mortality, by reducing traffic speeds (van Langevelde and Jaarsma 2009). This is achieved by providing stimuli to cause a driver to slow down. Physical traffic calming can incorporate structures such as speed humps, roundabouts and rumble strips while other psychological forms of traffic calming may include painted lines on a road to give it the appearance of narrowness, signage to make the driver aware of the risk of speeding to themselves, others or the environment, or increased police presence and stricter enforcement of speed limits. Modelling has shown that some forms of traffic calming can have a positive effect on the persistence of species (Jaarsma et al. 2006; van Langevelde and Jaarsma 2009).

This study was aimed at determining the parameters of traffic flow along the two main access roads into Mission Beach, one from El-Arish to the north and the other from Tully to the south. In addition, road markings and rumble strips designed to slow the flow of traffic were assessed for effectiveness. These factors were then used to assess the potential threat of traffic to the endangered southern cassowary, an iconic, keystone species of the area.

1.3 METHODOLOGY.

4.2.1 Traffic Counter Set Up.

MetroCount 5600 series traffic counters (Microcom Pty Ltd, Fremantle WA) were used in this study and set up with paired axle sensors in a classifier layout. Each vehicle was then classified by type, speed and direction of travel and total counts of each vehicle type recorded. These counters use two air pressure switches with a rubber road tube attached to each, spaced 1m apart, across the road. The tube was fixed in place using two wire figure-8 tube clamps at each road edge and nylon road flaps at the road's centre-line and mid-lane. Bitumen road tape was also used on occasions where road nails would not stay fixed into the road surface. The tubes were tensioned using the cleats and each hose attached to the counter.

Each counter had 1MB of memory, which was sufficient for approximately 500 000 individual axle hits to be logged. Batteries last for approximately 290 days before needing to be replaced. Data was downloaded periodically and the counters reset when weather and other commitments permitted. This opportunistic data collection meant the memory was occasionally full when checked and in these cases recent axle hits had not been logged.
The counters were chained and padlocked to traffic signs or other sign posts to prevent theft and, where required, mounted to these off the ground using plastic cable ties to prevent inundation by water during periods of heavy rain.

4.2.2 Traffic Counter Locations.

Mission Beach is located at the end of a loop road made up of the two main access roads into the area: the El Arish Mission Beach Road from the north and the Tully Mission Beach Road from the south. Both roads traverse a range of habitats including agricultural land (sugar cane, fruit orchards and cattle pasture), rainforest and rainforest regrowth, fan palm forest and swamp, and woodland with a rainforest understory (Tully Mission Beach Road only). Land tenures include private freehold land and national park. Six sites were selected for traffic counter installation, three on the El Arish Mission Beach Road (established in 2005) and three on the Tully Mission Beach Road (established in 2008). These were located to assess the performance and effectiveness of traffic calming on each road.

4.2.2.1 El Arish Mission Beach Road.

The western-most counter (Mountain View Close; 17°50'31.49"S, 146°03'13.95"E) was attached to an 80 km/h speed limit sign on a slight slope approximately 1km east of Mountain View Close. The bitumen at this site was 9 m wide and bounded on its northern edge by a 2m wide grassy verge and rainforest. On its southern side there was a 5m wide grassy verge bounded by disturbed rainforest regrowth and agricultural land. The road was slightly undulating with less than 200 m of visibility in each direction due to crests and dips and as such contained a double solid line where overtaking was not permitted.

The second counter (Lacey's Creek; 17°51'4.13"S, 146°03'48.05"E) was located on the western side of the Lacey's Creek bridge, attached to the northern "Speeding has killed cassowaries" warning sign. This was also in an 80 km/h zone with double solid lines and no overtaking. The road at this site was wider (12 m) due to a pull-off section at the edge of the west-bound lane. Visibility was again less than 200 m in each direction, however this was due to bends in the road rather than crests and dips. This site was on level ground. Both sides of the road were bounded by rainforest, with the northern side having a 3 m grassy verge and the southern side a 10 m verge with trees planted for restoration. This site was in the middle of psychological traffic calming in the form of rumble strips on the road and signage, designed to encourage motorists to slow down.

The third counter (Clump Mountain Cooperative; 17°52'00.64"S, 146°05'3.81"E) was located approximately 500 m west of the Mitre 10 hardware shop, fixed to an 80 km/h speed limit sign. The bitumen was 9 m wide and again there were double solid lines and no overtaking due to poor visibility to the west of the counter caused by a bend in the road. Visibility to the east was good, with a long straight section extending for several hundred metres. Vegetation adjacent to the site was *Acacia*-dominated rainforest with 2 m wide grassy verges at each edge.

4.2.2.2 Tully Mission Beach Road.

Data collection on this road was more difficult, due to the substrate not being amenable to the road flap nails holding the hoses in place, resulting in hoses becoming loose or in total removal from the bitumen. Unfortunately road counter hoses were often cut along this road, either during road verge maintenance or immediately after they had been reinstated on several occasions.

The western-most counter (Tully-MB West; 17°55'58.11"S, 146°03'44.97"E) was attached to a "Road narrows" warning sign on the southern edge of the road approximately 2 km west of Stoney Creek within the 80 km/h speed limit zone. The road surface was 9 m wide with 4 m wide grassy verges on each side leading to rainforest. Overtaking was possible in the west-bound lane, but was not permitted if heading east due to poor visibility caused by a bend in the road. Unfortunately, this counter in particular, suffered inconsistent data collection due to at least one rubber hose being cut or pulled out of the road, sometimes only the day after they had been reinstated.

The second counter (Stoney Creek; 17°55'11.65"S, 146°04'4.59"E) was located at the Stoney Creek bridge, attached to the Stoney Creek sign. This section of road has an 80 km/h speed limit. Overtaking is permitted in the east-bound lane but not the west-bound lane due to low visibility caused by a bend in the road. The road was bounded on each side by a 6 m wide grassy verge leading to rainforest. Lines in the bicycle lanes diagonal to the traffic flow direction have been painted at this site. This apparent narrowing of the road is psychological traffic calming designed to encourage motorists to slow down.

The eastern-most site on the Tully Mission Beach Road (Hull River; 17°54'40.98"S, 146°04'36.03"E) was located 200 m to the west of the North Hull River Bridge and was attached to a "Cassowary Conservation Area- Please drive carefully" sign. The bitumen at this site was 10 m wide with a 5 m grassy verge leading to fan palm forest/rainforest on the northern edge and a 12 m verge on the southern edge leading to rainforest. There was no overtaking permitted in either direction on this section of road as the site was located on a large bend with only 150-200 m of visibility in both directions and was leading to the bridge on which no overtaking is permitted. There were numerous lines painted perpendicular to the traffic flow direction across the road surface at this site. Again this psychological traffic calming was designed to encourage motorists to slow down.

4.2.3 Data Analysis.

Data was extracted and sorted from the traffic counter data sets using the MCReport component of MetroCount Traffic Executive v3.16 (Microcom Pty Ltd, Fremantle WA). Data was first assessed, using this program, to look for inaccuracies in the data sets. The main indicator of this was obvious sensor imbalances (>5%) which can lead to errors in vehicle classification and speed determination. The bad data was removed from the analysis and reports were created using MCReport that tabulated the counts of vehicles, vehicle speeds, vehicle classification types and other information for each counter site.

For counts and speeds at individual sites, vehicles were divided into classes as defined by the ARX vehicle classification scheme. Vehicles from classes 2, 4 and 5 were used in the analyses. Class 2 vehicles, as classified by the MetroCount software, are defined as short vehicles with two axles where the distance between the axles is more than 1.7 m and less than 3.2 m. This includes sedans, wagons, 4WDs, utilities and light vans. It does not include these vehicles if they are towing a trailer, caravan, boat, etc. Class 2 vehicles are the most common vehicle type on the roads into and out of Mission Beach. For this report, vehicles from classes 4 and 5 have been grouped as they represent a similar type of vehicle that is common on the roads at Mission Beach. Class 4 and 5 vehicles are two and three axle trucks or buses, respectively, with greater than 3.2 m between front and rear axles. These include delivery vehicles and tourist and passenger buses.

The tabulated data from MCReport was transferred to a Microsoft Excel 2007 (Microsoft Corporation, California USA) spreadsheet for use in statistics software. Means, analyses (t-tests, ANOVA, Kruskal-Wallis and Mann-Whitney U tests) and graphs were produced using SPSS v17 (SPSS Inc., Chicago USA). Means are given as mean +/- standard error and $\alpha=0.05$.

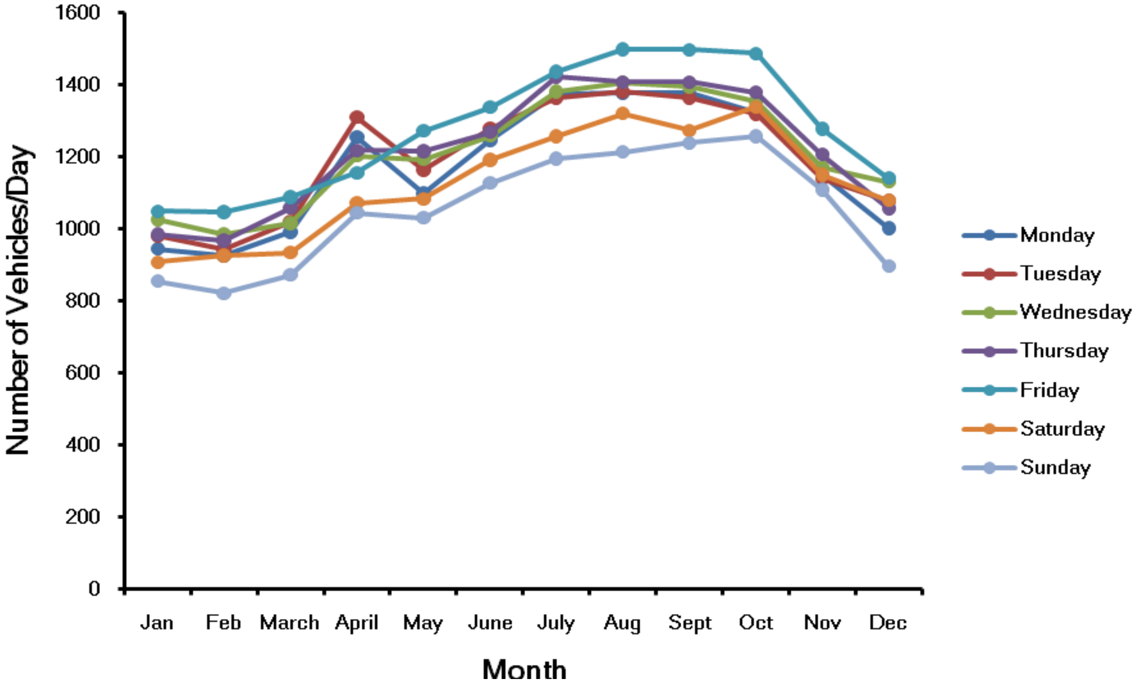
4.3 RESULTS.

4.3.1 Traffic Volume and Direction.

4.3.1.1 All Vehicles

On the El Arish Mission Beach Road (Figure 4.1) weekly vehicular traffic peaked on Fridays (1313 +/- 12 vehicles per day; Table 1) in all months, except April, where it was surpassed by all other weekdays. This anomaly was a result of two consecutive days (a Monday and Tuesday) of heavy traffic flow soon after Tropical Cyclone Larry in April 2006 where numbers were almost twice the monthly average. Sunday was consistently the least busy day on this road (1089 +/- 13.01 vehicles per day; Table 4.1), while significantly fewer

<u>Figure 4.1.</u>
<u>Mean monthly number of vehicles of all classes, travelling each day on the El Arish Mission Beach Road.</u>



<u>Table 4.1.</u>
<u>Daily mean traffic volume on the El Arish Mission Beach Road and Tully Mission Beach Road.</u>

Road	**Day of the Week**	**Mean Traffic Volume +/- S.E.**
El Arish	Monday	1207 +/- 13.1
	Tuesday	1226 +/- 12.54
	Wednesday	1245 +/- 10.24
	Thursday	1252 +/- 11.34
	Friday	1313 +/- 12
	Saturday	1164 +/- 10.36
	Sunday	1089 +/- 13.01
	Weekdays	1249 +/- 5.39
	Weekends	1127 +/- 8.45
Tully	Monday	2255 +/- 18.83
	Tuesday	2275 +/- 16.04
	Wednesday	2336 +/- 13.84
	Thursday	2351 +/- 25.75
	Friday	2464 +/- 27.96
	Saturday	1918 +/- 29.11
	Sunday	1634 +/- 30.32
	Weekdays	2338 +/- 10.2
	Weekends	1778 +/- 23.69

vehicle movements occurred on weekends compared with weekdays (Mann-Whitney U-test, $Z=-12.201$, $p<0.0001$).

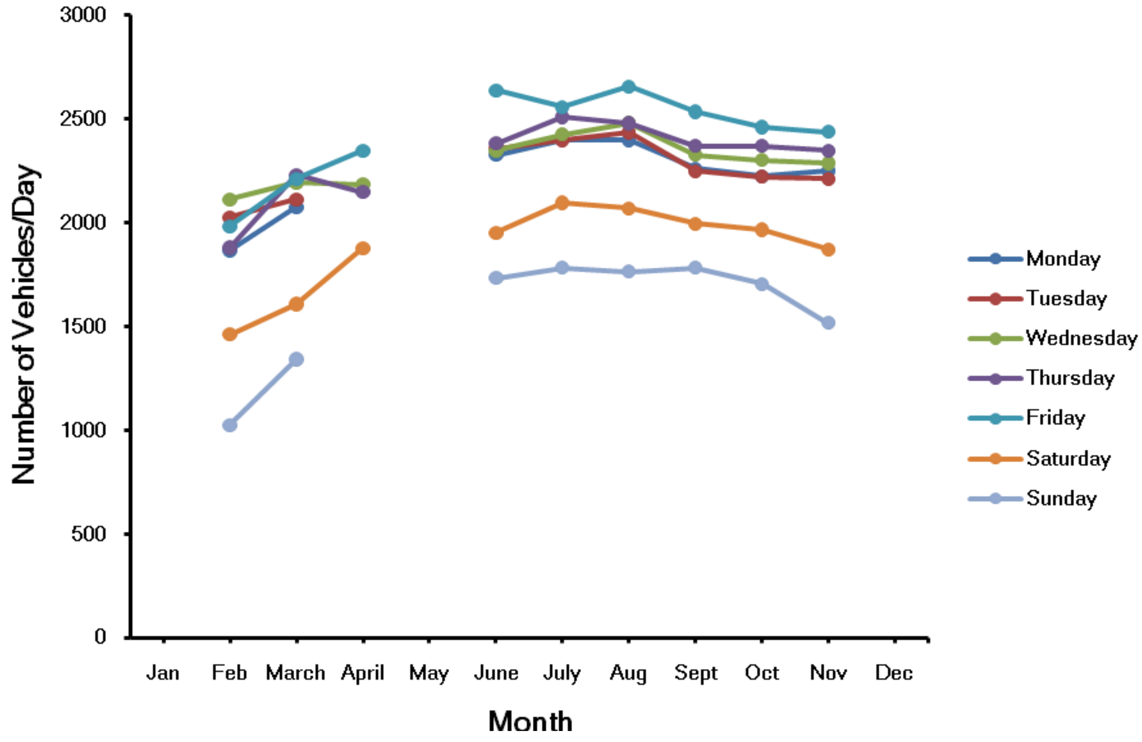
During the year, peak traffic flows occurred between July and October, coinciding with the dry season and peak tourist period. Traffic flow was lowest during the wet season from December to May, with the exception again being April. February was generally the month of least traffic for each day except for Saturday when January had least traffic.

No traffic data was obtained on the Tully Mission Beach Road during January, May and December due to the failure of all three counters. The gaps in the lines for Sunday, Monday and Tuesday (Figure 4.2) represent a lack of data for these days in April for similar reasons.

Similar trends for weekly and yearly peaks and troughs in traffic flow averages were observed on the Tully Mission Beach Road (Figure 4.2) as on the El Arish Mission Beach Road (Figure 4.1). Again Friday was the peak day of the week for traffic volume in all months except February and March and had the highest overall mean number of vehicles per day (2464 +/- 27.96 vehicles per day; Table 1). Sunday represented the lowest vehicle movements in all months (1634 +/- 30.32 vehicles per day; Table 4.1) and weekend traffic volume was also significantly less than weekdays (Mann-Whitney U-test, $Z=-17.387$, $p<0.001$).

The peak of the yearly cycle again coincided with the dry season and peak tourist times but on the Tully Mission Beach Road occurred slightly earlier between June and August/September. Traffic volume was lowest during the wet season from November to April.

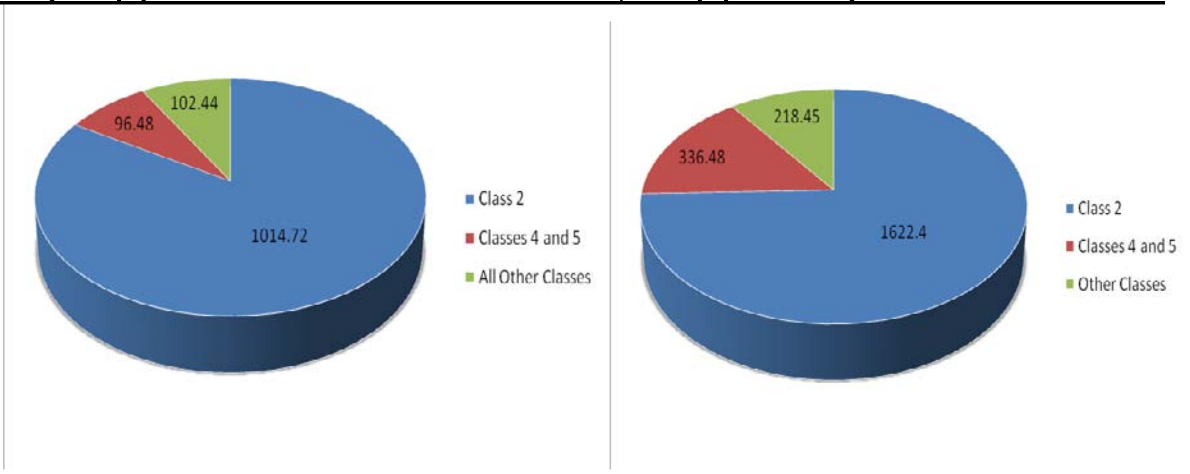
Figure 4.2.
Mean monthly number of vehicles of all classes travelling each day on the Tully Mission Beach Road.



When the three sites on each road were combined, there was significantly more traffic on the Tully Mission Beach Road compared with the El Arish Mission Beach Road (Mann-Whitney U-test, Z=-34.91, p<0.001). The Tully Mission Beach Road carried 2177 +/- 14.52 cars per day compared with 1214 +/- 4.71 cars per day on the El Arish Mission Beach Road.

For analyses of traffic volume and vehicle speeds, two groups of vehicles were selected. Class 2 vehicles (cars, utilities, 4WDs and small vans) make up 83.6% and 74.5% of all vehicles travelling on the El Arish Mission Beach (Figure 4.3a) and Tully Mission Beach (Figure 4.3b) Roads, respectively. Class 4 and 5 vehicles (2 and 3 axle buses and trucks) make up 7.9% and 15.5% of all vehicles travelling on the El Arish Mission Beach and Tully Mission Beach Roads, respectively.

Figure 4.3.
Mean number of vehicles from each class, as a component of all traffic, travelling daily on (a) the El Arish Mission Beach Road, and (b) the Tully Mission Beach Road.



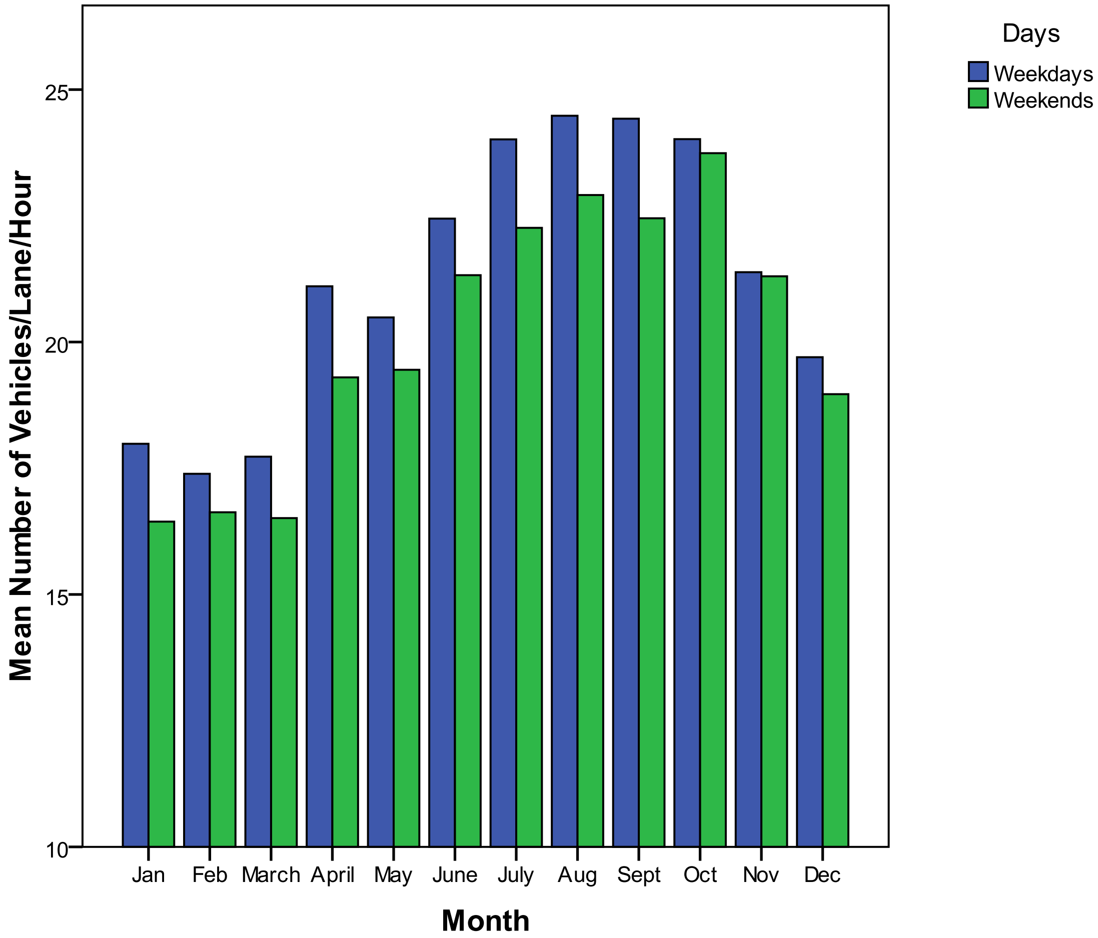
(a) (b)

4.3.1.2 Class 2 Vehicles (Small Vehicles- cars, utilities, 4WDs, small vans):

The yearly cycle of the number of small vehicles (class 2- cars, utilities, four wheel drives etc) travelling on the El Arish Mission Beach Road (Figure 4.4) showed a strong similarity to the yearly cycle exhibited by all classes of vehicles combined (Figure 4.1). The peak was again between July and October, while traffic volume was least during the wet season from December to May.

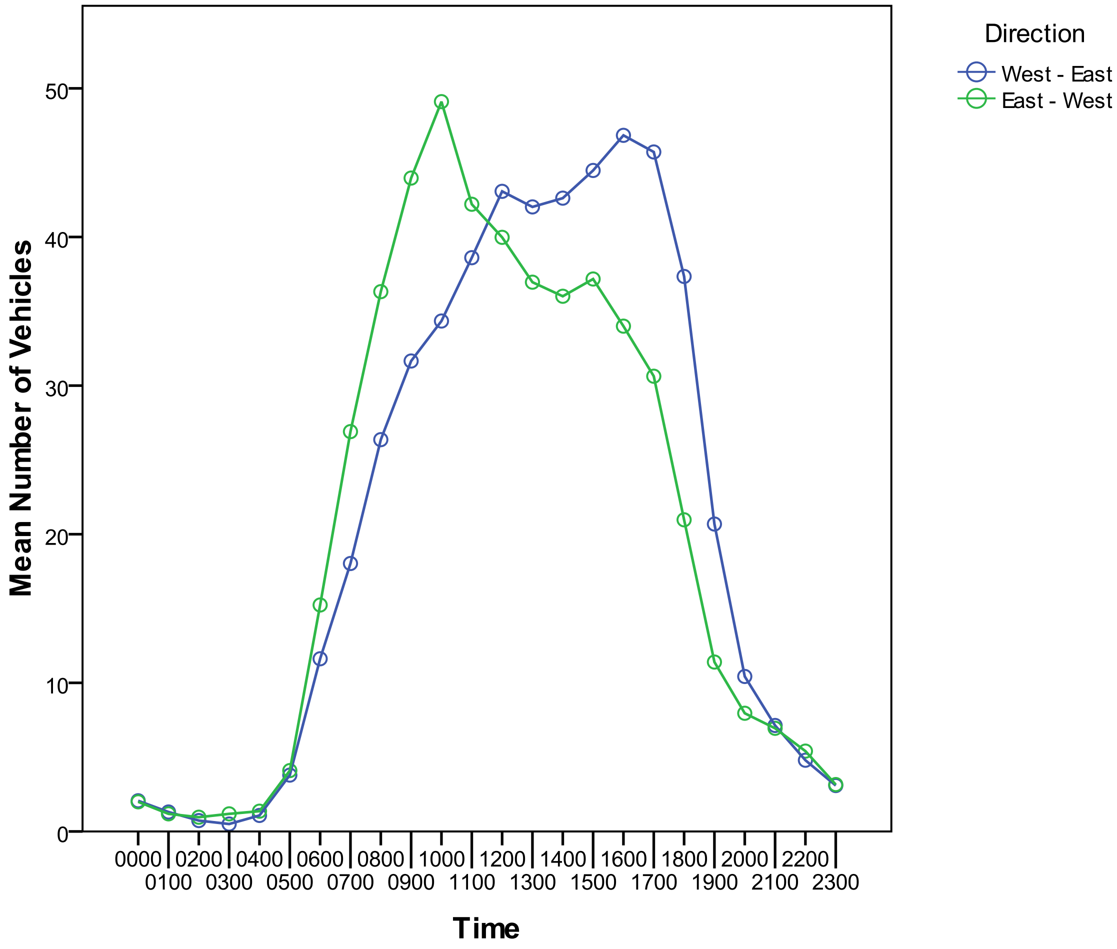
The difference in traffic volumes between weekdays (21.65 +/- 0.29 vehicles/lane/hour) and weekends (20.57 +/- 0.29 vehicles/lane/hour) was less obvious than that observed on the Tully Mission Beach Road (Figure 4.6) but was still significantly different (ANOVA, F=7.036, df=1, p=0.008), and the trend again appeared to reflect the pattern from all classes combined. From October to December traffic volumes on weekdays and weekends were almost identical indicating either an increase in weekend traffic flow (for sports, etc.) at this time of year or a decrease in weekday traffic flow at the end of the tourist season.

Figure 4.4.
Monthly mean numbers of small (class 2) vehicles travelling in each lane every hour on the El Arish Mission Beach Road on weekdays and weekends.



Discernible peaks in direction of travel (either west to east or east to west) on the El Arish Mission Beach Road were recorded for vehicles of the size of cars, four-wheel drives and utilities (class 2) over the course of the day (Figure 4.5). Traffic volume in an East to West direction (away from Mission Beach) peaked in the hours between 0800 hrs (8 am) and 1100 hrs (11 am) (shown on the graph as 0900 and 1100 as data points show traffic in the previous hour), with a steep increase from 0500 hrs (5 am) until 10 am and a gradual decrease afterwards. Traffic volume in the West to East direction (towards Mission Beach) peaked between 1400 hrs (2 pm) and 1700 hrs (5 pm), increasing steeply up until 1200 hrs (12 pm) and then gradually increasing until this time then decreasing steeply afterwards. These times and patterns reflect the movement of workers and school students to and from their places of work and study in locations external to Mission Beach.

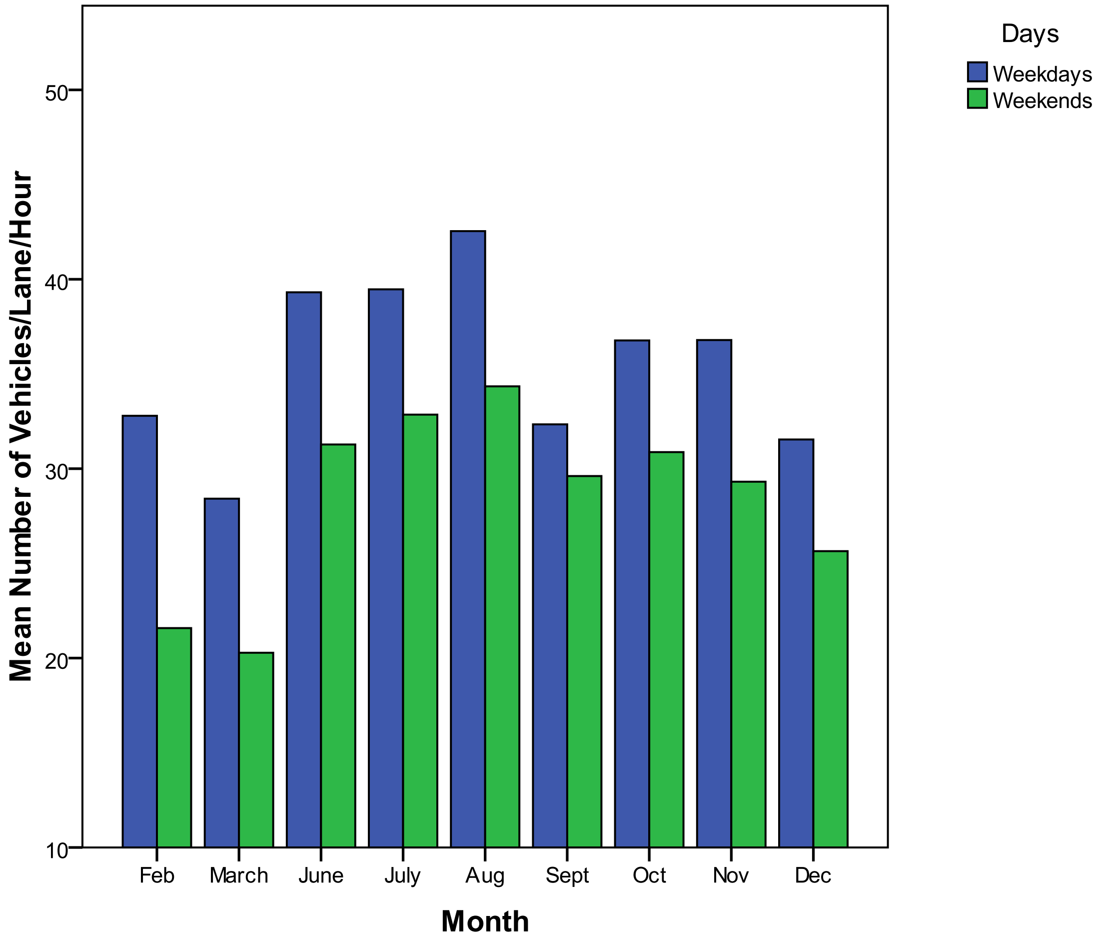
Figure 4.5
Mean number of small (class 2) vehicles travelling in an easterly or westerly direction on the El Arish Mission Beach Road over the course of the day.



For small vehicles (class 2) on the Tully Mission Beach Road, a yearly cycle in hourly numbers of vehicles travelling in each lane was observed (Figure 4.6). Traffic volume peaked between the months of June and November, the dry season, and decreased in the wetter months from December to March. The only deviation from this pattern occurred in September when vehicle numbers decreased, although the reason for this is unknown.

Traffic volume on weekdays (36.48 +/- 0.95 vehicles/lane/hour) was significantly greater than on weekends (29.52 +/- 0.72 vehicles/lane/hour; Mann-Whitney U-test, Z=-2.712, p=0.007), representing the working and student populations of Mission Beach travelling to and from work and school at external locations such as Tully from Monday to Friday.

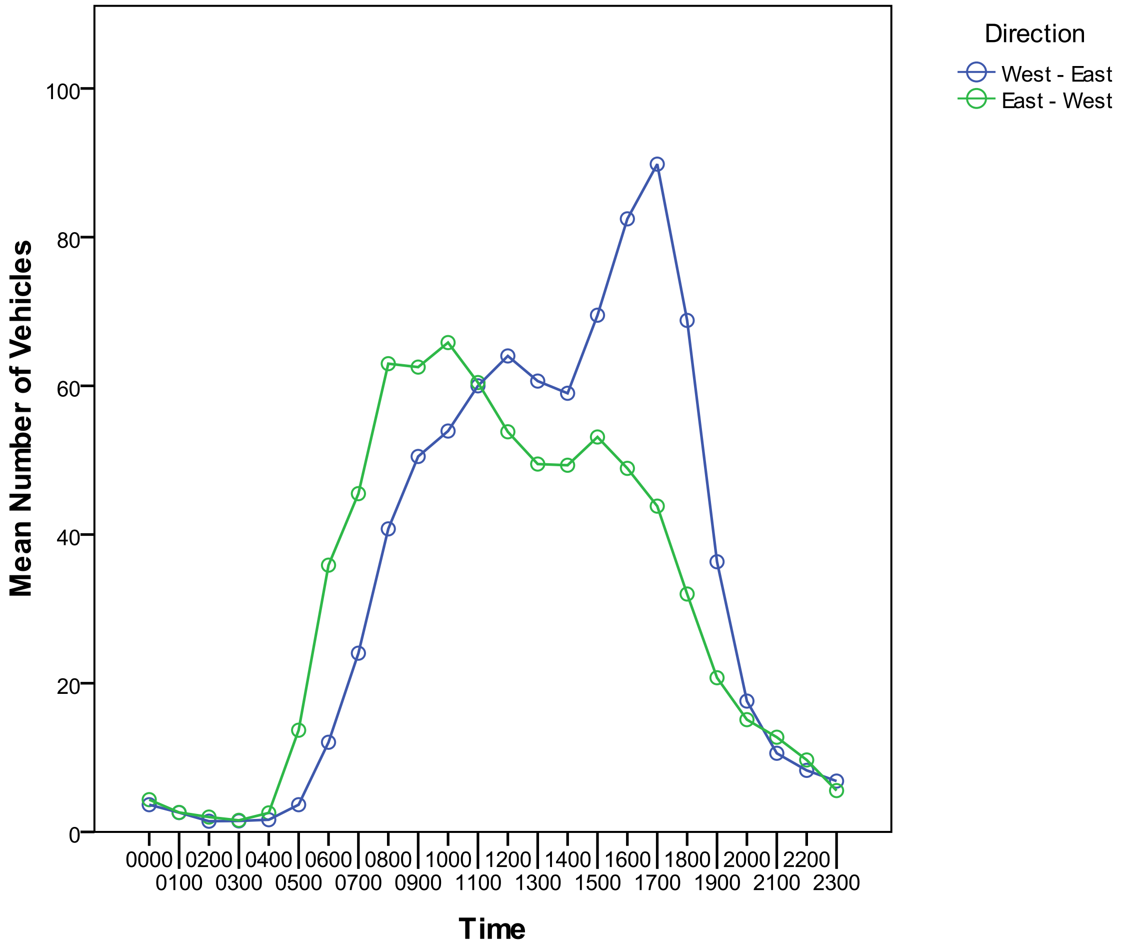
Figure 4.6.
Monthly mean number of small (class 2) vehicles travelling hourly in each lane on the Tully Mission Beach Road on weekdays and weekends.



Data was not available for January, April and May on the Tully Mission Beach Road due to insufficient number of days sampled during these months in the grouped categories of weekdays and weekends. This was due to traffic counter failures in these months.

The movement of workers and students is also reflected in Figure 4.7 which shows traffic flows over the course of the day. The peak for vehicles travelling away from Mission Beach (East to West lane) is between 0700 hrs (7 am) and 1000 hrs (10 am), while the peak in the other direction (towards Mission Beach; West to East lane) is in the afternoon from 1500 hrs (3 pm) until 1800 hrs (6 pm).

Figure 4.7.
Mean numbers of small (class 2) vehicles travelling easterly or westerly on the Tully Mission Beach Road over the course of the day.

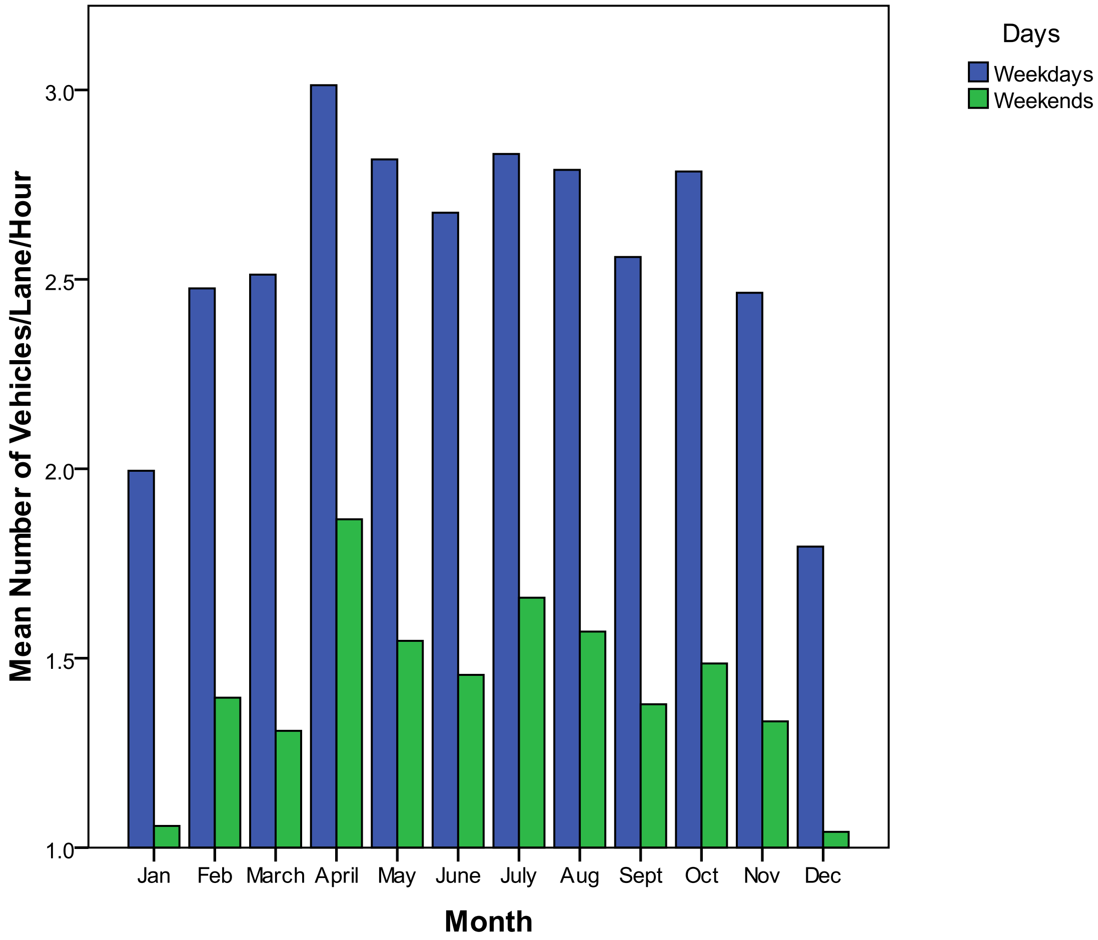


4.3.1.2 Class 4 and 5 Vehicles (Vehicles with 2 or 3 axles, >3.2m apart e.g. buses and medium-sized trucks):

There were no distinct yearly patterns in buses and medium-sized trucks (class 4 and 5 vehicles) travelling on the El Arish Mission Beach Road (Figure 4.8), unlike small vehicles (class 2) on the same road (Figure 4.4). The only exception was a peak in April and slight decreases in December and January. The difference between the most (April; 2.44 +/- 0.15 vehicles/lane/hour) and least (December; 1.42 +/- 0.06 vehicles/lane/hour) busy months was 1.02 vehicles/lane/hour.

There was a significant difference in the number of vehicles on the road on weekdays and weekends (Mann-Whitney U-test, Z=-18.4, $p<0.001$), with more vehicles of this size travelling on weekdays (2.58 +/- 0.04 vehicles/lane/hour) than weekends (1.43 +/- 0.03 vehicles/lane/ hour), as would be expected if many vehicles of this size of vehicle carry workers in industries such as construction and road maintenance or the vehicles deliver goods to businesses.

Figure 4.8.
Monthly mean numbers of medium-sized trucks and buses (classes 4 and 5) travelling hourly in each lane on the El Arish Mission Beach Road on weekdays and weekends.

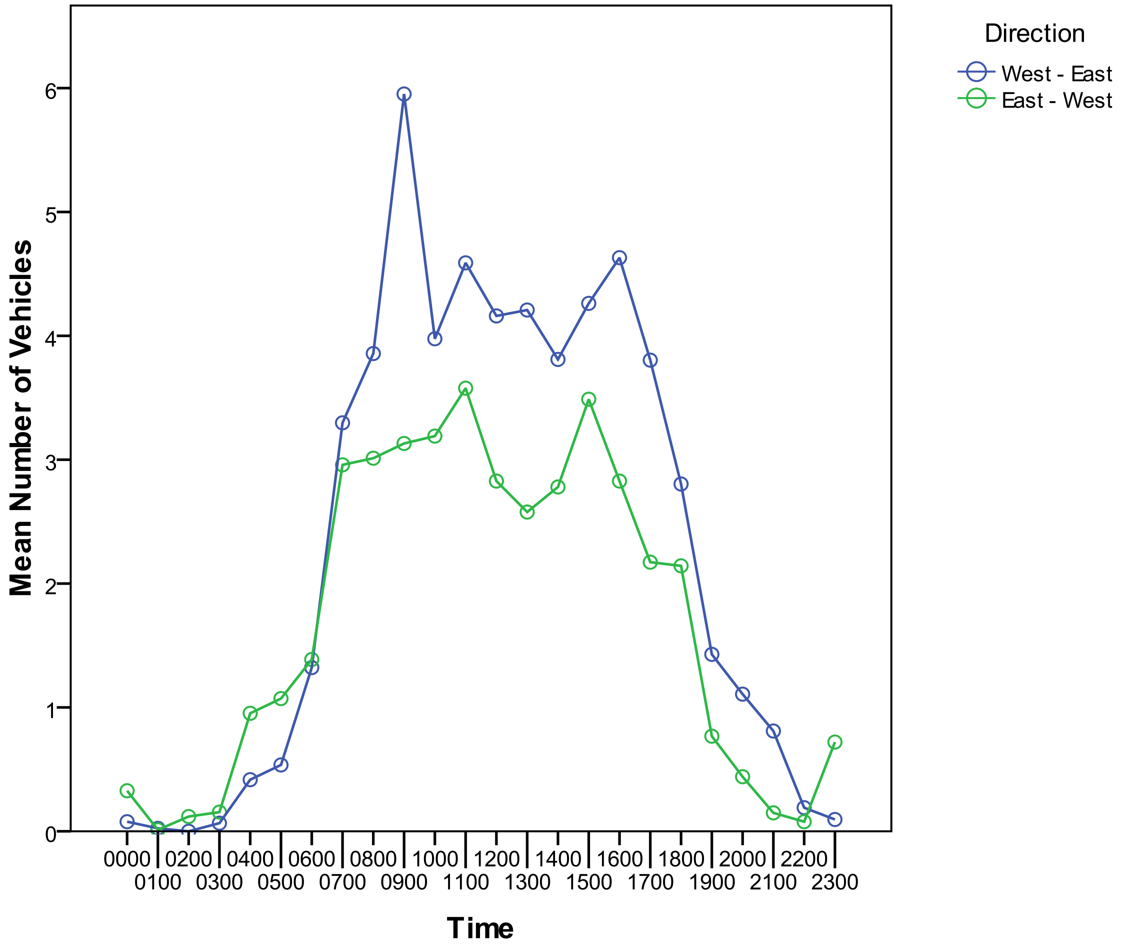


The daily pattern of buses and medium-sized trucks (classes 4 and 5) travelling on the El Arish Mission Beach Road was not as distinct (Figure 4.9) as that for small vehicles (class 2 - mainly cars) on the same road (Figure 4.5), or that observed for buses and medium-sized trucks on the Tully Mission Beach Road (Figure 4.11).

For vehicles travelling away from Mission Beach (East to West lane) there was a steep increase in volume until 0700 hrs (7 am), but following this, vehicle numbers were relatively stable until 1800 hrs (6 pm) when numbers decreased to overnight levels. Likewise, there was a slight peak in vehicle numbers travelling towards Mission Beach (West to East lane) between 8 and 9 am (shown in graph at 0900 hrs) but levels were stable after this again until 1800 hrs (6 pm) when they decreased overnight. There were very few vehicles from classes 4 and 5 travelling on the road in either direction between 2000 hrs (8 pm) and 0500 hrs (5 am) as vehicles from these classes are generally delivering people or goods and businesses likely to receive goods are closed during the night.

Also, significantly more vehicles of this size travelled towards Mission Beach (West to East lane; 2.31 +/- 0.04 vehicles/lane/hour) on the El Arish Mission Beach Road than away (East to West lane; 1.7 +/- 0.03 vehicles/lane/hour) from it (Mann-Whitney U-test, $Z=-5.574$, $p<0.001$), consistent with medium-sized tourist buses travelling from the north and leaving Mission Beach via the southern road to allow tourists to see a variety of attractions.

Figure 4.9.
Mean number of medium-sized trucks and buses (class 4 and 5 vehicles) travelling on the El Arish Mission Beach Road in an easterly or westerly direction over the course of the day.

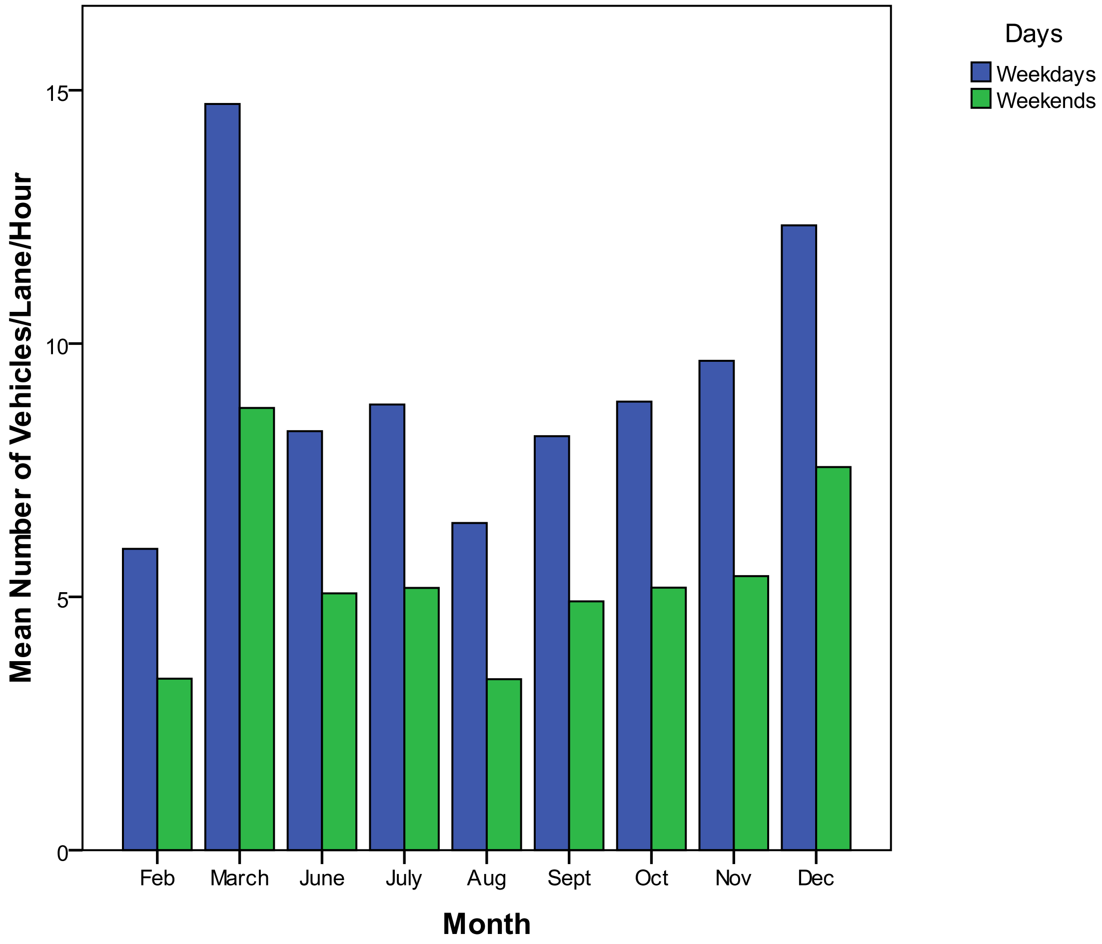


Due to insufficient number of days sampled following traffic counter failure in January, April and May, no data was obtained for these classes on the Tully Mission Beach Road in those months.

Numbers of buses and medium-sized trucks (class 4 and 5 vehicles) travelling on the Tully Mission Beach Road did not fluctuate a great deal throughout the year (Figure 4.10). However there were peaks in March and December, the reasons for which are not known. There is no peak in the dry, tourist season like that observed for small vehicles on the same road (Figure 4.6). This lack of a yearly cycle is probably due to the constant schedule of bus companies and goods delivery vehicles that make up the majority of this class of vehicle.

There was, however, a significant difference in the number of vehicles from classes 4 and 5 travelling on weekdays and weekends (Mann-Whitney U-test, $Z=-7.663$, $p<0.001$). On weekdays 9.85 +/- 0.32 vehicles/lane/ hour were on the road compared with 5.17 +/- 0.2 vehicles/lane/hour on weekends, possibly due to fewer good delivery trucks travelling on the road on weekends.

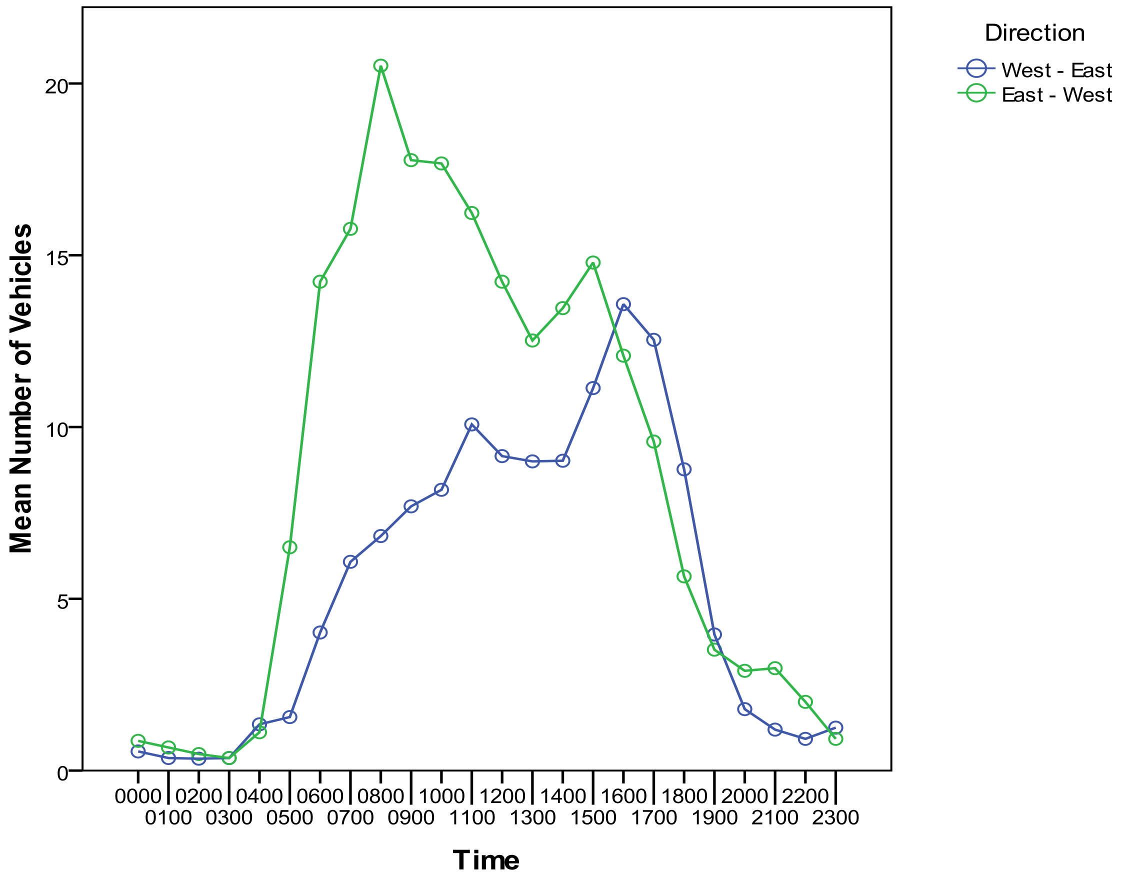
Figure 4.10.
Monthly mean number of buses and medium-sized trucks (class 4 and 5 vehicles) travelling hourly in each lane on the Tully Mission Beach Road.



Daily movements of buses and medium-sized trucks on the Tully Mission Beach Road show obvious peaks in each direction (Figure 4.11). The number of vehicles travelling away from Mission Beach (East to West lane) peaks between 0700 hrs (7 am) and 1000 hrs (10 am), with a sharp rise from 0400 hrs (4 am) and a gradual decrease after 10 am. The peak of vehicle movements towards Mission Beach (West to East lane) occurs between 1500 hrs (3 pm) and 1700 hrs (5 pm), with a gradual increase in vehicle numbers up to this time and a steep decrease after this period. This may again be representative of workers who drive larger vehicles going to their place of work in an area external to Mission Beach.

Significantly more vehicles travelled away from (East to West lane; 8.72 +/- 0.34 vehicles/lane/hour) than towards (West to East lane; 5.41 +/- 0.16 vehicles/lane/hour) Mission Beach (Mann-Whitney U-test, $Z=-3.601$, $p<0.001$). This is the reverse of the El Arish Mission Beach Road suggesting a proportion of vehicles from these classes are travelling a one way route into Mission Beach from the north (El Arish Mission Beach Road) and out of Mission Beach to the south (Tully Mission Beach Road).

Figure 4.11.
Mean number of buses and medium-sized trucks (class 4 and 5 vehicles) travelling in an easterly or westerly direction on the Tully Mission Beach Road over the course of the day.



4.3.1 Traffic Speed.

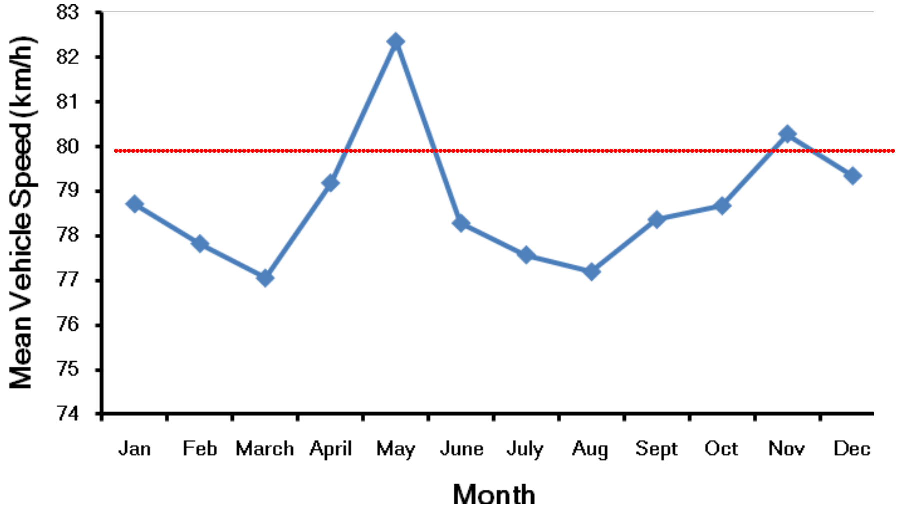
4.3.2.1 Class 2 (Small Vehicles – cars, utilities, 4WDs, small vans):

Mean speeds of small (class 2) vehicles were significantly different on the two roads (t-test, t=-383.22, df=222465, $p<0.001$). Vehicles on the Tully Mission Beach Road had a significantly higher mean speed (85.24 +/- 0.01 km/h) than those on the El Arish Mission Beach Road (78.66 +/- 0.01 km/h).

Aside from a peak in May, mean speeds of small (class 2) vehicles on the El Arish Mission Beach Road showed little variation throughout the yearly cycle (Figure 4.12). Mean speeds ranged from 77.05 +/- 0.04 km/h in the slowest month (March) up to 82.35 +/- 0.03 km/h in the fastest month (May). Average speeds in May and November were above the posted speed limit of 80 km/h.

There was a significant difference in the mean speeds on weekdays (78.97 +/- 0.18 km/h) compared with weekends (78.34 +/- 0.17 km/h) on this road (ANOVA, F=638.03, df=1, $p<0.001$), although this difference was very small.

Figure 4.12.
Mean speed of small vehicles (cars, four-wheel drives, utilities - class 2) for each month on the El Arish Mission Beach Road. Note: the red line denotes the legal speed limit.

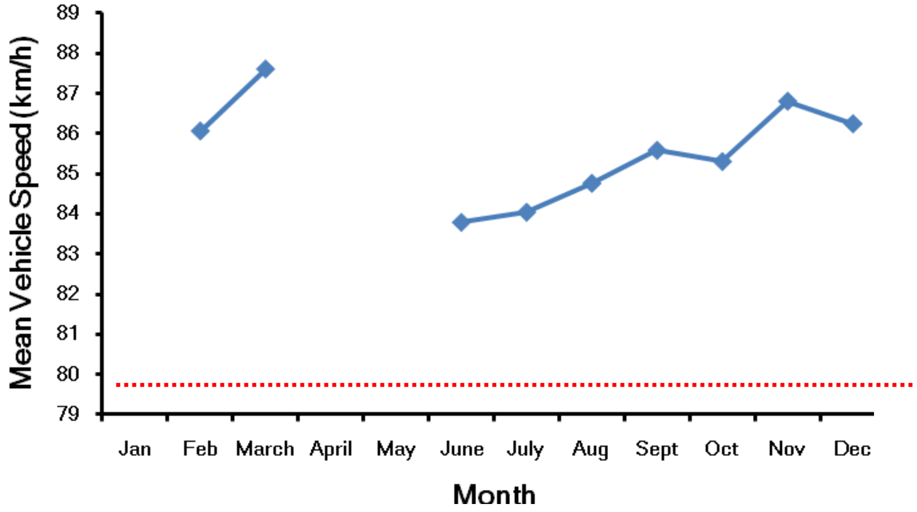


There were only slight differences in mean speeds of small vehicles throughout the yearly cycle on the Tully Mission Beach Road (Figure 4.13), although average speeds during the wet season (November-March) were slightly higher than during the dry season (June-October). Monthly means varied from 83.79 +/- 0.03 km/h in the month with slowest speeds (June) up to 87.6 +/- 0.06km/h in the month with fastest speeds (March).

Mean speeds of small vehicles were above the legal speed limit of 80 km/h throughout the year.

There was also a significant difference in mean speeds of small vehicles between weekdays (85.43 +/- 0.02 km/h) and weekends (85.01 +/- 0.02 km/h) on this road (Mann-Whitney U-test, Z=-15.41, $p<0.001$).

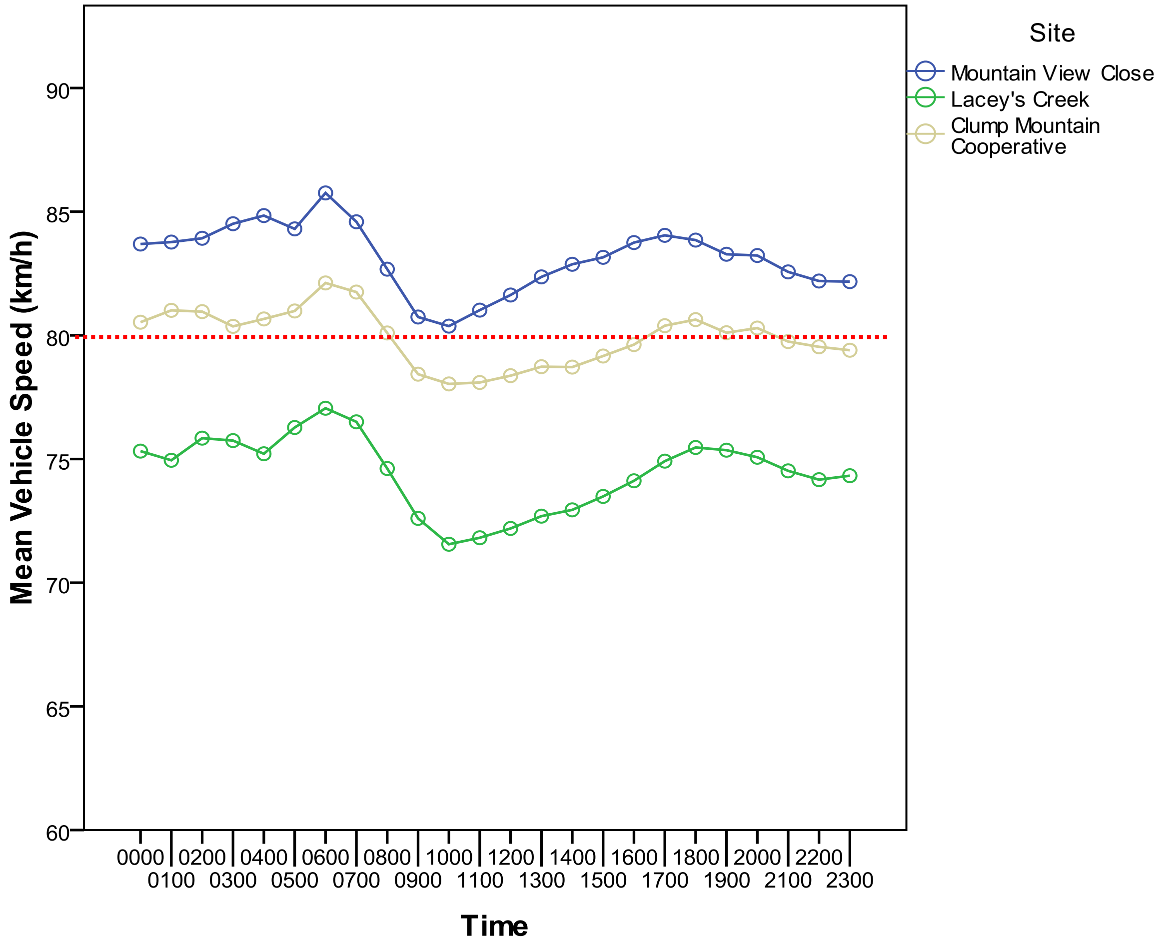
Figure 4.13.
Mean speeds of small (class 2) vehicles for each month on the Tully Mission Beach Road. Note: the red line denotes the legal speed limit.



Speeds of small vehicles (class 2) at all three traffic counter locations on the El Arish Mission Beach Road follow a similar daily pattern (Figure 4.14). Speeds were elevated during the night and early morning hours between 0000 hrs (12 midnight) and 0700 hrs (7 am), peaking between 5 and 7 am. Following that peak, mean speeds decrease until 1000 hrs (10 am), then steadily rise to higher speeds which peak around 1700 hrs (5 pm) or 1800 hrs (6 pm), then slightly decrease after 2100 hrs (9 pm) until they rise again in the early hours of the morning.

The early morning daily peak in mean speeds between 0500 hrs (5 am) and 0700 hrs (7 am) may coincide with workers heading to work in locations external to Mission Beach (Figure 5). This idea is reaffirmed by the second daily peak occurring between 1600 hrs (4 pm) and 1900 hrs (7 pm) when workers would generally be returning home. During the middle part of the day mean vehicle speeds are generally lowest.

Figure 4.14.
Mean speeds of small vehicles (class 2) at each traffic counter location on the El Arish Mission Beach Road during the course of the day. Note: the red line denotes the legal speed limit.



Average speeds of small vehicles (class 2) on the El Arish Mission Beach Road were significantly different at the three traffic counter locations (Kruskal-Wallis, χ^2=55787.32, df=2, p<0.001). Mean speed was highest at the westernmost location (Mountain View Close: 82.63 +/- 0.02 km/h) and this was significantly higher than at both Lacey's Creek (Mann-Whitney U-test, Z=-210.77, p<0.001) and the Clump Mountain Cooperative (Mann-Whitney U-test, Z=-84.97, p<0.001) sites. Average speeds at that location were 79.37 +/- 0.01 km/h, also significantly higher than Lacey's Creek (Mann-Whitney U-test, Z=-184.3, p<0.001), which had the slowest mean speed of 73.65 +/- 0.01 km/h.

Maximum recorded speeds by small vehicles on this road exceeded the posted speed limit of 80km/h by between 60 and 100km/h (Table 2), exceeding the speed limit the most at the easternmost counter (Clump Mountain Cooperative).

Table 4.2.
Maximum speeds of small (class 2) vehicles recorded at each traffic counter location on the El Arish Mission Beach Road.

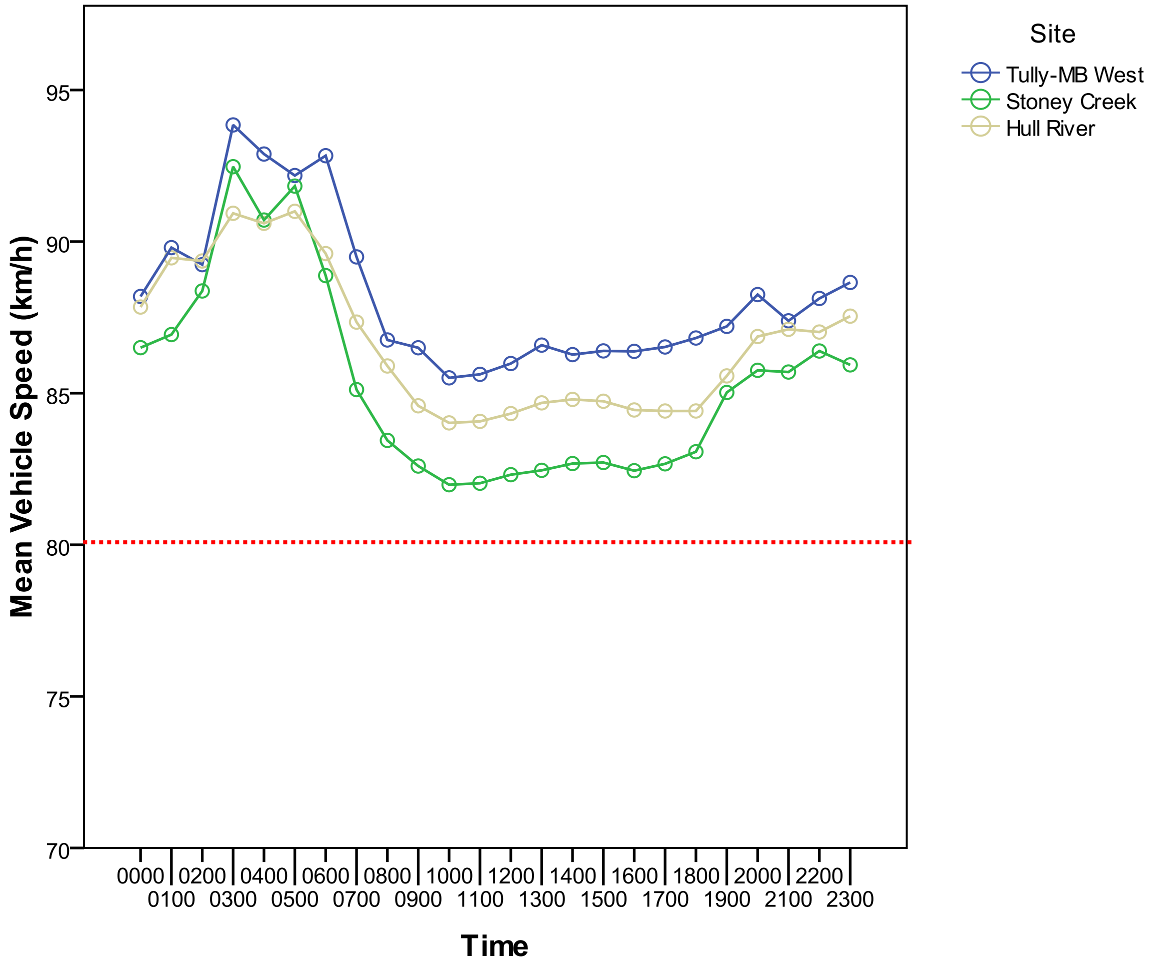
Site	Maximum Speed (km/h)	Date Recorded
Mountain View Close	160.8	Monday 8th January, 2007
Lacey's Creek	140.6	Monday 19th October, 2009
Clump Mountain Cooperative	180.0	Sunday 30th July, 2006

Similarly to the El Arish Mission Beach Road, data from the three traffic counter locations on the Tully Mission Beach Road mirrored each other for average speeds of small (class 2) vehicles during the course of the day (Figure 4.15). Highest speeds were recorded between 0300 hrs (3 am) and 0600 hrs (6 am) before dropping off and levelling out around 0800 hrs (8 am). Speeds then remained steady until around 1900 hrs (7 pm) when they increased slightly and remained elevated throughout the night. In contrast to the El Arish Mission Beach Road (Figure 4.14), higher speeds on the Tully Mission Beach Road only corresponded to the very earliest movements of workers rather than those travelling between 8 and 9 am. Similarly to the El Arish Mission Beach Road, vehicle speeds were lowest on the Tully Mission Beach Road during daylight hours.

At all times and at all locations on the Tully Mission Beach Road, average speeds of small vehicles such as cars, four-wheel drive and utility vehicles, were above the posted speed limit of 80 km/h, with maximum recorded speeds at each site exceeding this by 100 km/h or more (Table 4.3).

Mean speeds at the three traffic counter locations were also significantly different (Kruskal-Wallis, χ^2=15881.45, df=2, p<0.001). The highest mean speeds were recorded at the westernmost location on the road (Tully-MB West; 86.87 +/- 0.02 km/h) and this was significantly higher than both the Stoney Creek (Mann-Whitney U-test, Z=-131.59, p<0.001) and Hull River (Mann-Whitney U-test, Z=-76.63, p<0.001) sites. The second highest mean speeds of small vehicles were recorded at the Hull River location (85.14 +/- 0.02 km/h) and this was significantly higher than at Stoney Creek (Mann-Whitney U-test, Z=-58.76, p<0.001), where the slowest mean speeds were recorded (83.37 +/- 0.02 km/h).

<u>Figure 4.15.</u>
<u>Mean speeds of small vehicles (class 2) at each traffic counter location on the Tully Mission Beach Road during the course of the day.</u> Note: the red line denotes the legal speed limit.



<u>Table 4.3.</u>
<u>Maximum speeds for small vehicles (class 2) recorded at each location on the Tully Mission Beach Road.</u>

Site	**Maximum Speed (km/h)**	**Date Recorded**
Tully-MB West	199.6	Tuesday 10th February, 2009
Stoney Creek	189.8	Monday 25th August, 2008
Hull River	179.9	Wednesday 23rd September, 2009

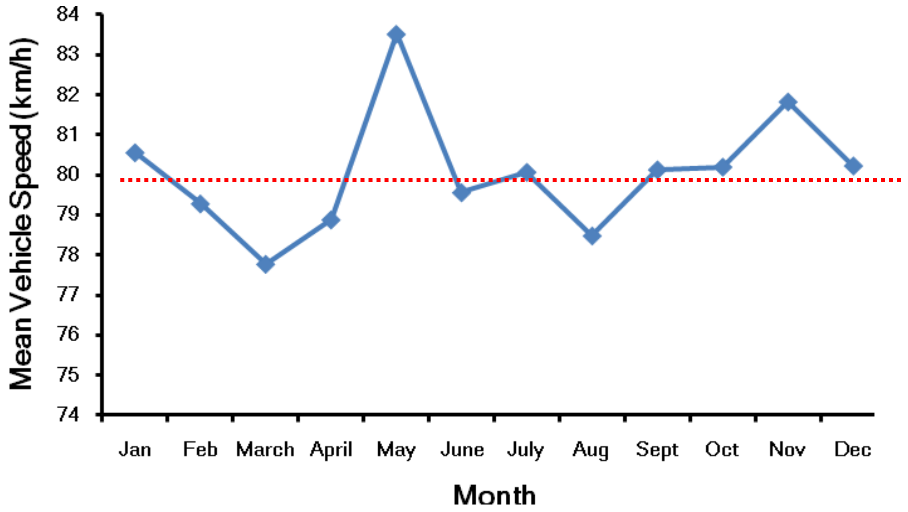
4.3.1.2 Class 4 and 5 Vehicles (Buses and Medium-sized Trucks with 2 or 3 Axles >3.2m apart):

Mean speeds of buses and medium-sized trucks (classes 4 and 5) were significantly different on the two roads (T-test, t=-114.84, df=30178, p<0.001). Vehicles on the Tully Mission Beach Road travelled at significantly higher mean speeds (88.81 +/- 0.04 km/h) than those on the El Arish Mission Beach Road (80.04 +/- 0.06 km/h).

No seasonal patterns could be discerned in mean speeds of buses and medium-sized trucks (class 4 and 5 vehicles) on the El Arish Mission Beach Road (Figure 4.16). A peak occurred in May but there were no prolonged periods of higher or lower speeds, although mean speeds exceeded the legal speed limit in January, May and November. Means varied by only 6 km/h between the highest monthly mean speed, May (83.52 +/- 0.21 km/h), and the lowest monthly mean speed, March (77.77 +/- 0.18 km/h).

There was, however, a significant difference between mean speeds on weekdays and weekends (Mann-Whitney U-test, Z=-3.07, p=0.002). Unlike small vehicles on both this road and the Tully Mission Beach Road, the mean speed was higher on weekends (80.34 +/- 0.11 km/h) than during weekdays (79.86 +/- 0.08 km/h).

Figure 4.16.
Average monthly speeds for buses and medium-sized trucks (class 4 and 5 vehicles) on the El Arish Mission Beach Road. Note: the red line denotes the legal speed limit.

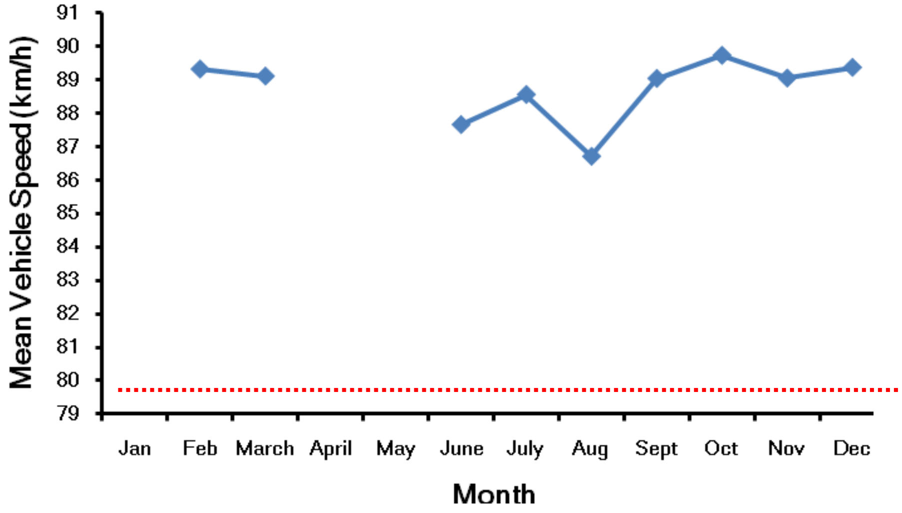


There was also no clear seasonal pattern in speeds of buses and medium-sized trucks throughout a yearly cycle on the Tully Mission Beach Road (Figure 4.17). Speeds of these vehicles were the least variable (smallest range) of either class analysed on either road, with only 3 km/h difference between the highest monthly mean, October (89.73 +/- 0.1 km/h) and the lowest monthly mean, August (86.71 +/- 0.13 km/h).

There was, however, a significant difference between weekday and weekend mean speeds (Mann-Whitney U-test, Z=-4.4, p<0.001). Like the buses and medium-sized trucks on the El Arish Mission Beach Road, speeds were higher on weekends (88.93 +/- 0.07 km/h) than weekdays (88.63 +/- 0.05 km/h), although the difference is very small. In contrast to the El

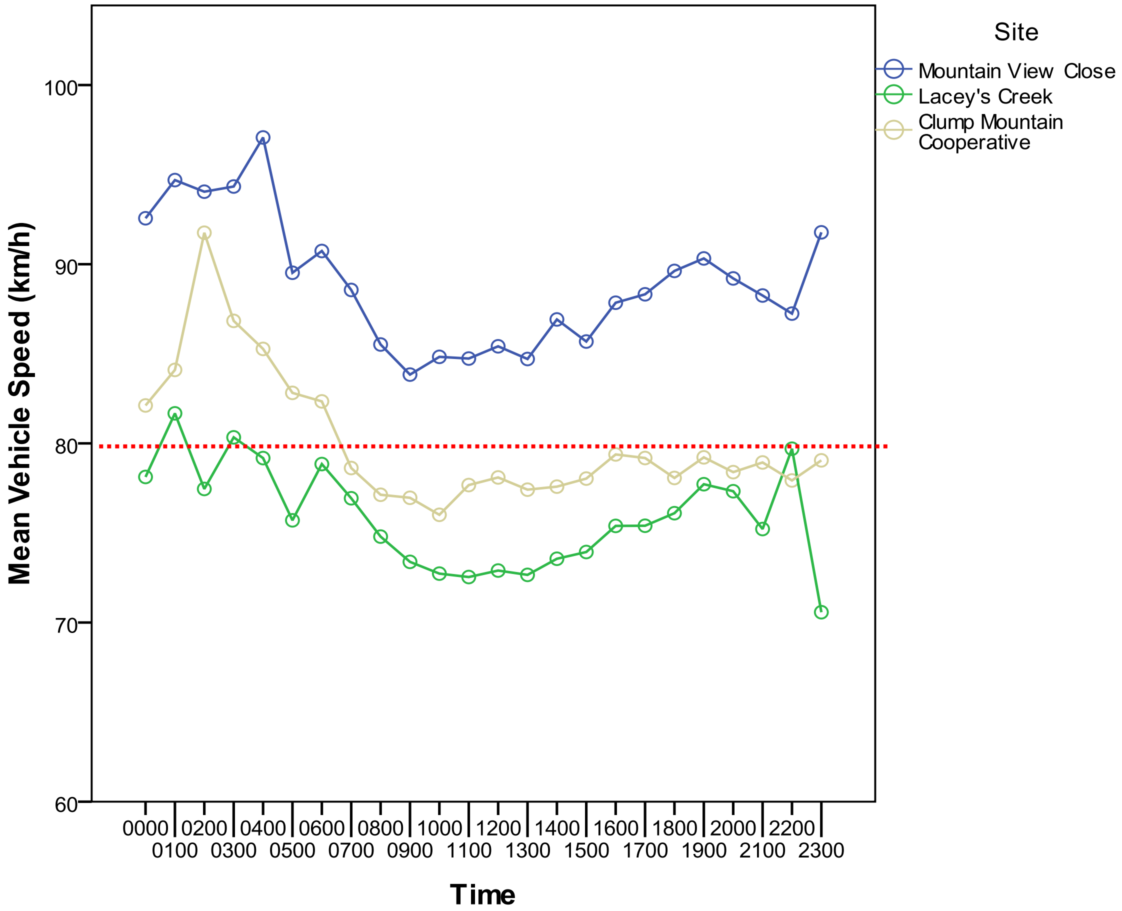
Arish Mission Beach Road, mean speeds of buses and medium-sized trucks exceeded the legal speed limit on the Tully Mission Beach Road throughout the year (Figure 4.17).

<u>Figure 4.17.</u>
<u>Mean monthly speeds of buses and medium-sized trucks (class 4 and 5 vehicles) on the Tully Mission Beach Road.</u> Note: the red line denotes the legal speed limit.



The mean speeds of buses and medium-sized trucks (class 4 and 5 vehicles) on the El Arish Mission Beach Road show similar patterns of variability at each of the three traffic counter locations over the course of the day (Figure 4.18). Like small vehicles on either road (Figures 4.14 and 4.15), the highest vehicle speeds were recorded during the night. For these vehicles highest speeds occurred from around 2200 hrs (10 pm) or 2300 hrs (11pm) until 0600 hrs (6 am). Early morning speeds at Lacey's Creek were very variable but remained above day time mean speeds. The lowest mean speeds were recorded during the middle of the day from around 1000 hrs (10 am) until 1400 hrs (2 pm). After this time there was a gradual increase to an early evening peak at both the westernmost location on the road (Mountain View Close) and Lacey's Creek at 1900 hrs (7 pm), while speeds at the Clump Mountain Cooperative location remained relatively stable until 0000 hrs (12 midnight). There was a marked decrease in mean speeds at Lacey's Creek at 2300 hrs (11 pm) and a dip in vehicle speeds at the Mountain View Close location between 2000 hrs (8 pm) and 2200 hrs (10 pm), after which there was a rise in mean speeds to early morning peaks.

<u>Figure 4.18.</u>
<u>Mean speeds of buses and medium-sized trucks (class 4 and 5 vehicles) at each location on the El Arish Mission Beach Road over the course of the day.</u> Note: the red line denotes the legal speed limit.



Average speeds of class 4 and 5 vehicles on the El Arish Mission Beach Road (85.34 +/- 0.09 km/h) were only above the posted speed limit of 80 km/h at the westernmost location (Mountain View Close), although speeds in the early morning also exceeded this limit at the easternmost site (Clump Mountain Cooperative).

Maximum recorded speeds at all locations were more than double this limit (Table 4.4).

Mean speeds at the three locations were significantly different (Kruskal-Wallis, χ^2= 6462.78, df=2, p<0.001). Speeds at the westernmost site (Mountain View Close) were significantly higher than at both Lacey's Creek (Mann-Whitney U-test, Z=-76.52, p<0.001) and Clump Mountain Cooperative sites (Mann-Whitney U-test, Z=-46.71, p<0.001) while mean speeds at that location (78.68 +/- 0.11 km/h) were significantly higher than at Lacey's Creek (Mann-Whitney U-test, Z=-33.82, p<0.001). Average speeds recorded at Lacey's Creek were slowest for vehicles of this class on the El Arish Mission Beach Road (74.41 +/- 0.08 km/h).

Table 4.4.
Maximum speeds recorded at each location on the El Arish Mission Beach Road by buses and medium-sized trucks (class 4 and 5 vehicles).

Site	Maximum Speed (km/h)	Date Recorded
Mountain View Close	163.5	Thursday 14th December, 2006
Lacey's Creek	164.5	Wednesday 11th November, 2009
Clump Mountain Cooperative	163.3	Monday 17th July, 2006

Speeds of buses and medium-sized trucks (class 4 and 5 vehicles) on the Tully Mission Beach Road varied over the course of the day in a similar fashion to small vehicles on the same road (Figures 4.19 & 4.15). This included a peak in mean speeds in the early hours of the morning, between 0100 hrs (1 am) and 0200 hrs (2 am), slightly earlier than on the El Arish Mission Beach Road, and starting to decrease after 0300 hrs (3 am), dropping to the day time lows between 0800 hrs (8 am) and 1800 hrs (6 pm). Following this time there was a general upward trend to early morning peaks, with small anomalies at 2000 hrs (8 pm) and 2300 hrs (11 pm) at Stoney Creek where speeds decreased slightly before continuing to rise.

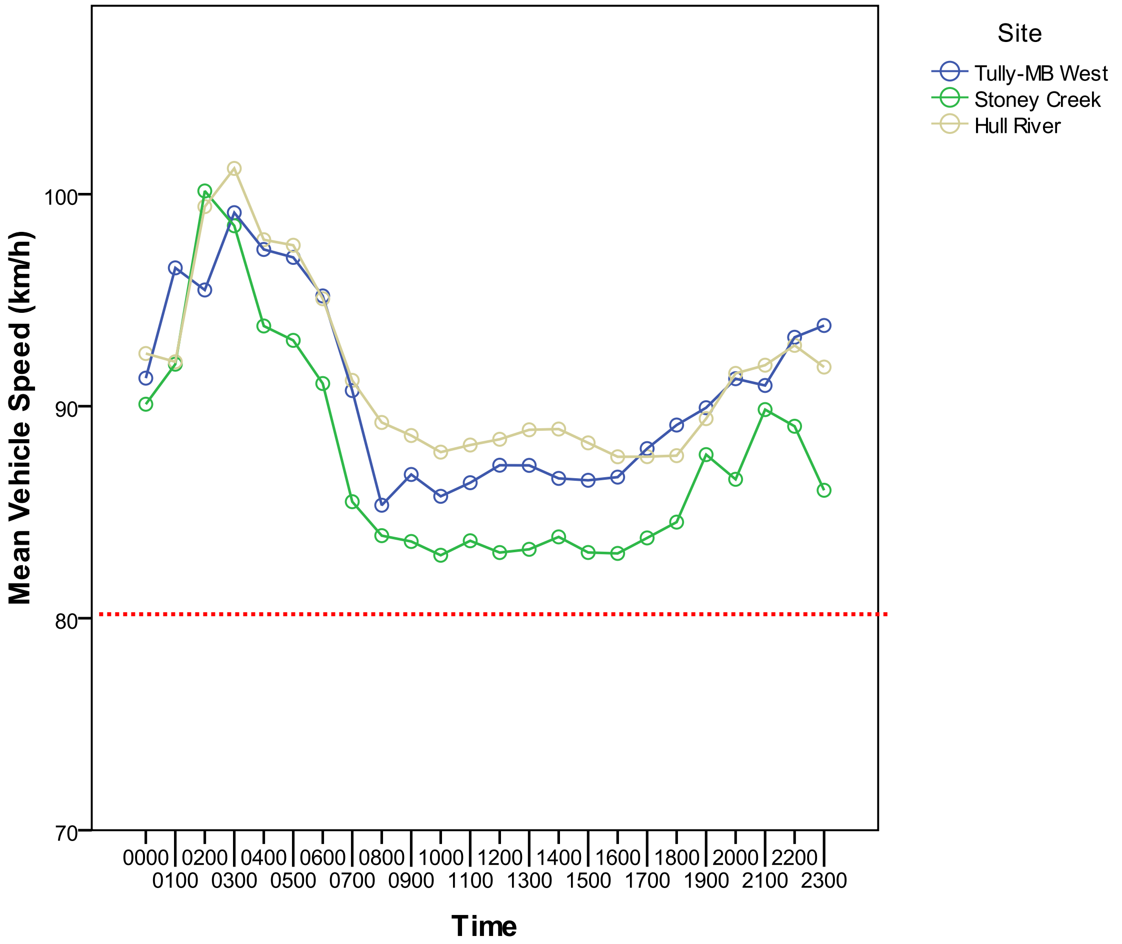
Mean speeds of buses and medium-sized trucks on the Tully Mission Beach Road were above the legal speed limit of 80 km/h at all three locations at all times of day, while maximum recorded speeds exceeded this limit by 88-120 km/h (Table 4.5).

Mean speeds at the three sites were also significantly different (Kruskal-Wallis, χ^2=1931.44, df=2, p<0.001). Average speeds of vehicles at the Hull River site were highest (89.53 +/- 0.05 km/h) and this was significantly higher than both the westernmost location (Tully-MB West) on the road (Mann-Whitney U-test, Z=-13.7, p<0.001) and the Stoney Creek (Mann-Whitney U-test, Z=-42.34, p<0.001) location. Mean speeds of vehicles at the western location were second highest (88.36 +/- 0.1 km/h) and were also significantly higher than mean speeds recorded at Stoney Creek (84.99 +/- 0.1 km/h, Mann-Whitney U-test, Z=-29.92, p<0.001).

Table 4.5.
Maximum speeds recorded at each location on the Tully Mission Beach Road by buses and medium-sized trucks (class 4 and 5 vehicles).

Site	Maximum Speed (km/h)	Date Recorded
Tully-MB West	182.0	Friday 8th August, 2008
Stoney Creek	168.4	Friday 18th July, 2008
Hull River	199.8	Friday 10th October, 2008

Figure 4.19.
Mean speeds of buses and medium-sized trucks (class 4 and 5 vehicles) at each location on the Tully Mission Beach Road over the course of the day. Note: the red line denotes the legal speed limit.



4.3 DISCUSSION.

4.3.1 Traffic Patterns and Volume.

Overall, the Tully Mission Beach Road carried a higher volume of traffic than the El Arish Mission Beach Road. This is believed to be a reflection of the high number of workers and students who attend work and school in the nearby town of Tully. Tully has a high school and more diverse industries than Mission Beach, including a sugar mill. People, particularly those living in South Mission Beach and Wongaling Beach, need to travel to access these. This travel for work and school is also reflected in the significantly greater number of vehicles on both roads on weekdays compared to weekends. During the week, traffic volume on the two roads is relatively stable on weekdays, with a gradual increase to peak numbers on a Friday (Figures 4.1 and 4.2). Peak vehicle movements on a Friday suggest weekend excursions to Mission Beach from larger urban areas such as Innisfail, Tully and Cairns, as the timing of these extra trips along the roads is concentrated in the dry tourist season.

Traffic volumes for all vehicles (Figure 4.1) and small vehicles such as cars, utilities, 4WDs and small vans travelling on both the El Arish and Tully Mission Beach Roads (Figures 4.4

and 4.6) showed distinctly seasonal patterns throughout the year with increases in the dry season (June-October) and decreases in the wet season (December-April). The similarity in these results is a reflection of the high proportion of small vehicles in the traffic flow. Small vehicles form the majority of all vehicles moving on these roads (Figures 4.3a and 4.3b). This seasonal fluctuation is in response to an increase in tourist numbers into north Queensland and subsequently to and from Mission Beach during the dry season (Department of Infrastructure and Planning 2007). This same pattern was not discernible for buses and medium-sized trucks on either road (Figures 4.8 and 4.10). This may be due to the reliance on these vehicles for the movement of goods and people year round to Mission Beach. Numbers of medium-sized trucks are not necessarily driven by tourists, the main source of monthly fluctuations in other classes.

Patterns in daily traffic volume were also found for both classes of vehicles on both roads. Movements of small vehicles away from Mission Beach peaked on both roads in the morning and movements towards Mission Beach peaked in the late afternoon (Figures 4.5 and 4.7). We believe these peaks are a reflection of the movement of workers and students to and from work places and schools in locations external to Mission Beach, such as Tully and Innisfail. A similar pattern was observable for buses and medium-sized trucks on the Tully Mission Beach Road (Figure 4.11), but was not as obvious on the El Arish Mission Beach Road for these classes (Figure 4.9). There were also significantly more buses and medium-sized trucks travelling to Mission Beach on the El Arish Road compared to the Tully Road and travelling away from Mission Beach on the Tully road, suggesting that a proportion of traffic from these classes travels a one-way route through to Mission Beach from the north (El Arish) and out of Mission Beach to the south (Tully).

4.3.2 Vehicle Speed.

Vehicle speeds for small vehicles and for buses and medium-sized trucks were higher on the Tully Mission Beach Road than on the El Arish Mission Beach Road (Figures 4.12, 4.13, 4.16 and 4.17), averaging more than 80 km/h, the legal speed limit. Maximum recorded vehicle speeds were also higher on the Tully Road (168.4-199.8 km/h) than the El Arish Road (140.6-180 km/h) although maximum speeds at all locations on both roads far exceeded the legal speed limit. The Tully Road is generally straighter and flatter than the El Arish Road and has wider cleared verges giving drivers the perception that it is safe to drive faster along this road.

Mean speeds were also significantly different on weekdays than weekends. Cars and other small vehicles on both roads travelled faster on weekdays while the buses and medium-sized trucks travelled faster on weekends. These larger vehicles also travelled faster in the early morning hours, suggesting that the reduced traffic late at night and on weekends allowed them to travel faster than when traffic was heavier during the day on weekdays.

Unlike traffic volume, there was no clear yearly pattern of vehicle speeds for either small or larger vehicles on either road (Figures 4.12, 4.13, 4.16 and 4.17). The range between monthly maximum and minimum mean speeds was usually very small, varying by no more than 6 km/h from month of fastest travel to month of slowest travel for either class on both roads. Although reductions in speed in the wet season might be expected, there were no reductions in speed compared to the dry season, with one sample (small vehicles on the Tully Road) actually slightly increasing speeds during the wetter months. There were, however, discernible patterns in the daily cycle of vehicle speeds on both roads (Figures 4.14, 4.15, 4.18 and 4.19).

The main feature of all sites and classes was elevated speeds in the early morning hours, generally between 0000 hrs (12 midnight) and 0700hrs (7 am). It is probably the perception of drivers that they are much less likely to be caught speeding at these hours due to a reduced police presence on the road. There is also much less traffic at these hours that would form platoons of cars that slow faster drivers down compared with other hours of the day. The lowest daily speeds were usually recorded during the daylight hours between 0800 hrs (8 am) and 1700 hrs (5 pm), when traffic volumes and likelihood of enforcement of speed limits are both greater.

4.3.3 Effectiveness of Traffic Calming.

Traffic calming is designed to reduce the speed of vehicles through the implementation of physical or psychological features, or a combination of both, on or near the road. Physical calming can be in the form of roundabouts, speed humps and rumble strips while psychological traffic calming involves the use of signage or lines painted on the road to give the visual illusion that the road is narrower than the actual width of the pavement.

Traffic calming has been implemented at three of the sites in this study. Lacey's Creek on the El Arish Mission Beach Road has signage (Figure 4.20a) and rumble strips on approaches from either direction. Stoney Creek on the Tully Mission Beach Road has diagonal lines painted in the bicycle lanes on the edges of the road (Figure 4.21). Hull River, also on the Tully Mission Beach Road, has signage and lines painted across the road (Figures 4.20b and 4.22). The lines painted at Stoney Creek and Hull River have not been regularly maintained and are fading.

<u>Figure 4.20.</u>
<u>Signs warning of the risk to cassowaries at (a) Lacey's Creek on the El Arish Mission Beach Road, and (b) Hull River on the Tully Mission Beach Road.</u>

(a) (b)

Figure 4.21.
Traffic calming lines on the edge of the road at Stoney Creek on the Tully Mission Beach Road.

Figure 4.22.
Traffic calming lines across the Tully Mission Beach Road at Hull River.

Traffic calming at Lacey's Creek (signage and rumble strips) may be effective to some extent, as evidenced by the mean speed at this site being significantly lower than either of the other two sites on the El Arish Mission Beach Road for both the small and larger vehicle classes (Figures 4.14 and 4.18). However, the road surrounds at this site probably also exert an effect on speed. The site is located to the west of Lacey's Creek picnic area and walking tracks, to which there is an entry from the main road causing people to slow if they wish to pull off when coming from El Arish. When re-joining the road from the picnic area to travel in a westerly direction, some vehicles may also take a while to increase speed and therefore be recorded at a slower speed. Vehicles entering the picnic area and leaving it will also exert a slowing effect on through traffic. Additionally, a large curve occurs to the east of the picnic area entrance and this is likely to cause some vehicles to reduce speed in the vicinity of the traffic counter location. The presence of the signage at Lacey's Creek may also cause lowered speeds, at least for tourists, many of whom slow or stop to look at or take photographs of the sign. Therefore, the effectiveness of the traffic calming implemented at this site is difficult to assess, although the mean speed for small vehicles and buses and medium-sized trucks was 6 km/h below the posted legal speed limit (80 km/h).

The potential effectiveness of traffic calming at Stoney Creek (lines on road) on the Tully Mission Beach Road is not likely to be confounded by other aspects of road design as there are no roads turning off from this section and the site is located on a long, straight stretch of road. There are no reasons for vehicles to slow down, aside from the traffic calming. Vehicle speeds, for all classes tested, were 2-3 kph lower at Stoney Creek than at the other two sites on the Tully Mission Beach Road, suggesting that there may be an advantage accruing from this traffic calming. The effectiveness is negligible, however, when the mean recorded speeds are considered: both small and larger vehicle speeds were above the posted speed limit on this section of road (80 km/h). Maximum recorded speeds at this site were at least twice the legal speed limit.

The Hull River location on the Tully Mission Beach Road also produced mixed indications as to the effectiveness of the traffic calming at this site (lines on road and signage). The mean speed for small vehicles was less than the westernmost Tully-Mission Beach Road location which was the only site on this road with no traffic calming. However mean speeds were still significantly higher than those recorded at Stoney Creek. Results were very different for buses and medium-sized trucks, however, because mean speeds at the Hull River location were significantly higher than mean speeds at either of the other two Tully Road sites. For all classes of vehicle, the mean speeds were still 5-10 km/h above the posted legal speed limit (80 km/h) and maximum speeds recorded were 100-120 km/h above this. Two possible causes of the slightly decreased speed at this site compared to westernmost Tully Mission Beach road location for smaller vehicles is that the Hull River site is located on a large, sweeping bend in the road approaching a bridge, which may cause some drivers to decrease their speed slightly. There is the added complication of the large intersection with the South Mission Beach Road just beyond the bridge, also with the potential to slow some drivers.

4.3.4 Potential Impacts of Traffic on Southern Cassowaries.

4.3.4.1 General Risks:

The majority of new chicks in the Mission Beach area appear around September (Moore 2007), making them susceptible to vehicle collisions during the increased traffic volumes recorded on both roads studied during the dry, tourist season. Young chicks are accompanied by the male parent for around a year (Latch 2007), during which time they are afforded some road sense by the parent bird, but are still known to run onto the road ahead of their parent or remain on the road when the parent bird has completed crossing (Personal observation). After this time they become independent and the sub-adult birds must establish their own territory. Due to the high territoriality and solitariness of this species (Latch 2007) they will often have to travel widely to find such an area, being forced to cross roads. These young birds may also be more susceptible to collisions as they learn to survive independently and negotiate the danger of roads. Again, the higher traffic volume and speeds recorded on the Tully Mission Beach Road will represent a greater threat to sub-adult birds than on the El Arish Mission Beach Road. Independence from the parent also occurs during the dry, tourist season when traffic volume is higher on both roads.

At maturity (>3.5 years; Moore 2007) they are still at risk of collision with vehicles. Because cassowaries require a high diversity of fruiting trees to provide a year-round food supply and therefore need to be highly mobile and move as feeding opportunities arise (Latch 2007), they must cross roads to access more favourable habitat. The significantly higher traffic volume and increased mean speeds recorded on the Tully Mission Beach Road represent a major risk to this species, more so than the El Arish Mission Beach Road. Cassowaries are also strictly diurnal, or active during the day (Moore 2007). Mean speeds are lower during these times but traffic volumes are much greater and gaps between vehicles, and therefore safe crossing opportunities, are also reduced.

4.3.4.2 Site-specific Risks and Improvements:

Some design characteristics and traffic variables at the individual sites studied may increase or lower the risk to cassowaries that cross at these locations. These include the following:

- All three sites on the Tully Mission Beach Road and Mountain View Close on the El Arish Road recorded the highest mean speeds, over 80 kph, which would increase the likelihood of a collision occurring and being fatal to the cassowary.

- Traffic volumes were greatest at the three sites on the Tully Mission Beach Road, reducing gaps between vehicles where cassowaries could cross safely.

- Lacey's Creek on the El Arish Road and Stoney Creek on the Tully Road have alternatives for crossing, in the form of structures under the road. If they were used, cassowaries would not have to cross the road's surface (However, see Chapter 3 for negative assessments of cassowary use of these potential crossing areas). Lacey's Creek has culverts under the Lacey's Creek bridge, but these are not useable in the wet season. Stoney Creek has modified culverts under the Stoney Creek bridge, with cement ledges above the water level on one side so cassowaries could move through in all but the wettest months. This site also has shade-cloth fencing on each side of the road to direct animals into the culverts, however these are high enough off the ground to allow a cassowary chick to pass under. If these culverts were used regularly, they could provide safe passage for cassowaries under the road. Unfortunately, recent monitoring suggests otherwise (see Chapter 3).

- Approximately 200 m east of the Hull River site is the North Hull Bridge, beneath which the west creek bank has been modified and revegetated to facilitate the passage of wildlife, including cassowaries (see Chapter 3 for positive assessment of this potential crossing).

- The Mountain View Close and Lacey's Creek locations on the El Arish Road and Hull River location on the Tully Road have poor visibility from either direction. This poor visibility is due either to bends in the road or crests and dips reducing the view to the site to less than 200 m. All other sites have an obstructed view from one direction due to bends. This reduced visibility makes it more difficult to spot, and stop for, cassowaries moving onto the road.

- There is a possibility that the width of the grassy verge or open space on the edge of the road may increase the likelihood of drivers of noticing an approaching cassowary, or of a cassowary observing an approaching car. Most of the grassy verges at the study sites were between 2 m and 6 m wide, providing some potential for sighting of a cassowary as it approaches the road. Lacey's Creek on the El Arish Road and Hull River on the Tully Road had one 10 m and one 12 m wide verge, respectively, increasing the chances of seeing a cassowary as it moves onto the road. This clearing width may, however, have other detrimental impacts on rainforest species, including the cassowary, by producing edge effects and increasing the likelihood that the road will act as a barrier.

  Although the idea of maintaining wider clearings along road verges to allow the driver a chance to sight a cassowary moving onto the road has often been postulated at Mission Beach, in reality it appears not to be a means of reducing risk to cassowaries (See Chapter 2). There have been at least 5 cassowaries killed on the Tully Mission Beach Road in areas with wide clearings such as the 5.0 km from our Hull River location almost to Carmoo. It may be that drivers who are driving at the faster speeds measured along the Tully Mission Beach Road are focused on the road much further ahead and are therefore unlikely to see a cassowary standing in the cleared road verge (Chapter 2).

- Mountain View Close on the El Arish Road is bounded on one side by disturbed vegetation and agricultural land. The presence of fruit orchards may cause increased road crossings by cassowaries and potential fatalities, particularly during periods of low fruit availability in the rainforest.

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MISSION BEACH ROAD IMPACTS ON CASSOWARIES AND OTHER VERTEBRATES

SECTION 5:

REVIEW OF POTENTIAL OPTIONS FOR MITIGATION OF THE IMPACTS OF ROAD MORTALITY ON LARGE FAUNA INCLUDING CASSOWARIES

5. REVIEW OF POTENTIAL OPTIONS FOR MITIGATION OF ROAD MORTALITY IMPACTS ON LARGE FAUNA INCLUDING CASSOWARIES

Miriam Goosem, Leslie Moore and Marina Gibson

Summary.

The first principle of mitigating the impacts of roads on wildlife is to avoid the impact by routing new roads and road upgrades so that they do not pass through sensitive habitats. For existing roads that pass through protected areas this is generally not possible, so other approaches aim either to change driver behaviour or to attempt to change the behaviour of the target species or species group.

The speed travelled by a vehicle has a large effect on road deaths and the severity of injury to both driver and wildlife, as slower speeds have shorter stopping distances and provide greater time for both driver and animals to respond and attempt to avoid the collision. Slower speeds also result in less severe injuries should a collision occur. Therefore reduction in vehicle speed is a primary aim of many types of road mortality mitigation strategies. In Queensland most crashes involving animals occur in high speed (≥100kph) zones.

Reducing the legislated speed limit is one potential measure to mitigate road impacts. However, simply reducing the limit generally does not produce the desired effect if the road design speed remains unchanged. The road design speed is the speed environment for which the road was designed and is increased by factors such as wider lanes and road shoulders, wider roadside clearings, fewer curves and dips and overall greater driver visibility. Unless speed limit is continuously enforced, drivers tend to maintain higher speeds because of the perception that it is safe to do so. To reduce actual speeds, a variety of road features and traffic calming mitigations can be implemented. These include reducing lane width and sight distances, and incorporating in-road structures including speed humps, chicanes and roundabouts. A variety of psychological traffic calming methods have also been trialled, some on the Mission Beach roads, but have proved ineffective. These include painting road shoulders in various ways, painting stripes across the road and rumble strips. In contrast, in-road traffic calming structures including speed humps appear very successful in limiting speeds on Council-controlled roads in the Daintree Lowlands. Roundabouts, chicanes, and curved, divided roads with planting to limit sight distances are also successful in reducing speeds in urban areas and on highways in the Cairns region.

Roadside wildlife warning signs are a very common mitigation measure. However, evidence shows that passive signs in a fixed location with a static message do not have any effect on traffic speeds due to driver habituation. Signs such as these are most useful in public education rather than reducing mortality. More unusual permanent signs such as those showing cassowary collisions possibly have more effect, particularly for visitors to an area who are not habituated to them. Signs with active messages are more noticeable due to flashing lights or variable messages. If they are used only when animals are likely to be on the road, such as migration times, speeds can be reduced by 5 – 10 kph in comparison with standard warning signs which have little effect. Recent innovations include permanently visible signs that are blank until activated by a speeding vehicle, when they show drivers their speed, and potentially can als0 provide automated information for enforcement. Speed cameras are another device which may assist in enforcing speed limits. Temporary warning signs tend to be more effective than standard signs by providing a more specific warning signal to a driver. The temporary cassowary crossing signs erected for short periods of time

at Mission Beach locations where a bird has recently crossed fall into this category although there has been no monitoring of effectiveness in reducing driver speed.

Animal detection systems are activated only when large animals are near the road. These sensor-driven systems can be very effective in reducing driver speeds and road mortality, with reductions of 82 and 91% in animal collisions recorded. However, these work most effectively with herding species that migrate, using a specific route. Solitary animals such as cassowaries that can cross in a wide range of locations are unlikely to be successfully protected by such a mechanism. They are also subject to reliability issues in extremes of humidity, heat, rain and wet or moving vegetation.

Wide road clearings free of vegetation are often implemented with the aim of providing greater visibility and therefore longer times for drivers to respond if an animal attempts to cross. However, this also encourages faster speeds which tend to negate any advantage from increased visibility. Speeds are higher on Mission Beach roads with wider clearings. Wider road clearings also cause greater loss of cassowary habitat and potentially longer periods of stress when crossing exposed areas away from habitat cover.

Mitigation measures that have proven successful for prevention of road mortality in large animals in other parts of the world are large underpasses such as viaducts and high bridges. Large overpasses are similarly successful. Design of the structure including furnishings needs to be targeted to the species of concern. Structures are teamed with exclusion fencing to prevent animals crossing in other areas and to direct them to the crossing structures. High bridges with vegetation underneath have also proven successful for cassowaries as monitoring demonstrates that type of structure is used reasonably often. However cassowaries will still cross the road surface not far from these large structures. Smaller structures such as box culverts have proved ineffective, with regular monitoring not recording use. However, in the past decade there are at least 3 records in the Wet Tropics of a cassowary or a family party using a culvert in the Wet Tropics.

Exclusion fencing designed to guide animals to crossing structures poses a number of serious issues for cassowaries, although successful for large mammals. Fences must include escape routes to allow animals trapped between the fence and the road to escape back into habitat on the other side of the fence. Certainly wire mesh fences should not be considered when dealing with cassowaries, due to danger of injury to the birds. Shadecloth fencing has yet to be satisfactorily tested due to faults in design implementation and difficulties in monitoring.

Designs for fencing and crossing structures for cassowaries should be incorporated on Mission Beach Roads and monitored systematically. During road upgrades, high bridges or overpass structures should be seriously considered for crossing and/or mortality hotspots and connectivity bottlenecks, such as larger stream crossings and the Bruce Highway at Smith’s Gap. Other measures that warrant consideration, trials and implementation include roundabouts, chicanes, speed humps, revegetation of wide road clearings with low growing vegetation. All of these measured are aimed at reducing the design speed of roads and should be teemed with reduced legislative speed limits and permanent speed monitoring equipment. All measures need to be monitored to determine effectiveness. The community can assist with this to reduce monitoring programme costs. Public education programmes and temporary sign placements are continuing measures that can assist in raising awareness of cassowary mortality issues.

5.1 INTRODUCTION.

Originally mitigation of vehicle-wildlife collisions was motivated by issues of public safety because of the risks to humans of death or serious injury when a speeding vehicle collided with a large animal such as a deer, moose or kangaroo (Goosem 2004; Huijser and McGowen 2010; Jones 2010). In the United States the total number of large mammal-vehicle collisions was estimated at 1-2 million annually (Huijser and McGowen 2010), resulting in 211 fatalities, 29,000 human injuries and $1 billion in property damage (Conover *et al.* 1995). An increase in deer population size caused these figures to rise over the last decade. Although not the case with deer, road mortality may affect species at the level of the population (Fahrig and Rytwinski 2009), which may even affect population viability in endangered bird species, such as the Florida Scrub Jay (Mumme *et al*. 2000). The classic response in Europe and North America was to fence the highway. However it was soon recognised that although fencing may have reduced human risk, it had increased problems for wildlife and could also increase problems for drivers if broached by animals that could then not escape from the roadside (Forman *et al.* 2003).

More recently, as the negative impacts of roads on wildlife became more widely recognised (Forman *et al.* 2003), a variety of mitigation options have been explored in many areas of the globe; over forty types have been described (Huijser and McGowen 2010). However the effectiveness of these mitigation measures as well as the quantity and quality of data concerning their effectiveness is extremely varied. The term ‘fauna-friendly’ roads has been coined (Chenoweth 2008) and Fauna Sensitive Design Manuals have been prepared (QDMR 2002; QTMR 2010). In 2010, “Roads in Rainforest: Best Practice Guidelines - Planning, Design and Management” was published by the Australian Government’s MTSRF and Queensland Transport and Main Roads to assist in decisions regarding planning, design and operation of roads in tropical forests (Goosem *et al.* 2010). As discussed in Chapter 1, besides road mortality, road impacts on wildlife can be related to habitat loss from clearing, edge effects in adjacent habitat, disturbance within the road clearing and permeating adjacent habitat, invasions by weeds and alien fauna, and barrier effects that inhibit, reduce or prevent movements across the road. Several of these impacts may appear unavoidable if roads are to provide safe transport routes. However, in most cases, the potential for mitigation remains, with the major impediment to certain options being their expense. In regions where conservation is of major importance including important remaining habitats of endangered species that are particularly susceptible to one or more road impacts (such as cassowaries and road mortality), expense should not preclude consideration and incorporation of these more expensive mitigation options.

The types of options that have been considered and used in Australia and/or overseas include:

a) Avoiding the impact by choosing road routes that avoid sensitive habitats;
b) Mitigating the impact over a variety of scales by:
   (i) Changing driver behaviour; or
   (ii) Attempting to change animal behaviour;
c) Compensating for ecological impacts when mitigation does not completely solve the problem; and
d) Monitoring of the effectiveness of these solutions so that adaptive management can provide better solutions in future.

Mitigation can also be undertaken at several spatial scales (Magnus *et al.* 2004):

a) Black spot mitigation – applied to a short section of road where many individual animals are killed or where individuals of a species of particular importance are killed;
b) A specific road section; or
c) A whole of region or State application.

Several recent international reviews clearly strengthen the requirement for mitigation measures by pointing to the fact that road impacts are proven in many habitats. Fahrig and Rytwinski (2009) argued that strong evidence existed for negative effects on wildlife populations caused by roads and traffic, particularly for most amphibian, bird and large mammal species. Benitez-López *et al.* (2010) found clear evidence for declines in the abundance of birds and mammals by 28-36% within 2.6 km of the road for birds and a similar reduction within 17 km for mammals. Laurance *et al.* (2009) reviewed the impacts of tropical rainforest roads, demonstrating that roads through tropical forests can cause declines in many species, particularly larger species. Population declines near roads are not necessarily related to road mortality *per se*, but may be a result of animals avoiding the area adjacent to the road because of changes to habitat caused by the road. Avoidance can be caused by edge effects and disturbance. However, several studies have shown that road mortality can cause declines. One of the first studies to demonstrate local extinctions of a species relating to road mortality was in Australia by Jones (2000), who witnessed the decline of quolls and Tasmanian devils when a road was upgraded in a Tasmanian National Park, and followed the subsequent recolonisation by those species when the road impacts were mitigated.

When considered in relation to best available population estimates, the numbers of individuals removed from the Mission Beach cassowary population due to road mortality are high (Chapter 2, Kofron and Chapman 2006; Moore 2007). Although declines in population and causal factors are difficult to demonstrate in a rare species with a small population, population estimation remains the focus of other studies. However, it has been pointed out that for a long-lived, slow-reproducing species like the cassowary, it is possible that each road death could affect the dynamics and reproductive fitness of the population (Latch 2007). Road mortality of charismatic species is also a significant community issue (Hill *et al.* 2010, Jones 2010).

5.2 AVOIDING THE IMPACT

When new roads or road upgrades are considered, the first and most important means of mitigating impacts is to avoid areas with sensitive ecosystems, threatened communities, or populations of threatened species. As noted above, construction of any road involves clearing of vegetation and therefore loss of habitat. The loss of habitat includes not only the road surface but also ditches and road verges and, if a divided highway, also the median strip. There is also the permeation of edge effects that alter the habitat near the road and disturbances such as pollution, noise and light, beyond the road clearing. Invasions of weeds generally occur and generalist fauna alien to the habitat and feral animals often use the road to gain access to resources in the adjacent habitat (see Chapter 1).

If avoidance of the sensitive area is not possible, habitat loss and edge effects can be minimised by creating the narrowest width of clearing acceptable to satisfy safety concerns (Goosem 2007), although this will not address road mortality concerns. Under this treatment, habitat loss and alterations still ensue, but these are minimised so that less habitat is lost and less adjacent habitat is altered. Smaller areas of adjacent habitat are altered because the clearing is narrow, and therefore there is a smaller area with attendant microclimate changes such as hotter temperatures during the day, drier air, and there is also less surfaced road to increase runoff from rain. Thus the distance that edge effects penetrate the habitat is reduced. In tropical rainforest environments, maintaining a canopy of rainforest trees that do not drop branches over the road can also greatly reduce the change in microclimate and the extent of edge-altered habitat (Goosem 2008). The canopy cover will also reduce or prevent invasions by weeds and alien and feral fauna. Therefore the clearing of wide verges in tropical rainforest areas is counter-productive for rainforest wildlife. However, vehicular traffic will still cause disturbance from noise, headlights, pollutants and movement (Laurance *et al.* 2009).

Legislative frameworks that require infrastructure builders to maintain connectivity in sensitive areas is one of the major reasons for success in reducing the severe fragmentation of habitats caused by roads, highways and motorways in Europe, even in the face of increasing construction of this infrastructure (Jones 2010). The three key tenets of the projects to achieve these goals were:

a) Acceptance of the issues of fragmentation caused by transport infrastructure at the policy level and an interdisciplinary approach involving economists, engineers and ecologists to provide the necessary skills to address the problem, together with public engagement;
b) Preservation of habitat connectivity is a strategic goal of environmental policy in the transport sector;
c) Avoiding and mitigating impacts is a leading principle from the very start of infrastructure planning.

Currently in Europe, full avoidance of conservation sites designated in European legislation (Natura 2000) through route alignment is taken to be the first principle of effective road planning. The general guiding principle is to work with the topography at the broad and local scales of landforms to minimise habitat fragmentation while maximising the opportunities for retaining (or enhancing) habitat connectivity. This can involve inclusions of tunnels, embankments, viaducts and bridges (Jones 2010).

It would be unrealistic and naive to imagine that the majority of road infrastructure projects can avoid sensitive sites. For example, in the Mission Beach situation, all of the roads cross habitat of endangered species, and the main entry roads cross long sections of this habitat. Therefore a range of integrated measures is required. Avoidance of sensitive habitat through provision of satisfactory fauna passage may be able to be achieved in some sections of the roads during future upgrades.

However, in the meantime, alternative means of reducing the impacts of the roads are required.

5.3 MITIGATING THE IMPACT

As mentioned above there are two types of means used to mitigate the road mortality impacts of roads, highways and motorways. The first attempts to reduce vehicle – wildlife collisions through altering driver behaviour and the second attempts to alter the behaviour of the animal. Unfortunately there is little scientific evaluation of effectiveness of many of the techniques used to mitigate wildlife-vehicle collisions that fall under these headings (Forman *et al.* 2003). However, more recently, several reviews concerning mitigation have been published that provide information on the likelihood of success for some methods (Clevenger and Ford 2010; Huijser and McGowen 2010; Huijser *et al*. 2010; Hilty *et al.* 2010).

5.3.1 Changing Driver Behaviour

A variety of means of altering motorist behaviour have been tried in international studies. These include public information and driver education, various types of wildlife warning signs, measures that increase visibility for drivers, animal detection systems, means to reduce traffic volume, temporary road closures, people who assist wildlife to cross and measures that focus on reducing traffic speed. The speed travelled has a large effect on the severity of injury both to wildlife and to vehicle drivers, as slower speeds provide greater time for both vehicles and wildlife to avoid a collision (Huijser and McGowen 2010). Techniques used include road designs that reduce the design speed of the road or result in psychological traffic calming, and inclusion of physical means such as speed humps and chicanes. These may be teamed with alterations to advisory or legislated speed limits.

5.3.1.1 Reduced Vehicle Speed

A reduction in vehicle speed allows both drivers and wildlife more time and distance to respond and possibly avoid a collision (Forman *et al*. 2003; Knapp *et al.* 2004; Huijser and McGowen 2010). Huijser *et al*. (2010) note that although upgrading of rural two-lane roads to create wider lanes, wider shoulders, and wider roadside clearings may create mainly safer roads for humans, wildlife-vehicle collisions tend to increase rather than decrease. This is likely to be caused by faster road design speeds (Vokurka and Young 2008). At relatively high (e.g., ≥ 80 km/h) speeds, reducing speed reduction by just a few kilometres per hour can greatly decrease the risk of a severe collision (Huijser and Kociolek 2008). For example, Kloeden *et al.* (1997) found that reducing speed from 80 km/h to 75 km/h could lower casualty crashes by 31-32 percent. The lowered speed results in shorter stopping distances which may assist in avoiding or reducing the severity of a collision. In Yellowstone National Park, fewer wildlife-vehicle collisions occurred on roads with lower design speeds and speed limits (<70 km/h) than those with higher design speeds and limits (90 km/h, 5.4 times the number expected), although there were also more cars on the faster roads (Huijser and Kociolek 2008). In Queensland Transport (2007) data, most crashes involving animals occur in higher speed zones (particularly 100 kph or more). Similarly, Hobday and Minstrell (2008) found more roadkill than expected on higher speed (>70 kph) sections of road in Tasmania. Rowden *et al.* (2008) suggest that this may be caused by decreased driver reaction times when driving at higher speed, or by a lack of driver alertness or higher animal population densities in these zones.

However, just reducing the legislated speed limit is unlikely to produce the desired effect if the road design speed remains unchanged. The road design speed is the speed environment for which the road was designed. A higher design speed road has wider curves, wider lanes and shoulders and wider road clearing widths. For example, a straight road with low traffic volumes and long visibility distances (such as the Tully-Mission Beach Road) encourages faster speeds than a curved road with narrower clearing widths (such as the El Arish-Mission Beach Road). Many vehicles continue to travel at the design speed due to the driver perception that it is safe, even if there is a lower speed limit. However, some drivers will drive at the legislated limit and this has the potential to result in an increase in vehicle crashes overall, as the faster-moving drivers overtake the slower ones. For example, when the speed limit in Jasper National Park, Canada, was reduced from 90 km/h to 70 km/h with police enforcement, less than 20% of vehicles obeyed the lower speed limit (Huijser and Kociolek 2008) and wildlife-vehicle collisions did not reduce, although alterations to other factors including increased wildlife populations, habituation to traffic and greater traffic flows probably influenced the results. Dique *et al.* (2003) found no reduction in traffic speed or koala road mortality in an area where reduced speed limits were trialled. Therefore, to reduce speed limits, both road safety and efficiency in achieving the speed goal, dictate that the design speed of various road features should be altered in order to achieve a safer result for both humans and wildlife. This can be achieved through reducing lane and road shoulder width and sight distances, and/or incorporating traffic calming methods such as speed humps, roundabouts, chicanes, raised medians and rumble strips.

5.3.1.2 Public Information and Education

Driver education and public information campaigns are often promoted as a means to reduce wildlife-vehicle collisions (Knapp *et al.* 2004; Huijser *et al.* 2007). Campaigns can include videos, brochures, posters, signs, bumper stickers and presentations in media outlets including newspapers, magazines, radio and television. Many international transportation agencies provide information to the public regarding the number of collisions with large animals such as deer, together with sections of road particularly susceptible to these impacts and when the collisions occur, there have been no studies that demonstrate that this information was effective (Huijser and McGowen 2010). Generally the information provided also includes details on how to respond when large animals are on or close to the road to avoid a collision or reduce its severity. This type of information means that drivers must be constantly alert often over large distances. Huijser and McGowen (2010), when considering deer-vehicle collisions, concluded that public information was unlikely to result in substantial reduction in road kill and injury, although it may be useful for other reasons. These include raising public awareness of the problem and generating public support for mitigation measures. The reasons postulated for lack of success of campaigns in reducing collisions were that dangerous situations could not be identified by the driver until too late and that occurrence of wildlife near the road is too unpredictable to allow information to be applied (Huijser *et al.* 2007).

Other studies have concluded that public information and driver education efforts work best when combined with other mitigation measures (Hardy *et al*. 2003). A Parks Canada “Drivers for Wildlife” program in Jasper National Park combined public education in the form of bumper stickers and billboards with two digital signs that recorded speed and advised drivers to slow down in the high risk wildlife zone. Animal deaths decreased by 15% for the first 10 months following introduction of the integrated program. However, the active signage was credited with most of the reduction (Walker 2004).

Suggestions from the Community for Coastal and Cassowary Conservation (C4) to use brochures placed on vehicle windscreens to enhance public awareness of the problem of cassowary roadkill for those visitors who do not visit the information centre, would therefore be most likely to be effective in combination with other means of mitigation.

5.3.1.3 Warning Signs

Roadside wildlife warning signs are installed to alert drivers to the increased likelihood at a particular location of animals occurring on the road or roadside. The aim is to increase the alertness of drivers and also potentially reduce traffic speed, particularly where large animals such as deer, moose, elk and bear are likely. They are also used to warn of hotspots for roadkill of small species like koalas in Australia or badgers or frogs in Europe (Jones 2010).

There are four major types of warning signs

- Permanently visible signs in a fixed location with a static message;
- Permanently visible signs that are enhanced to be more noticeable with permanently flashing amber lights, bright orange flags, or signs that are completely lit up which may display dynamic or variable messages;

- Temporary signs that are placed out only when animals have been sighted in a precise location;
- Active signs that light up or flash when animals are detected on or near the road (also called Wildlife Protection Systems of Animal Detection Systems).

Wildlife awareness signage is used extensively worldwide, generally depicting the animal concerned or providing information to raise awareness. However, wildlife signage is generally agreed to be ineffective without other mitigation measures (QDMR 2002; Weston 2003; Pyper 2004; Deller 2005; QTMR 2010). Disadvantages are that information signs can include too much information for driver assimilation. Second, confusion can be caused to drivers (such as tourists associating signage with wildlife viewing sites) and third, there is little change of local driver attitudes (Magnus *et al.* 2004). However, because it is economical and also has an educative purpose, signage is widely used. It may enhance the efficacy of other mitigation measures and cause local drivers to slow initially (Magnus *et al.* 2004).

5.3.1.3.1 Permanently visible signs in fixed locations with static messages

Standard black on yellow or black and red wildlife warning signs are probably the most widespread roadside road mortality mitigation measure used throughout the world (Bank *et al.* 2002; Huijser and McGowen 2010; Figure 5.1a,b), due to being economical (Magnus *et al*. 2004). These are also the most common signs warning of the potential for cassowary crossings (Figure 5.1c). Warning signs tend to be installed when thresholds of wildlife-vehicle collisions are reached (Knapp and Witte 2006). However, permanently visible signs that remain in the same location and show the same message in words or pictures at all times and in all seasons do not appear to be effective in reducing mortality, even when road, traffic and landscape factors are accounted for (Rogers 2004; Meyer 2006; Huijser *et al*. 2010). Aberg (1981) investigated whether a standard moose warning sign helped Swedish drivers detect a dummy moose placed within 5 metres of the road, finding no change in either rates of detection or driving speeds. We found no further scientific evaluations of whether such passive signs are effective in either increasing driver awareness of large animals or in reducing driving speeds and thus the likelihood of animal-vehicle collisions (Hedlund *et al.* 2004). There appears to be a general consensus that drivers ignore permanently visible standard signs (Aberg 1981; Putman 1997; Sullivan *et al.* 2004; Rogers 2004; Meyer 2006; Huijser *et al.* 2007; Huijser and McGowen 2010), particularly when they are placed in areas where animals are only occasional road crossers. Signs such as these are likely to be most useful in public education rather than increasing driver alertness and reducing ***cassowary*** mortality.

Figure 5.1 Permanently visible signs in fixed locations with static messages
a) European deer b) Kangaroo c) Cassowary crossing teamed with speed hump, Cape Tribulation Road

It is possible that more unusual permanent signs, such as those showing a cassowary-vehicle collision (Figure 5.2) may be more effective than standard signs, at least for visitors who are not habituated to the signs, rather than the local community. However, there is little scientific data about unusual permanent signs with static messages. Knapp *et al.* (2004) concluded that all passive deer crossing signs had limited effectiveness. Enhanced black on yellow deer warning signs showing a deer and a car combined with a black on orange sign stating HIGH CRASH AREA did not reduce collisions (Rogers 2004). Some visitors have been observed to slow down at ***Lacey's Creek*** near the sign in Figure 5.2a. However, unless they stop completely to take photographs of the sign, it is impossible to determine whether the speed reduction is due to the sign, the presence of the picnic ground or the likelihood of vehicles entering the roadway from the picnic ground (see Chapter 4). Although numbers have not been quantified, the majority of vehicles passing through the area did not slow down.

Figure 5.2 a) b) c) Non-standard signs on Mission Beach roads

a) c) Photos Les Moore b) After Chenoweth EPLA (2008).

5.3.1.3.2 Permanently visible signs in fixed locations with active messages

Signs with active messages are also permanently visible to drivers and generally placed in fixed locations, but compared to standard signs these are more noticeable due to bright flags, a permanently flashing amber light, being entirely lit up, or displaying dynamic or variable messages. Huijser and McGowen (2010) state that the effectiveness of such enhanced warning signs is not fully clear. Field study results have been equivocal. Pojar *et al.* (1975) found that speeds past lighted animated deer crossing signs were about 5 kph less than when the same signs were switched off. However, even more important was the presence of a deer carcass near the sign, resulting in a 10-12 kph speed reduction. Similarly, when Hardy *et al.* (2006) trialled signs with dynamic messages warning of wildlife-vehicle collisions, significantly lower speeds were recorded than where a similar sign was turned off. The greatest speed reductions occurred during the night and at weekends. In a driving simulator study, Hammond and Wade (2004) found that speeds with a standard deer warning sign were 99.6 kilometres per hour, but when an enhanced sign with a flashing light was included the speeds were 99.5 km/hr with the light turned off and 95.9 km/hr with the light switched on. In a similar study, Stanley *et al.* (2006) found significantly slower speeds near three types of enhanced warning sign (116-120 km/hr) than near a passive standard sign (123.3 km/hr). Although these results are encouraging in terms of lowered speeds, greater speed reduction and decreased driver reaction time compared with standard signs, none of these studies demonstrated a significant reduction in deer-vehicle collisions (Huijser and McGowen 2010).

Figure 5.3 shows permanently visible signs which are blank until activated by a speeding vehicle moving along the roadway. The message shows the driver either vehicle speed, registration number or a message of slow down combined with the speed limit. Data can be collected remotely. The distributor claims that Department of Transport studies have proved this device has a dramatic and instant impact in reducing traffic speeds and accident occurrence rates, although no details are given. These are commonly used in Brazilian towns (pers. obs.). Again there appears to be no scientific evaluation of whether this type of sign would be effective in reducing animal-vehicle collisions when remote from enforcement, so trials are required. A trial of signs such as these along the ***entry roads to Mission Beach*** would determine whether these would be likely to have a long-term effect on drivers and whether enforcement could be linked to the signs.

Figure 5.3 Permanently visible sign activated by speeding vehicle.

Photo: Manufacturers

5.3.1.3.3 Temporary Warning Signs

Temporary warning signs (Figure 5.4) are placed out only when animals have been observed in an area or alternatively at certain times of the year such as seasonal migrations. Therefore they are a much more specific warning signal to drivers compared with permanent signage. Messmer *et al.* (2000) found a 13 kph drop in vehicle speeds and a 50-70% decrease in mule deer-vehicle collisions during seasonal migrations when large warning signs with flashing amber lights were placed on roads only at migration times. This was a one year trial compared with three previous years of migration death rates. Similar signs produced similar results for Sullivan *et al.* (2004) when dealing with migrations of the same species. They saw collision reductions of 51% (ranging between 41.5 and 58.6% in different areas) compared with areas without signs. Speeding vehicles were reduced from 19 to 8% in the first year of operation but the effect was less pronounced in the second season the signs operated, suggesting driver habituation and the possibility that over time these types of signs may become far less effective (Huijser and McGowen 2010). In contrast, Rogers (2004) did not find a reduction in deer-vehicle collisions using a sign with flashing lights that was deployed in the season of peak collisions. This is the type of sign currently used at Mission Beach when ***cassowary*** crossings are reported (Figure 5.4)

Figure 5.4 Temporary Warning Signs a) for cassowary crossing at Mission Beach

Photo: Les Moore

5.3.1.3.4 Animal Detection Systems

Animal detection (or wildlife protection) systems are activated only when large animals are detected near the road (Newhouse 2003). They use infrared light, radar, laser or radio frequency beams set parallel to the road or heat detecting cameras to detect large animals that approach the road (Figure 5.5). Fibre optic signs which become illuminated when wildlife encroach onto roadsides are used throughout France (Bank *et al.* 2002). Once activated, animal detection signs urge drivers to slow down and be more alert, thereby providing a time-specific warning signal. While permanent warning signs need to be installed in the correct location, and temporary warning signs need to be installed in the right location at the right time, animal detection systems can theoretically be installed anywhere provided the warning signals are only activated when an animal is detected (Huijser and McGowen 2010). However, the system must reliably detect almost all large animals that approach the road and must not produce too many false warning signals (Huijser *et al.* 2009). Otherwise driver confidence in the sign is destroyed which means the system becomes ineffective.

Huijser *et al.* (2009) tested a number of systems in an experimental field. More than half the systems tested reached a satisfactory level of reliability in ideal conditions, suggesting that in those cases, the response of drivers would be the most important factor driving effectiveness of the mitigation strategy. Huijser *et al.* (2009) also reviewed studies listing speeds of vehicles when faced with an activated sign and found the results were variable, ranging from speed reductions of 5 kilometres per hour or more, through much smaller speed reductions, to no speed reduction or even speed increases. The variability in results related to the type of sign, whether the message was combined with advisory or mandatory speed limit reductions, road and weather conditions and whether the driver is a local resident. However, two animal detection systems have been estimated to reduce collisions with large mammals by 91% (Dodd and Gagnon 2008) and 82% (Mosler-Berger and Romer 2003). Even small reductions in speed have a disproportionately large decrease in the likelihood of a fatal accident (Kloeden *et al.* 1997), and an increase in driver alertness induced by such a sign can reduce driver reaction time from 1.5 to 0.7 secs (Green 2000), with a potential reduction in stopping distance of 21 metres at 90 kilometres per hour (Huijser and Kociolek 2008).

Figure 5.5 Wildlife detection systems

Photo: a) copyright Marcel Huijser, Montana State University b) An animal detection system is combined with signage and lights to warn drivers that animals may be in or near the roadway (Wildlife Crossings Toolkit)

Huijser and McGowan (2008) list advantages of this technology as the potential to allow wildlife crossings anywhere along a road rather than being limited by a number of relatively narrow wildlife crossing structures. They can also be relocated with changes in animal behaviour and crossing routes and do not require major road construction and traffic control for long periods. Once mass produced they are likely to be cheaper than wildlife crossing structures, although currently they are very expensive and are only expected to work effectively for about 10 years. In terms of disadvantages, they are not yet proven in a wide range of conditions and currently only detect large animals (e.g. deer, elk, moose), so that smaller animals are not detected and drivers are not warned about them. Many of them have problems in that they may be activated by other factors such as tall, wet or moving vegetation, rain, sun, heat, humidity, lightning, vehicles on access roads or roadside, or non-target species. Such false activations can result in drivers ignoring the sign. Others may fail to activate when the target species crosses because of curves, gullies or slopes (Huijser and Kociolek 2008), with the result that drivers who expect the system to work are less alert than normal. Some types of systems are only active in the dark so animals that cross during the day are not protected. Poles and equipment are erected in the roadside so may be considered a safety hazard. And maintenance/vandalism can also be an issue (Huijser and Kociolek 2008). Another problem is that drivers do not always reduce speed when confronted by an activated sign (Muurinen and Ristola 1999), whereas, if the signs are accompanied by a legislated speed limit reduction, the majority of drivers will do so.

With respect to ***cassowaries***, the problem also remains that, although in some situations, hotspots of cassowary crossings can be identified, in many cases there is no means of predicting with sufficient accuracy, where the birds will cross. Therefore, to provide adequate protection against collisions, there would need to be a very large number of systems to effectively detect the majority of attempted crossings. Alternatively, a limited number of systems could be implemented in recognised mortality hotspots, provided that this did not encourage drivers to believe that they were unlikely to meet cassowaries in other locations.

5.3.1.4 Traffic Calming through Road Design

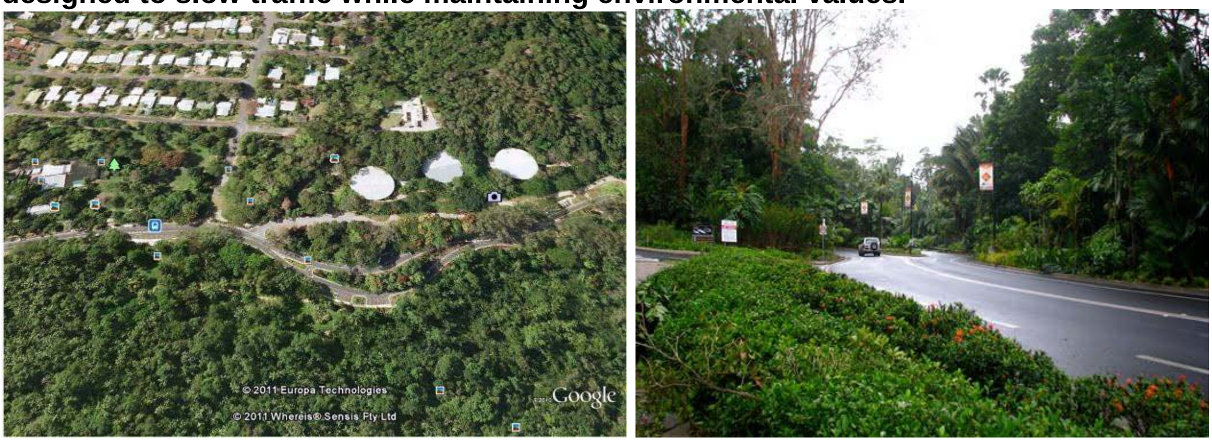
5.3.1.4.1 Structures built into the road for traffic calming

Traffic calming is used to reduce traffic speed through careful road design. In urban areas it is generally accepted by the majority of the community that speeds should be reduced on sections of urban access roads where the community wishes safety to be paramount (van Langevelde and Jaarsma 2009). For example the inclusion of roundabouts at intersections and/or chicanes along straight or curved sections of the road is a common feature of urban areas designed to slow traffic (Figure 5.6). The objectives are to ensure safety for residents, particularly children, and to reduce the tendency for through traffic to speed along suburban roads when trying to avoid traffic jams on main roads. Similarly, traffic calming is used to create a low speed environment in areas where the aims of local government are for drivers to enjoy the environment rather than rush through an area (Figure 5.7). This requires careful design to ensure that areas where people cross are not obscured from drivers ignoring warning signage (Cairns Regional Council personnel, pers. comm.). Roundabouts can also be used to reduce speeds on high speed roads, particularly at important intersections (Figure 5.8).

Figure 5.6
Chicanes used for slowing urban traffic in Cairns, Far North Queensland

From Google Earth, July 2011. Imagery Date 9/1/2008.

Figure 5.7
Divided road with curves and planted centre islands at Collins Avenue, Cairns, designed to slow traffic while maintaining environmental values.



From Google Earth, July 2011. Imagery Date 9/1/2008. From Google Earth contributed photos, taken Feb, 2011

Figure 5.8
Roundabouts used to reduce traffic speed at important intersections on major roads and smaller intersections on minor roads.

From Google Earth contributed photos, taken Feb, 2011 From Google Earth, July 2011. Imagery Date 9/1/2008.

Currently traffic calming designs such as chicanes, curved divided roads with planted medians, and roundabouts are mainly used in urban situations in residential neighbourhoods or on highways approaching urban areas but rarely in rural situations. In Australia, the placement of traffic calming measures on high speed roads is generally accepted as impractical and potentially dangerous. However, the roundabouts on the Cook Highway between Cairns and Kewarra Beach are a notable exception. In conjunction with appropriate speed limits for safety of drivers (such as recently implemented along the Cook Highway), such designs could reduce traffic speeds in areas where wildlife such as cassowaries cross. For example, in Tasmania in Cradle Mountain National Park, Jones (2000) observed a decline in Tasmanian Devils and Eastern Quolls after a road upgrade increased vehicle speeds. The populations subsequently recovered once chicanes reduced the road width and design speed (Figure 5.9b).

Figure 5.9 Traffic calming in the form of a) speed humps and signs on the Cape Tribulation Road, Daintree National Park, north Queensland; b) chicanes in Cradle Mountain National Park, Tasmania

Phpto: Les Moore Photo: Russell Bauer (Magnus *et al.* 2004)

Chicanes with landscaping has the potential to be implemented on urban Mission Beach roads in ***cassowary road mortality hotspots,*** whilst ***roundabouts*** could be considered for intersections with ***known cassowary crossings*** such as near the South Mission Beach Road intersection with the Tully-Mission Beach Road and the Wheatley Road intersection with the South Mission Beach Road.

In the Daintree lowlands of north Queensland, speed bumps and cassowary signage have been installed on the main Council road to Cape Tribulation to reduce vehicle speed and the ***risk of cassowary road deaths*** (Figure 5.9a, Figure 5.10, Moore and Goosem 2009). Unfortunately no studies have been conducted to determine their effectiveness. However, ***cassowary*** road death in the Daintree area is very low in comparison with Mission Beach, where there is no similar mitigation and vehicle speeds are high (Chapter 4). This type of installation has potential for installation on local ***Cassowary Regional Council roads*** to reduce speeds in cassowary road crossing hotspots.

Traffic calming in the form of speed humps together with signage and psychological measures (see 5.3.1.4.2 below) has recently been trialled at ***Mission Beach*** near urban areas (Figure 5.12). Although the design in terms of speed humps appeared successful in reducing vehicle speeds, the community nearby was disturbed by the noise of vehicles going over the speed humps and they were removed (Queensland Transport and Main Roads, John Breen pers. comm.). Relatively recent innovations include rubber speed humps (Figure 5.11) that are slightly flexible, allowing the unit to conform to the road camber. These are marketed as “quiet and vehicle friendly”, and aimed at reducing noise from the structure, although this would not be expected to completely nullify noise from vehicle springs as they cross the structure,

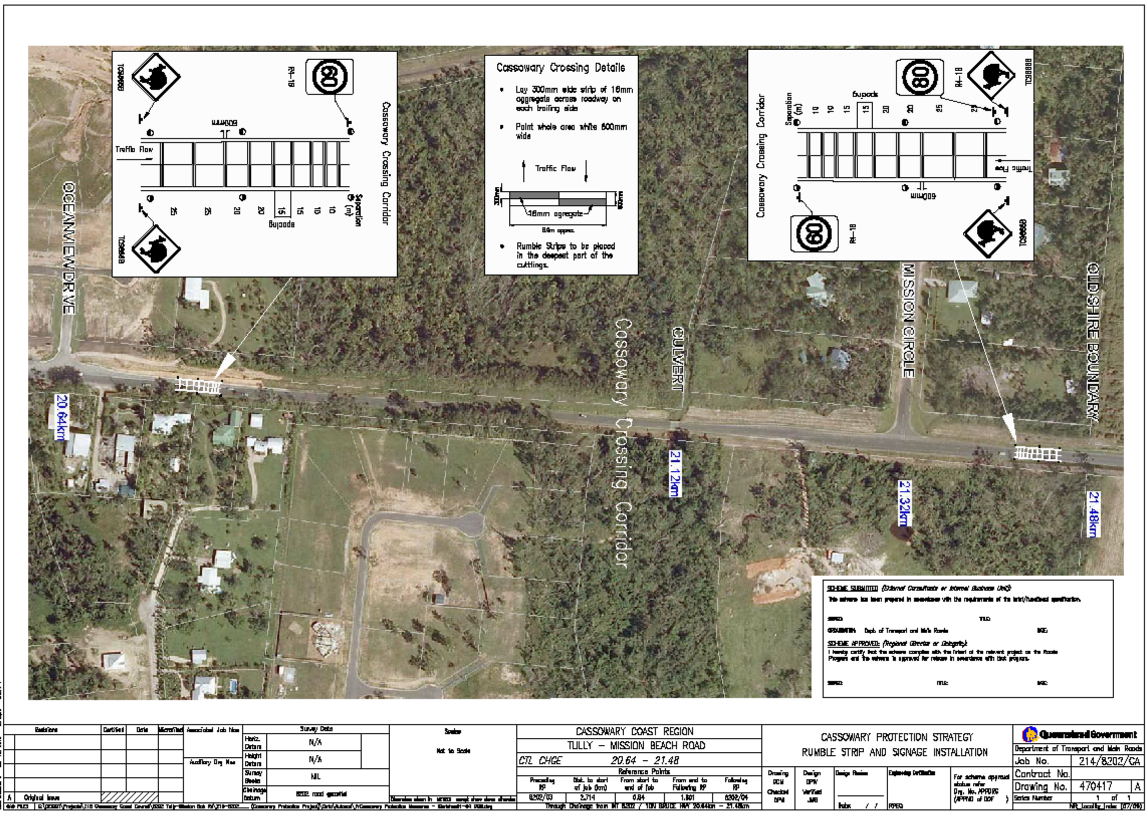
Figure 5.10 Speed humps along the Cape Tribulation Road, Daintree National Park, north Queensland. a) Speed hump and signage b) Large stone-lined speed hump

Photos: Les Moore

Figure 5.11 Rubber speed humps are an innovation that are claimed to reduce noise

Photo: Manufactures

Figure 5.12 Design of traffic calming with speed humps on Cassowary Drive (QTMR 2010)



5.3.1.4.2 Psychological Traffic Calming

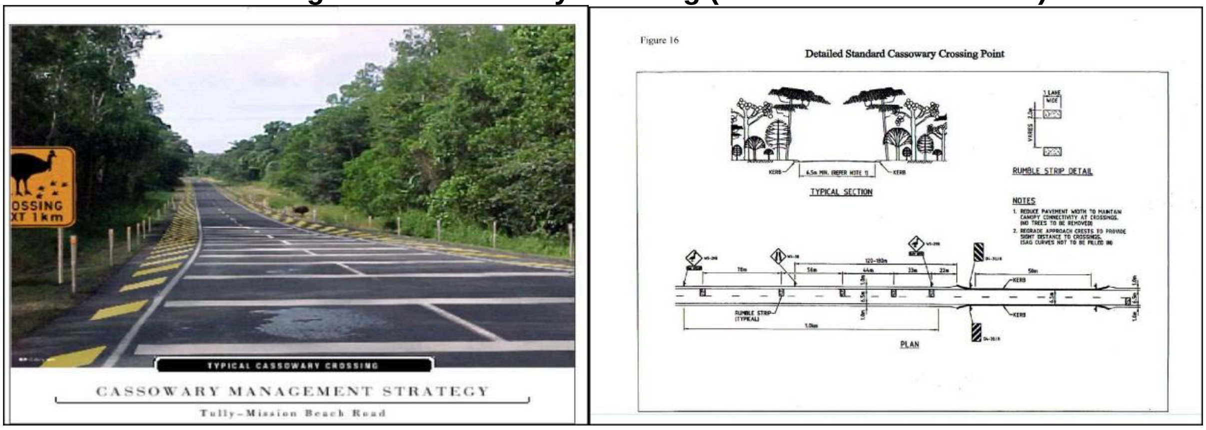
Psychological traffic calming aims to reduce speeds that drivers travel along higher-design speed roads. A higher design speed occurs when lanes are wide, shoulders are wide, roadside clearing widths are large, a driver can see further and there are few curves. These road conditions encourage drivers to drive faster, but psychological traffic calming aims to reduce the speed that drivers travel without reducing those safety features by influencing their perception of the road design speed. This can be achieved by a number of measures:

a) Making the lane width appear narrower through road markings with wide striping on the shoulders (peripheral herringbone road markings) may encourage drivers to slow down as it is more difficult to remain in the lines at higher speeds;
b) Rumble strips – strips with larger gravel in the bitumen to cause vibrations in the vehicle may alert drivers and encourage slower speeds (raised pavement markings). These are often placed closer together as the driver approaches the feature where he needs to slow down;
c) Lines painted completely across the road (transverse road markings), gradually becoming closer together as the driver approaches the area where he needs to slow down;
d) Reducing the width of roadside clearing causes the whole road to appear narrower, encouraging reduced speeds.

Road markings include transverse, peripheral herringbone, checked pattern and raised pavement markings. These are easy and economical to install and may produce a short-term effect without drivers being aware of the change. However local drivers are less likely to alter behaviour and tend to habituate to the markings. Advantages include their relative ease and economical installation, and that speed reduction can be achieved, albeit for a short time, without drivers being aware of the change (Deller 2005). Disadvantages are that often markings on roads produce less of an effect on local drivers as these drivers are more averse to changing their behaviour and also have greater opportunity to habituate to the markings and learn to ignore them (Deller 2005). Some studies have suggested that markings can have long-term effects, while others found no change at all. Overall, there is general consensus that markings alone are ineffective but can be assisted by using other mitigation methods such as signage (Deller 2005).

A number of mitigation options were developed as part of a road upgrade assessment at Mission Beach undertaken for Queensland Department of Main Roads (Figure 5.13, Moore and Moore 1998; Moore 1999). On the ***Tully-Mission Beach Road***, perpendicular lines across the road (transverse road markings) aimed to cause drivers to slow down, particularly when diagonal wide lines were placed along the road shoulder (peripheral herringbone markings) and signage was included on the roadside. Unfortunately having the lines so close together became a safety issue for drivers and every second one was removed after several months. There is little evidence that the perpendicular lines at the double spacing that remain in place (although now faded) cause drivers to slow down, as the average speed is now >85 kph (>5 kph above the speed limit, Chapter 4). Similarly, where the road shoulders only are painted with diagonal strips (again faded), average speed is still >83 kph, more than 3 kph above the speed limit. In another trial, rumble strips (raised pavement road markings, Figure 5.14) were placed across the ***El Arish-Mission Beach Road*** in the approaches to Lacey's Creek and also near the Clump Mountain Cooperative. Although these also had faded, again there was little evidence that they were successful, with average speeds at the Clump Mountain Cooperative very close to the speed limit of 80 kph, while, although less at Lacey's Creek (~73 kph), the results were confounded by the presence of curves, signage and traffic entering and leaving the picnic ground area.

Figure 5.13 a) Cassowary crossing designed for Mission Beach; b) Detailed structure of the Mission Beach generic cassowary crossing (Moore and Moore 1998)



More recently, rumble strips and psychological road narrowing through road painting was included with the design for ***Cassowary Drive*** traffic calming (John Breen, QTMR, pers. comm.). The legal speed limit was also reduced so any speed reductions could also be related to the potential for enforcement. Overall, Huijser *et al.* (2010) point out there is little data that suggests effectiveness of these types of measures without concurrent other mitigations, such as the approach to roundabouts (in Cairns) or other reasons for reducing speed, such as reduced legal speed limits (Cassowary Drive, Mission Beach).

Figure 5.14 Rumble strips placed near Lacey Creek a) half lane rumble strip b) close up of larger gravel size designed to make vehicle tyres 'rumble'

Photos: Miriam Goosem

5.3.1.5 Increase Visibility of Crossing Animals

Several options have been trialled to increase visibility of animals for drivers.

5.3.1.5.1 Roadway lighting

Increased roadway lighting had been trialled to increase visibility of nocturnal large mammals, so that drivers can see wildlife on or near the road more clearly (Huijser and McGowen 2010). However, lights may also cause nocturnal animals to avoid the road side (Chapter 1) and will not assist in detecting diurnal species like ***cassowaries***, while creating a zone of disturbance that will reduce habitat quality next to the road for many nocturnal species (Chapter 1).

5.3.1.5.2 Vegetation Clearing

Providing increased visibility for drivers through mowing or clearing vegetation has been proposed to allow drivers to see wildlife better when they are on or near the road. Drivers have a clearer line of sight along the road corridor. In Norway, clearing vegetation to a distance of 20-30 m on each side of a railway reduced collisions of trains with moose by 56% (Jaren *et al*. 1991), although the data were limited and variable and the researchers were not satisfied with their research design. Similarly, in Sweden, roadside clearing reduced moose-vehicle collisions by 20% (Lavsund and Sandegren 1991). However, Huijser and Kociolek suggest that the reason for the reductions seen in these two studies may be more the removal of the shrubs on which moose feed, rather than greater visibility. Moving the forest edge further from the pavement by removing vegetation may therefore reduce the risk of animal-vehicle collisions for species such as deer and moose. However, this may not necessarily be the case for ***cassowaries*** which are frugivorous and territorial. Although cassowaries may find fallen fruit on the roadside, their primary motivation for approaching roads is probably to utilise the forest habitat on the other side of the road. Widening the existing road corridor by removing vegetation would therefore only increase the barrier effect and probably make crossing the road a more stressful activity. Overall, although there is some evidence that vegetation removal may assist in reducing wildlife-vehicle collisions in some situations for some species (Putman 1997; Knapp *et al.* 2004), there is also evidence that clearing can attract animals including wallabies and kangaroos to roadsides to forage (Osawa 1989; 1990). Huijser *et al.* (2007) suggested that any effects are likely to be temporary and that more research should evaluate the true effectiveness of this type of mitigation. Additionally, removal of roadside vegetation removes cassowary habitat and therefore could also reduce the potential size of cassowary populations.

Chapter 4 investigated traffic speeds recorded on both the Tully-Mission Beach Road and the El Arish-Mission Beach Road. The results appear to support the idea that where there are wide roadside clearings such as on the Tully-Mission Beach Road, traffic tends to drive faster, as suggested in Section 5.3.1.1. Average speeds were always greater on the Tully-Mission Beach Road (86.9, 85.1, 83.4), even compared with straight sections of the El Arish-Mission Beach Road (82.6 and 79.4). The higher speed shown for the El Arish-Mission Beach Road was recorded in an area with wide roadside clearing, and was greater than the speed limit, even though the site was close to another road entry and a blind hill and curve. The higher speeds on the Tully-Mission Beach Road occur despite the greater traffic volume carried by the road, and thus the greater likelihood of cars forming 'platoons' behind a slow driver.

There are also more ***cassowaries*** killed on the Tully-Mission Beach Road than the El Arish-Mission Beach Road, although the El Arish-Mission Beach Road has a higher death/forested km ratio and higher death/forested km/ average daily traffic volume ratio. However, multiple factors could influence this figure – besides traffic speed and traffic volume, habitat quality will also affect population numbers in the vicinity of the road and thus the potential for cassowary deaths. The melaleuca habitat along sections of the Tully-Mission Beach Road is likely to be lower quality habitat than habitat along the El Arish-Mission Beach Road where the majority is rainforest. Overall, more studies are required to evaluate the usefulness of this mitigation technique in reducing road mortality.

5.3.1.5.3 Other Measures to Increase Animal Visibility

Wide road striping has been suggested as a means of providing greater visibility of large animals to drivers (Huijser and McGowen 2010). When the animal is crossing the driver may see a break in the pattern of highway striping. However, no monitoring data is available that examines effectiveness and, if effective, is more likely to be noticeable at night. Certainly the diagonal striping used along the Tully-Mission Beach Road does not appear to improve ***cassowary*** visibility. Similarly, although reflective tape on the radio-tracking collars of large animals such as bison has been considered but not implemented, so no data is available, although this is not likely to be useful for ***cassowaries***, as it would require capture of every individual.

5.3.1.6 Reducing Traffic Volume

The amount of traffic travelling along a road would be expected to affect the number of wildlife killed on the road. Evidence for this type of effect has been found for migratory amphibians such as salamanders (Gibbs and Shriver 2005), where road mortality was highly and positively correlated with volume of traffic. In Sweden, Seiler (2005) similarly found that traffic volume was one factor influencing vehicle collisions with moose. In contrast, although traffic volume was found to be correlated with road mortality of small mammals on the Kuranda Range behind Cairns in north Queensland (Goosem 2000), this was a seasonal effect that could also be related to greater mobility of small mammals at times when the seasonal traffic volume increased. Modelling studies of traffic volume and number of collisions with roe deer have shown correlations between the factors (Jaarsma and Willems 2002; van Langevelde and Jaarsma 2004), leading to suggestions that motorists should be encouraged to use major highways, by installing traffic calming on minor country roads. This strategy should reduce collisions on the minor roads, and concentrate traffic on one major highway that is fenced to prevent animals accessing the road. However, as Huijser and

McGowen (2010) point out, this may not be a useful strategy in many cases, because higher traffic volumes often cause greater barrier effects and thus may reduce road mortality on minor roads by preventing crossing attempts.

More ***cassowary*** deaths occur on the greater traffic volume Tully-Mission Beach Road than on the El Arish-Mission Beach Road, however other factors also interact with this statistic including habitat quality and traffic speed. However, reducing traffic volume (e.g. encouraging bicycle use, walking in urban areas) on any of the Mission Beach roads could be a good preventative strategy, provided other measures were employed to ensure that traffic speeds did not increase.

5.3.2 Changing Animal Behaviour

Strategies used to influence the behaviour of animals include measures aimed at scaring animals away from the roadside and measures that might alert them to an approaching vehicle. Attempts have been made to reduce the attraction of roadside habitat and increase the attraction of areas at a distance from the road. Other options involve an area of safety in divided road median strip and measures that allow escape from the roadside. However, the most common ways of influencing behaviour are incorporating physical barriers such as fences that prevent animals accessing the road and roadside, and measures that elevate the road above the area the animal moves (bridges, underpasses) or carry the road under the route that animals can move (tunnels, overpasses).

5.3.2.1 Scaring Animals Away from the Road

5.3.2.1.1 Light Reflectors and Mirrors

Reflectors are designed to reflect vehicle headlight off the roadway and into the surrounding habitat. However, these have mostly proven ineffective (Rogers 2004; D'Angelo *et al.* 2006), have maintenance issues in needing to be kept clean (Sielecki 2004) and could only have an effect on nocturnal species, rather than diurnal species such as cassowaries. However, Ramp and Croft (2002; 2006) found a slight flight response in kangaroos.

5.3.2.1.2 Whistles and Audio Scarers

Deer whistles and other animal warning devices are mounted on vehicles or installed on or along the roadside to alert wildlife of oncoming traffic and keep them away from the roadside (Huijser *et al.* 2007). Although deer can hear ultrasonic frequencies up to at least 30 kHz (D'Angelo *et al.* 2007), most studies report no changes in animal behaviour (150 groups of free-roaming deer, Romin and Dalton 1992) or habituation within a short period (10 days habituation to acoustic road markings, Ujvari *et al.* 2004) or in number of animal-vehicle collisions (Romin and Dalton 1992, Ujvari *et al*. 2004). The Shu Roo audio warning device was designed to repel kangaroos using an ultrasonic tone. However, Bender (2001) found no difference in kangaroo vigilance, flight response or number of animals hit compared with vehicles without the device. The auditory capabilities of ***cassowaries*** are very little known (Chapter 1), although it is known that they can detect very low frequencies, so it appears unlikely that ultrasonic tones or high-pitched whistles would have any effect, given the evidence that shows fast habituation for species that hear well in this range.

5.3.2.1.3 Olfactory Repellents

Predator scents have been trialled for deer, moose and kangaroos using the rationale that many animals that are hit by vehicles have been attracted to feed on grass growing on the roadside. By spraying roadside verges with predator scent, it was hoped that animals will avoid feeding at these areas. Captive trials showed no repellent effect on caribou or deer (Brown *et al.* 2000; Shipley 2001). Ramp and Croft (2002) trialled a synthetic canine urine product Plant Plus to determine aversion responses for parma wallabies and red-necked pademelons. Parma wallabies were repelled but red-necked pademelons were actually attracted to the scent.

Habituation of animals and the cost and effort of continuously replacing the odour repellent means this measure is not a viable and practical option for mammals (Huijser and McGowen 2010). Similarly it is unlikely to be effective for ***cassowaries***, given that their olfactory capabilities are little known, that predator scents are unlikely to deter them and that the high rainfall in their habitat would require frequent reapplications. However, both Huijser and McGowen (2010) and Rowden *et al.* (2008) agree that further research into this strategy would be useful, at least for mammals.

5.3.2.1.4 Chasing Animals from Roadsides

This has been trialled in the United States by scaring deer with human presence and movement, noise, lights and helicopters but appears to be ineffective in most cases. While noises from guns or cannons or helicopters may be temporarily effective, habituation ensues (Huijser and McGowen 2010). Overall this appears an inhumane approach.

5.3.2.2 Altering Foraging Strategies

5.3.2.2.1 Intercept Feeding

This involves strategically placing supplemental food sources in order to lure animals away from the road (Huijser and McGowen 2010). One study suggested that this strategy may have reduced vehicle-deer collisions by almost 50% (Wood and Wolfe 1988).

The reduced ***cassowary*** road mortality after Cyclone Yasi may also be an indicator that supplemental feeding away from roads can reduce mortality. However, as an expensive, labour-intensive, stop-gap measure, eventually supplemental feeding will cease, animals will recommence their normal foraging strategy, and road-crossing and road mortality will recommence, as has been recently observed at Mission Beach, following phasing out of the Cyclone Yasi feeding initiative when rainforest trees returned to more normal fruiting patterns. Added to this is the problem that animals may become dependent on supplemental feeding. If supplemental feeding occurs near residences, it may also encourage animals to perceive humans as the food source, and they may become aggressive. This often results in removal of the aggressive individual from the population. Alternatively, supplemental feeding may encourage animals to perceive the roads near residences as a route to food, in which case they will not be frightened by roads and vehicles and may move into dangerous situations on roads.

5.3.2.2.2 Minimise Attractive Forage along the Roadside

Roadside vegetation can attract animals for foraging purposes, which in turn can increase road mortality (Putman 1997). For example, Osawa (1989; 1992) found that swamp wallabies in North Stradbroke Island were attracted to the green grass along the roadside which occurs due to runoff from the impervious road surface. Similar results were found in western New South Wales for kangaroos (Klocker *et al.* 2004). Nutritional quality of vegetation for deer has been minimised by planting unpalatable species, mowing or cutting or applying noxious chemicals (Jaren *et al.* 1991; Groot Bruinderink and Hazebroek 1996; Putman 1997; Rea 2003).

The removal of ***cassowary*** food plants from road edges may reduce attraction of the birds to roadsides, but this could also remove a vital seasonal food source. Therefore this approach should only be considered after growth of an individual of the same species to fruiting stage that was planted in an anthropogenic or cyclone-caused gap nearby but at a distance from the road.

5.3.2.2.3 Roadkill Removal

Roadkill on the road can beget further road mortality by attracting scavengers to the road surface or roadside. Scavengers are common in road mortality statistics because of this attraction (Goosem 2000). ***Cassowaries*** have been known to scavenge on the carcasses of small animals killed on the road, so timely removal of these would remove this attraction for the birds.

5.3.2.3 Wildlife Fencing

5.3.2.3.1 Fencing to Prevent Access to the Road

Fencing is one of the most commonly used measures to mitigate against wildlife-vehicle collisions. In the middle of the last century, fencing was used to keep fauna off the road, thereby increasing the fragmentation effects of roads by dividing roadside faunal populations Exclusion fencing for large animals such as deer, bear and other carnivores, is designed specifically to prevent access to the road. Wildlife fencing of 2 - 2.4 metres in height has reduced ungulate-vehicle collisions by 78-99% (Lavsund and Sandegren 1991; Sielecki 1999; Clevenger *et al.* 2001; Dodd *et al*. 2007; Figure 5.15). Road mortality of large carnivores has also been reduced effectively (Foster and Humphrey 1995). Fence height is a key determinant of effectiveness for large animals. Effective fences were at least 2.4 metres high and constructed of woven wire or chain-link design (Foster and Humphrey 1995). For smaller species, fine plastic mesh or even solid, slippery rubber or plastic may need to be placed at the base of the fence overlaying the wire fence to prevent climbing of the wire and this barrier should also be dug into the ground to prevent digging underneath (Goosem 2005; Asari 2007; Veage and Jones 2007; Figure 5.16). Fencing introduces a need for continuous maintenance and repair to maintain its effectiveness (Feldhammer *et al*. 1986). Fencing in uneven terrain can also create difficulties in ensuring that the fence conforms to all the gullies and ridges.

Figure 5.15 Wildlife exclusion fencing: Coquihalla Highway, British Columbia

Photos: From Sielecki (2005)

However, fences lead to roads becoming complete barriers to most animals (Jones 2010). Jaeger and Fahrig (2004) describe the conditions where fencing would be recommended. They recommend exclusion fencing when traffic volume is so great that there is no opportunity for animals to cross the road safely – when any attempted crossing is likely to end in death and road mortality is known to be a threat to population persistence. In contrast, Jaeger and Fahrig (2004) do not recommend exclusion fencing when wildlife populations are stable, or if animals need to access resources on both sides of the road, unless fencing is combined with complementary mitigation measures that provide opportunities for wildlife to cross safely. If sections of road only are fenced rather than the road in total, animal-vehicle collisions tend to occur near the fence endings, thus displacing roadkill from one location to another on the road (Clevenger *et al*. 2001).

Figure 5.16 Wildlife exclusion fencing a) Koala exclusion fencing b),c),d) Exclusion fencing for variety of species to deter climbing over (0.5m PVC sheeting at base and 0.6m metal sheeting 1.4m above ground) and burrowing under (below- ground fence extends 50mm), Compton Road, Brisbane.

Photos: a) Koala safety fencing and measures guideline (2009); b) Darryl Jones (Veage and Jones 2007) c) d) Compton Road, Brisbane (Goosem 2005).

Therefore, fencing must be used with other measures to be effective, not only in reducing mortality but allowing connectivity of populations. There is now more emphasis on guiding fauna off roads and towards crossing structures (QDMR 2002, QTMR 2010). Research suggests that guide fencing has significantly reduced fauna-vehicle collisions (Goosem *et al.* 2004); however this may come at the cost of population fragmentation if insufficient crossing the underpasses. Guide fencing is different for each target species or group (Figure 5.16). For example, when frogs are the primary concern the fence is low and constructed to prevent hopping, whereas escape poles from the road side of the fence might be provided for climbing animals (Goosem 2003). Slippery sheeting can be installed to prevent climbing animals reaching easily-climbed fence materials (Goosem 2003; Caneris and Jones 2004). Whichever is used, fencing can be an expensive option in terms of maintenance because vegetation must be kept clear of the fence and holes in the fence must be mended immediately.

Total exclusion fencing along the ***Mission Beach roads*** would cause very large problems for ***cassowaries*** and not be appropriate in Mission Beach because:

- Fruiting in the rainforest is unpredictable and patch, requiring cassowaries to move widely across the landscape to locate fruiting trees and vines. Home ranges are large (up to 6 km^2), most of which encompass one or more roads. Fences preventing access to or enclosing areas that birds rely on for forage would increase the risk of mortality through starvation and stress. It would also increase the likelihood of antagonistic encounters between birds with concomitant deaths and social disruption. Genetic issues of isolation may also ensue in the small population.
- Frequent monitoring and maintenance of exclusion fences is essential with damage a continual problem, allowing wildlife access to the road and trapping the species within the road clearing. Regular cyclones and rapid vegetation growth in the Wet Tropics amplifies this problem over temperate zones, making successful operation of exclusion fences highly problematic and extremely expensive to maintain.
- Fencing detracts from visual amenity, particularly in natural areas.
- Fencing could confuse cassowaries that are accustomed to road crossing, trapping them against the fence and providing increased opportunities for predation.
- Poorly located fencing could channel cassowaries to cross roads at locations of poor visibility in areas that are difficult or impossible to fence.
- Trapping cassowaries within the road corridor would be a significant risk associated with wildlife exclusion fencing.

Figure 5.17 Fencing using shadecloth to prevent cassowaries easily seeing habitat on the other side of the road. Unfortunately the installation did not take the shadecloth close enough to the ground to prevent cassowary chicks from moving underneath. The fencing also did not conform to variability of the terrain,

Photo: Miriam Goosem

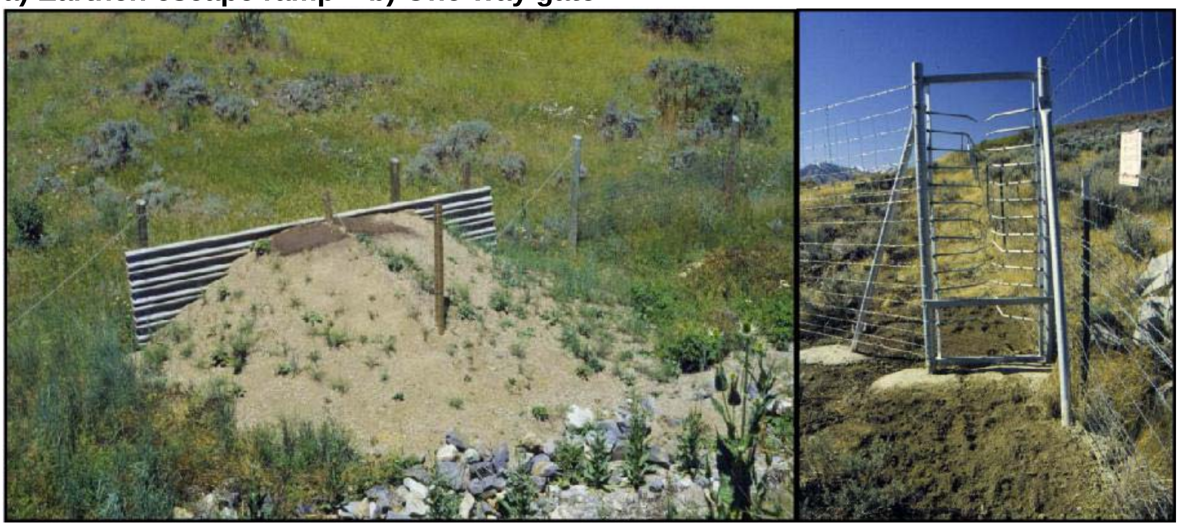
Fencing specifically for ***cassowaries*** has been constructed at one site on the Tully Mission Beach Road (Figure 5.17), and another in habitat adjacent to the El Arish Mission Beach Road (Chapter 3). The experience of cassowary researchers and the community indicates that fencing for cassowaries must not be constructed of wire mesh because birds will continue to attempt to move through it and thereby injure themselves (Bentrüpperbaumer and Goosem 2005). Instead shade cloth should prevent cassowaries observing habitat on the other side of the road and guide them to safer crossing areas (Goosem *et al.* 2004). Unfortunately the lengths of fencing erected so far and monitoring data available do not provide sufficient evidence as to the effectiveness of this design. Construction of the fence did not translate the design completely, leaving too much height at the base of the shadecloth, especially in dips in the terrain, allowing cassowary chicks to move under the fence. This could be easily adjusted to allow further trials.

5.3.2.3.2 Escape Routes from a Fenced Road Corridor

Good practice for fencing combines safe crossing opportunities but also provides opportunities to escape from the road corridor if animals become trapped there between fences on either side of the road (Huijser and McGowen 2010). These escape routes must be entirely one-way, ensuring that animals on the outside of the fence cannot access the road. Therefore, escape ramps up to the top of the fence from the road side of the corridor, or one-way gates or ‘returns’ must be provided for animals to return to habitat on the outside of the fence, working on the principle that animals caught within the road corridor will probably move along the fence until they find an opportunity to escape (Figure 5.18). Bissonette and Hammer (2000) and Clevenger *et al*. (2002) found that earthen escape ramps were 6-12 times more effective than gates in allowing deer to escape the road corridor. One-way gates are not recommended in many areas because of these results and due to animals becoming caught in them. Other returns can take the shape of gaps in the fence strategically angled to ensure fauna can only enter from the road*.*

The shadecloth fence designed to encourage ***cassowaries*** towards potential underpasses incorporated ‘returns’ in the fence in the form of narrow opening from the outside of the fence with a much wider funnel-shaped opening from the road side of the fence. This formed a funnel towards the forest side of the fence if birds walked along the fence within the road corridor, but the opening was so small it would be ignored if birds walked along the fence on the forest side (Bentrüpperbaumer and Goosem 2005).

Figure 5.18 Means of escape from the fenced road corridor
a) Earthen escape ramp b) One-way gate



Photos from Bissonette and Hammer (2000)

5.3.2.4 Wildlife Crossing Structures

Wildlife crossing structures allow the safe passage of animals over or under the road and are incorporated into road construction and upgrade projects to help restore animals movements across roads and also to reduce road mortality (Clevenger and Ford 2010; Jones 2010). They assist in creating landscape permeability for wildlife. Crossing structures are usually combined with fencing designed for the target species, and together these measures are proven to reduce wildlife road mortality and connect wildlife populations (Foster and Humphrey 1995; Clevenger *et al.* 2001; Huijser *et al*. 2007). The benefits of providing corridors and connectivity are generally agreed (Laurance *et al.* 2008) and wildlife crossing structures form part of the provision of landscape connectivity. Benefits of connectivity include increasing diversity through genetic exchange, maintenance of faunal population and community structure and decreasing competition for food resources (Goosem *et al.* 2006; Bond and Jones 2008; Bissonette and Adair 2008; Laurance *et al.* 2009).

In Europe, road engineering is required to integrate into the landscape so that earthworks conform to the broad landscape and local landform to minimise habitat fragmentation while maximising opportunities for habitat connectivity (Jones 2010). In the United States, environmental issues must be considered early in the planning process and this includes connectivity for wildlife (Clevenger and Ford 2010).

In Europe, wildlife crossings are considered necessary:

- where road construction causes significant habitat loss,
- where species are particularly sensitive to road mortality or fragmentation,
- where general landscape connectivity is significantly impaired;
- where other measures are unlikely to be effective;
- where target species are likely to use the structures;
- where the road is fenced;
- where species are threatened;
- where species are common or abundant with large home ranges (Iuell *et al*. 2003).

Jones (2010) cites the French transport agency as providing two design principles:

- persistence of common species is also important to biodiversity conservation so passages will be required at regular intervals in all habitat types, including agricultural lands, with priority and generally a greater number of passages provided for sensitive sites and species;
- provide a diversity of passage types including smaller culverts for small mammals, purpose-designed passages for amphibians and reptiles where appropriate, as well as larger structures for larger species. This has the potential to assist in providing connectivity even in the face of complex interactions between species that affect use.

5.3.2.4.1 Location of Wildlife Crossings

Decisions on the locations of wildlife crossing structures must first consider the species or groups of species which are of concern and will be the target. Then a number of techniques can be used to determine sites for inclusion of crossing structures (Clevenger and Ford 2010). These include field data and geographic information system analysis of potential habitat linkages that consider habitat type, topography, land tenure and potential wildlife corridors at the landscape scale that should be retained and strengthened. Hotspots for road kill of the species or group are one obvious site often considered most suitable for crossing structures. However, this is not always the case. Research suggests road mortality hotspots do not occur in the places where wildlife can safely cross roads (Clevenger *et al*. 2002) as road mortality is dependent on many road parameters and factors associated with the adjacent habitat (Goosem 2000; Malo *et al*. 2004; Ramp *et al.* 2005). These factors may not be the same in safe crossing areas (Clevenger and Ford 2010). Therefore road mortality data should be combined with habitat linkage mapping and wildlife movement data including traditional crossing locations if available. Other field data that can assist in determination of sites for wildlife crossing structures (Clevenger and Ford 2010) include radio or satellite tracking data from the species that shows where safe crossings occur; trapping and recapture data that shows movements across roads; sand beds for tracking animals positioned parallel to the road; remote camera systems that provide information on wildlife distribution and abundance (although not reliable for determining where road crossings occur); and genetic sampling (hair or dung for mammals, feathers or dung for birds).

Where such data are unavailable, expert opinion consensus can be a useful surrogate and can subsequently be tested in the field (Clevenger and Ford 2010). Local knowledge and participation can also assist in identifying crossing areas. Involvement of land management agencies can prevent landscape-scale habitat linkages which incorporate wildlife crossings being interrupted by other developments in the lifespan of the structures (possible 70-80 years for large constructions).

The ***DERM cassowary road mortality database*** and ***C4 cassowary crossings database***, together with information regarding ***habitat linkages*** (Biotropica 2008; 2009; 2010; Chenoweth 2008) and input from ***experts, stakeholders and the local community*** should all be considered if devising strategies for cassowary crossing locations.

5.3.2.4.2 Spacing of Wildlife Crossings

The positioning of and spacing required between wildlife crossing structures for large species is largely determined by landscape factors. The terrain, type of habitat and level of human activity all affect wildlife movements so these and the amount of important habitat adjacent to the road must all be considered when determining positions of structures at the landscape and local scale. Land management in nearby habitat now and planned in the future is very important – the structure needs to function for wildlife movements for up to 80 years or more (Clevenger and Ford 2010). Similarly, the potential for habitat change and associated changes in wildlife populations over that time scale (e.g. climate change) should be considered.

Clevenger and Ford (2010) list a group of principles to assist in deciding how many wildlife crossings are necessary, their locations and the distance between them:

a) Topography – movement corridors often follow riparian areas or ridgelines. Avoid steep slopes and human buildings.
b) Design and manage for multiple species, not just the focal species. These species vary in home range size so provide a range of wildlife crossing types at frequent intervals which are furnished with microhabitats to provide cover for small species.
c) Ensure habitat is under suitable tenure and management for the long term.
d) Ensure crossings form part of the larger regional corridor network, rather than ecological ‘dead-ends’.

Home range size can be used to determine spacings (Bissonette and Adair 2008). This information has been used for locating rope canopy bridges on the Palmerston Highway (Goosem *et al*. 2008). Average spacing of multiple structures for large mammals in North America varies between 1.5 and 6.0 km, averaging about one crossing every 1.9 km. Large North American mammals are similar to cassowaries in having large area requirements, in that road mortality can be a threat to populations and in posing a danger to motorists, but many are quite different in their herding and migratory behaviours.

One structure is unlikely to provide effective connectivity for wildlife populations as generally only individuals living near the structure or wide-ranging species are likely to benefit, so a package of different types of structures along the length of the road is generally necessary to allow use by multiple species (Jones 2010). In France, the transportation agency suggests one structure every 300 m and one every 30 m in critical habitats for certain species (Jones 2010).

5.3.2.4.3 Design

Design of wildlife crossings is just as important as location. The size of the crossing and species-specific behaviour must be considered. The logistics of the project, costs of the structure, available material and expertise and physical limitations of the site (soil, terrain, hydrology etc) may also define the type of crossing to be used (Clevenger and Ford 2010).
A wide variety of structure shapes and sizes have been constructed as 'wildlife crossings' and these may either be dedicated for wildlife use or also used by humans or for carrying water. Clevenger and Ford (2010) list 11 design types:

- Wildlife overpasses – landscape bridge, wildlife overpass, multiuse overpass, canopy crossing (for arboreal wildlife);
- Wildlife underpasses – viaduct, large mammal underpass, multiuse underpass, underpass with water flow, small to medium-sized mammal underpass, modified culvert, tunnels for amphibians and reptiles.

Types of wildlife crossings that have been implemented in North America in combination with fencing include gaps in the fence combined with warning signs or cross-walks and warning signs (Lehnert and Bissonette 1997), gaps in the fence combined with animal detection systems (see Section 5.3.1.3.4) as well as wildlife underpasses and overpasses (Huijser and McGowen 2010). They vary in estimated effectiveness in reduction of wildlife-vehicle collisions from 40% for fence gaps with crosswalks, through 82% for fence gaps with animal detection systems (see Section 5.3.1.3.4) to 87% for fence with under- or over-passes.

Underpass design and implementation must be addressed holistically to provide the greatest chance of success (Goosem *et al*. 2004). It is the integration of design guidelines with site-specific requirements and knowledge of the target species or group that encourages success (Jaeger 2007). An effective crossing structure is defined as one which enhances or re-establishes genetic exchange and connectivity and maintains population and community structure on either side of a road (Weston *et al.* 2011). Success may be encouraged by installing several structuress in one location to reduce competition between individuals, predator attraction, travel time to a safe crossing and habituation time (Barnes 2007) and incrementally increase connectivity (Jaeger 2007). Success can also be increased by installing structures that can be utilised by a large number of species (Bissonette and Adair 2008), by connecting larger areas before smaller ones (Jaeger 2007) and by undertaking research prior to installation that establishes local fauna pathways and behaviour (Forman *et al.* 2003; Taylor and Goldingay 2009).

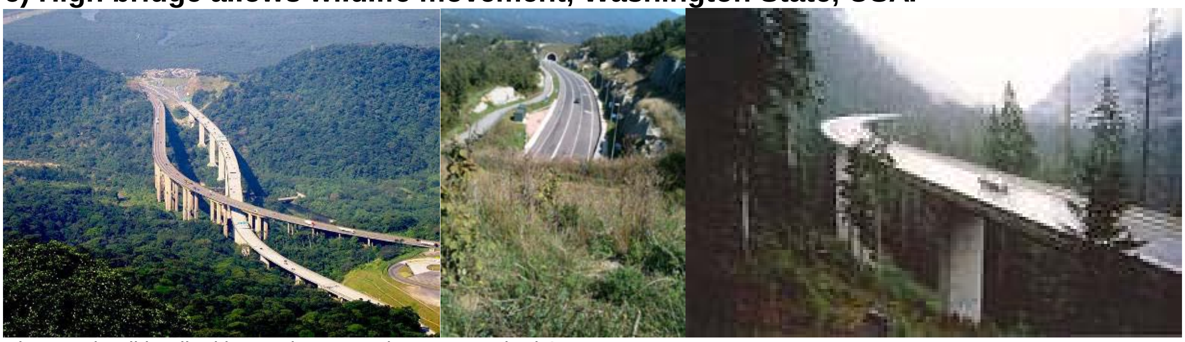
However, even though all these considerations may be taken into account, success can never be assured due to animal behaviour. For example, in Tasmania, purpose-built platypus culverts were ignored and high levels of roadkill continued (Magnus *et al.* 2004). Specialist species may also be more difficult to encourage; generalists such as bandicoots and rats tend to be frequent users (Taylor and Goldingay 2003; Magnus *et al*. 2004; Goosem *et al.* 2006). Prey funnelling has often been considered a disadvantage of crossing structures, but thus far has not been observed for a variety of structures in the Wet Tropics (Goosem *et al.* 2006; Weston *et al*. 2011), although occasionally observed elsewhere (Hunt *et al.* 1987).

5.3.2.4.4 Long Bridges (Viaducts) and Tunnels

Long bridges or viaducts that elevate roadways and road tunnels (Figure 5.19) under the landscape are defined by Huijser and McGowen (2010) as structures that are at least several hundred metres long, sometimes many kilometres. Although very expensive, these are now common among recent European road projects. Long bridges are often built above a floodplain or wetland as they maintain hydrological flows and the biological diversity of riparian habitats, leaving the landscape under the roadway intact. Long tunnels have little or no effect on the landscape above the road. The large span and clearance of viaducts (Figure 5.19a,c) allows movements by a wide range of wildlife, helping to keep habitat largely intact by keeping construction zone largely to the base of the pillar (Clevenger and Ford 2010; Jones 2010).Tunnels may be constructed by cutting through a hill (Figure 5.19b), covering with a roof and then revegetating above the roof or may simply be drilled through the terrain. Bridges have also been designed to sit just above the terrain to avoid disturbing the landscape and allow movements underneath. These were incorporated in the design when planning for upgrade of the Kuranda Range road behind Cairns (Goosem *et al.* 2004). All of these types of structures have been constructed to avoid ecologically sensitive areas, particularly river and creek bank. They generally also form part of the design to minimise the road grade, which has attendant benefits in transportation costs in terms of fuel and time (Jones 2010).

Unfortunately, the potential for these strategies in the ***Mission Beach area*** are limited by the extremely high cost relative to the relatively low traffic volumes carried. However, there is no doubt that, provided construction minimised habitat disturbance, these types of structures would function effectively to allow movements of ***cassowaries****.* Possibilities during road upgrades in the long-term include the Bruce Highway at Smiths Gap with its much larger traffic loads, possibly Fenby Gap and/or elevating sections of the major entry roads to heights of at least 3-4 m to provide connectivity underneath (Chenoweth 2008). For example, this might be feasible in the future in areas of the El Arish-Mission Beach Road where there are many small dips and rises. The viaduct being constructed across the Cardwell Range at ***Cardwell Gap*** as part of the Bruce Highway upgrade will provide connectivity for cassowaries (Figure 5.20).

Figure 5.19 Long bridges and tunnels
a) Highway over rainforest near Sao Paolo, Brazil
b) Tunnels for the road in Catalonia, Spain
c) High bridge allows wildlife movement, Washington State, USA.



Photos: a) Wikipedia b) Darryl Jones c) FHWA, United States

Figure 5.20 When completed the viaduct at Cardwell Range will provide connectivity for cassowaries

Photo: QTMR 2011

5.3.2.4.5 Landscape Bridges

Landscape bridges are the largest type of wildlife overpass. Clevenger and Ford (2010) define landscape bridges as generally more than 100 m wide. This width allows restoration of habitats on the top of the bridge over the road. This results in complete habitat continuity across the road for a wide range of wildlife from small mammals, reptiles, birds and amphibians to large animals. Animals with small home ranges and low mobility may even reside in the habitat over the road. These large structures are relatively unusual worldwide. However, wildlife overpasses of lesser width are very common in Europe and becoming more common in North America.

5.3.2.4.6 Wildlife Overpasses

Wildlife overpasses are generally 50-70 m wide, although some are narrower (Clevenger and Ford 2010). Structures should be placed to accommodate the natural movement patterns of target species. Although landscape topography and land use patterns may influence exact location (Jones 2010), ease of construction and human demands for multi-use structures should not override ecological function. This mistake has been made in the siting of a multi-use overpass in Brisbane (pers. obs.). Although overpasses have traditionally been built for large mammals, small and medium-sized fauna will also use them, provided habitat reconstruction occurs on the bridge (Clevenger and Ford 2010).

Figure 5.21 Overpasses in Europe: a) Austrian regrowth forest agricultural landscape b) Surface habitat, well-established overpass in the Netherlands (Jones 2010)

Photos: a) Fabrice Ottburg (from Jones 2010) b) Darryl Jones

Figure 5.22 Overpasses in North America
a) Red Earth overpass (50m wide x 70m long) in Banff National Park, Canada
b) Overpass in Banff National Park, Canada
c) Example from Deer-Vehicle Crash Information and Research Centre

Photo: a) Tony Clevenger b) CPAWS 2004 (Canada) c) Deer-vehicle crash information & research centre

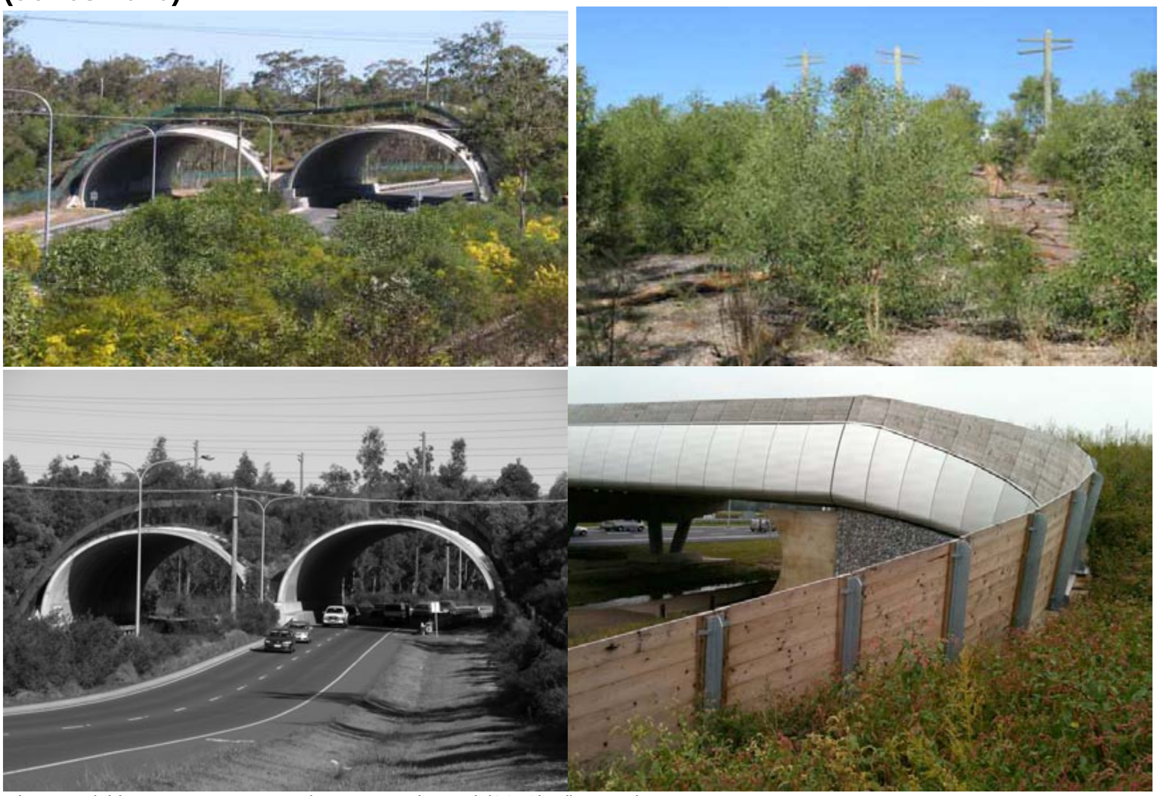
Pfister *et al.* (1997) determined that structures at least 60 m wide were more effective than narrower structures, especially for larger mammals. Anything less than 20 m wide is discouraged (Jones 2010), because of the likelihood of disturbance of wildlife by traffic noise and light. Widths of 60 m also allow animals to escape if necessary, and provide space to include fencing across the overpass to prevent any access to the road, as well as noise and light barriers and habitat features including vegetation and tree roots to provide habitat structural complexity (Figure 5.21). Treatments on overpasses include soil depth from 0.5-2.0 m, allowing for the growth of herbaceous vegetation, shrubs and small trees, including plant species that attract the target species. Some also include small ponds fed by rainwater to provide a water source and attract amphibians (Liu and Zhao 2003). Habitat plantings are also used at many overpasses in North America, although this is not invariably the case for these structures which often target large migratory mammals (Figure 5.22). At Compton Road in Brisbane, habitat plantings on the overpass include shrubs and trees (Figure 5.23).

Clevenger and Waltho (2000, 2005) and Clevenger *et al*. (2002) provide details of monitoring of overpasses constructed near Banff, Canada. Using track plates, cameras and hair sampling techniques, thousands of animal crossings have been recorded including elk, mule deer, moose, grizzly bear, black bear and puma. Some species (wolves, grizzly bears) require up to 5 years for habituation to the structures before commonly using them.

Clevenger and Ford (2010) state that wildlife overpasses should not include roads and should not be open to the public because that will hinder use by wildlife. The alternative is smaller multiuse overpasses which they believe may be adequate for some large mammals but that not all species will use them because of frequent human use and activity. Generalist species common in human-dominated environments are frequent users of such structures. The multiuse overpasses tend to be narrower (10 – 25 m wide) (Clevenger and Ford 2010). Edgar van der Grift (pers. comm.) has found evidence for use of multi-use overpasses in the Netherlands by a variety of wildlife species.

Bond and Jones (2008) found evidence for use of the Compton Road overpass in Brisbane by a variety of macropods and rodents, More recently, small birds that suffer the barrier effects of roads have also been observed in the dense vegetation (Figure 5.21) planted on the overpass (Jones and Bond 2010). It is believed that small reptiles are also present. Arboreal mammals also use the glider poles also situated on the overpass (Goldingay *et al*. 2011). However, entrances to structures such as the one at Compton Road, Brisbane may require habitat clearing if built on level ground.

Figure 5.23 Compton Road overpass, Brisbane a) 2005 b) close up of plantings 2005 c) 2010 d) wooden fence – noise and headlight barrier, overpass, the Netherlands (Jones 2010)



Photos: a) b) Lee-Ann Veage c) Jones and Bond (2010) d) Darryl Jones

Wildlife overpasses are also an expensive type of crossing structure. So again the potential to implement them within the Mission Beach area may be limited by cost factors. However, recent innovations in Europe and North America include bridges made of recycled fibre-reinforced polymer composites (plastic), which have been constructed and are used by vehicles, cyclists and pedestrians (Huijser *et al*. 2010b). Plastic bridges can be lighter and stronger than concrete bridges, have much less carbon output than steel and concrete, require less maintenance and have greater longevity and quicker installation as they can be assembled elsewhere. They also can be much more transportable, being modular, allowing adaptation if animals no longer use an area (Huijser *et al.* 2010). Such innovations may result in less expensive overpasses becoming feasible for roads carrying less traffic.

No overpass structure has been built in Far North Queensland, and so their use by ***cassowaries*** is untested. However, if sited properly, and with appropriate traffic noise and headlight barriers along the structure above the road and habitat features such as food shrubs planted along them, it appears likely that they may be used. However, this would require appropriate exclusion fencing to prevent birds accessing the road nearby in other ways. This cannot be the usual wire fencing due to likely damage to birds, but must incorporate shadecloth or wooden fences that also act as noise and light barriers.

Potential sites for these types of structures are similar to those for landscape bridges. Any upgrade of the Bruce Highway at Smiths Gap should consider including at least one of these structures (Chapter 6). Other options include Fenby Gap and areas along the major entry roads where clearings are already wide (to avoid habitat clearing during construction).

5.3.2.4.7 Underpasses for Large Animals

Underpasses are defined as 'a crossing structure allowing animals to pass under traffic' and can be further categorised into 'bridges' and 'culverts' (Wildlife Crossings Toolkit, USDA 2005; van der Ree *et al.* 2007). Clevenger and Ford (2010) say that these are the largest and most common crossing structures designed for wildlife movement. Their use will depend on adaptation to the requirements of the particular target species or group. They are often incorporated to accommodate the dual needs of water flow and wildlife movement, and are then associated with rivers and creeks (riparian habitats). They take the form of bridges over the area where wildlife can move (Figure 5.24). However, instead of just forming a bridge over the stream, they also provide sufficient space and habitat to encourage wildlife movement. A vegetated strip of land provides cover for animal movements (Huijser *et al.* 2007). Many species will use these structures, particularly if sufficient cover is provided for small mammals, reptiles and amphibians by revegetation of habitat and inclusion of logs, rocks and brush. These structures should be situated in areas where habitat is continuous on either side of the road, or the riparian zone itself forms a corridor between continuous habitats. Large animals are more likely to use underpasses if they are of appropriate large size for the animal (Holschuh and Otter 2000) and the animal can easily discern habitat on the other side of the passage (Foster and Humphrey 1995; Goosem *et al.* 2001). Minimal human disturbance should be a feature (Clevenger and Ford 2010). Underpass use is greatest when the underpass is situated in traditional movement trails (Foster and Humphrey 1995; Sielecki 2005).

Underpasses have proven highly successful for ungulates and carnivores in North America (Foster and Humphrey 1995; Clevenger *et al.* 2002; Forman *et al.* 2003; Hardy *et al.* 2006). Jones (2010) found that in Europe, technical standards documents for wildlife underpasses and culverts were freely available and contain very detailed specifications on size, shape, internal features and placement for the species likely to use the structures in Europe. They are generally adaptations of structures used routinely for carrying water through or under the road. Rubble left after construction, broken brick, large stones, edges of concrete slabs or bare concrete tend to discourage use by smaller species. Dry areas for passage, easy access and vegetation around entrances is also considered important in Europe, together with exclusion fencing to guide animals directly to the entrance of the structure (Jones 2010).

Figure 5.24 Wildlife Underpasses a) Chino Hills, California b) Vancouver Island Highway, Canada

Photo: a) From Wildlife and Roads (2005). The original box culvert at this site was removed and a bridge installed to create an effective passage for bobcat and coyote. b) from Sielecki (2005)

The ***North Hull River bridge*** is a "multi-span bridge' with intermediate support columns between abutments (USDA 2005). During upgrade of the Tully-Mission Beach Road it was revegetated along the banks under the bridge (Moore and Moore 1998) and has proven quite successful for ***cassowary*** movement (Chapter 3). However it should still be remembered that ***cassowaries*** still cross the road surface not far from the bridge, rather than search out the bridge crossing. To ensure greater use of the structure, exclusion fencing of the type described in Section 5.3.2.3. However, including exclusion fencing would bring attendant problems in the form of fence maintenance and potential for trapping birds on the road surface or possibly providing opportunities for domestic and wild dogs to target crossing birds. Although there may also be concerns with unavoidable antagonistic encounters between birds, these problems would require further research with trials. However, experience shows that neither antagonistic encounters or predation at underpasses has not proven a problem with the majority of species, including solitary species. Instead, individuals tend to time their movements to avoid others (Foster and Humphrey 1995; Clevenger *et al.* 2002).

Figure 5.25 Passage under the North Hull River bridge, showing revegetation with food plants to encourage cassowary movements

Photo: Les Moore

Similarly, although crossings are rare, cassowaries have been known to cross under the Bruce Highway at Lagoon South bridge (Figure 5.26; Tully Alliance, pers. comm.). Cassowary traces have also been recorded under the Maria Creek bridge on the Bruce Highway near Smith's Gap (Les Moore, pers. obs.).

Figure 5.26 Cassowary family party crossing Bruce Highway at Lagoon South bridge

Photos: Tully Alliance (2008, 2009).

Including more ***bridges*** similar to the North Hull River bridge would provide further opportunities for cassowaries to move across the major entry roads to Mission Beach without risk of road mortality. These should be one of the options considered during road upgrades ***at larger stream crossings*** such as at Lacey's Creek, Stoney Creek, Maria Creek, Wongaling Creek and other larger creeks. The Maria Creek bridge at the Bruce Highway near Smith's Gap could also provide greater connectivity under the highway for birds and the potential for increasing the span and/or height of this bridge should also be given consideration in highway upgrades.

5.3.2.4.8 Culverts

Culverts are defined as 'a conduit covered with embankment around the entire perimeter' which 'may or may not convey water' (USDA 2005). They may be purposely designed for faunal movements or modified to allow water flow and faunal passage. Culverts are widely used in North America and Europe to allow connectivity under the road for smaller wildlife and can vary from large box (Figure 5.28) and arch culverts (Figure 5.27) through to small pipe tunnels designed to allow amphibian movements. Adapting drainage culverts for wildlife use is an easy and cost-effective means of providing connectivity, but must not impede the water-carrying function, so ledges of various types have been included (Figure 5.27b)

Similar to underpasses, there is a need to integrate several factors into culvert design such as corridors in the form of continuous habitat leading to the structures (Figure 5.28) including food plants to entice fauna, inclusion of furniture within underpasses, provision of dry and wet pathways for different species groups and differences in culvert size required by different species groups (Forman *et al*. 2003; Goosem 2003; Goosem *et al.* 2006; Jones 2010). Vegetation requirements also differ between species. For example, most macropods prefer simple vegetation structure while many rainforest species prefer a more complex vegetation. Research shows that the further away vegetation is from the underpass, the more likely use is decreased (Goosem *et al*. 2006). On the other hand, excessive vegetation which hinders external or internal views of apertures can decrease use of underpasses by open habitat species (Forman *et al.* 2003; Barnes 2007). Vegetation can also assist in limiting penetration of noise and headlight glare, both of which may reduce underpass use (Goosem *et al.* 2006). Relatively flat and natural surfaces (soil, leaf litter or mulch) are preferred by smaller species (Jones 2010).

Figure 5.27 Arch culverts for carrying low water flows and wildlife passage
a) designed for roe deer in southern France
b) modified to include ledges to encourage small species to cross via a dry passage.

Photos: Darryl Jones

Figure 5.28 Large multiple box culvert, Spain. Natural vegetation continues to entrance encourages use by a variety of mammals (Jones 2010).

Photo: Darryl Jones

Culvert use can be encouraged, habituation time decreased and use increased by the provision of furniture (Figure 5.29) which includes leaf litter, soil and rocks (Goosem *et al.* 2001, 2005; Bond and Jones 2008). Goosem and Weston (2002) described successful furniture at a particular site that included escape poles for climbing animals to avoid ground predators and rocks and logs to provide connectivity, refuge and dry passage for small mammals, amphibians and reptiles (Goosem *et al.* 2004). Provision of dry passage is important because many underpasses serve a dual purpose, acting simultaneously as water channels and crossing structures. Dry passage can be ensured by using pipes and culverts at varying heights (Barnes 2007), ledges and logs within culverts. Underpasses need to provide dry and wet passage throughout all seasons to encourage use by all species groups (Goosem *et al.* 2004; QDMR 2004; Barnes 2007; Swanson and Hershfeld 2007) and prevent terrestrial fauna from crossing over the road surface when underpasses are wet, thereby increasing roadkill rate (Baker *et al.* 2004).

Figure 5.29 Furniture including logs, brush, escape poles, rocks and ropes in East Evelyn culvert underpass, Atherton Tablelands (Goosem *et al.* 2001).

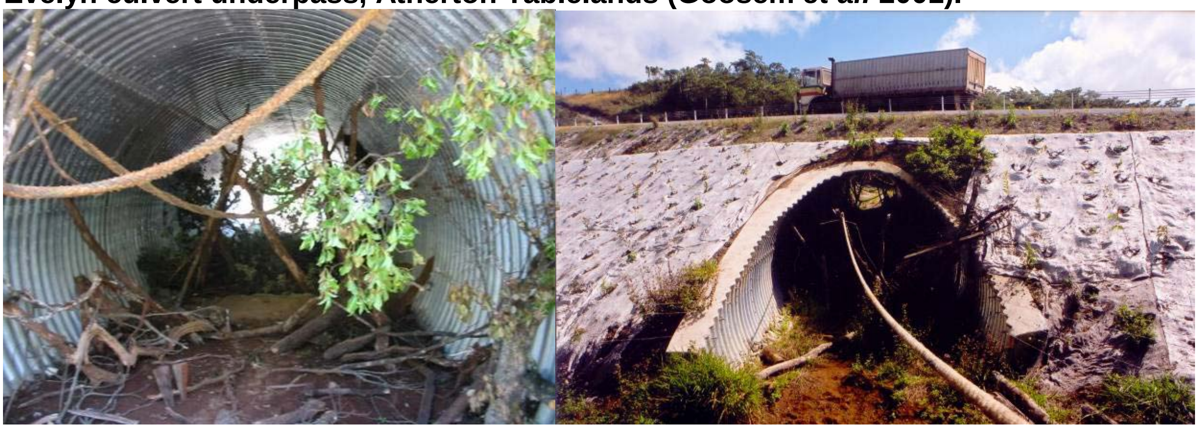


Photo: a) Miriam Goosem b) Jonathon Munro

Culvert efficacy is also affected by size. In general, wildlife use of culverts increases with an increase in structural dimensions (Goosem *et al.* 2001). Structures with greatest use have heights at least equal to their width and apertures that allow unobstructed view of habitat (Goosem and Weston 2002). However, size needs to be considered in terms of local fauna and targeted species. For example, small mammals tend to use smaller underpasses although furniture, vegetation and shelving in large underpasses may encourage their use (Bond and Jones 2008). The East Evelyn culvert underpasses (Figure 5.29) were targeted at Lumholtz's tree-kangaroo and cassowaries. Although at one stage, a cassowary appeared interested in using one of the underpasses, there is no evidence that any cassowary has used them (Goosem *et al.* 2006). This lack of use could be affected by the low population levels currently in the area.

The culverts at Lacey Creek and Stoney Creek (Figure 5.29) are 'box culverts' as they have 'four sides, including bottom' (USDA 2005). Stoney Creek culvert was retro-fitted with a ledge, together with sand track areas for monitoring and (at one stage) a camera, which unfortunately was not reliable. There has been evidence in the form of tracks in 2006 and a dropping that a ***cassowary*** or a family party has used the Stoney Creek culvert on at least one or two occasions in the past (DERM personnel, pers. comm.). However, monitoring undertaken in this study (Chapter 3) found no evidence that any individuals were using the culvert, so it appears that use is extremely occasional and is not occurring at all currently. Similarly there is one record of a family party approaching the Lacey Creek culverts but not crossing (DERM personnel, pers. comm.). Again, monitoring of that structure found no evidence of cassowary use (Chapter 3). There is also evidence that a family party crossed under the Bruce Highway in a 2 metre high culvert near Lagoon Creek (Tully Alliance, pers. comm.). However, again the family party appeared to prefer crossing at a higher bridge structure (Figure 5.26), as the larger structure was used multiple times. Therefore, it appears that even larger box culverts do not provide ideal conditions for cassowary crossings and are very seldom used, but that larger structures such as bridges are far more favourable options in terms of cassowary crossing opportunities.

Figure 5.29 a) Lacey Creek multiple box culvert
b) Stoney Creek box culvert with ledge

Photo: a) Les Moore b) Peter Byrnes

5.4 MONITORING AND MAINTENANCE- NECESSITIES

Monitoring is the only way to demonstrate whether mitigation measures are proving effective and should always form a funded component of any project (Goosem 2008; Clevenger and Ford 2010; Jones 2010). Mitigation is costly and an important investment of public funds, so monitoring to determine whether structures are effective is important and can save funds in the future (Clevenger and Ford 2010). For ***cassowaries i***n particular, where information regarding mitigation measures are limited to our recent monitoring of culvert underpasses (ineffective), high bridges (effective) and psychological traffic calming measures (ineffective overall), a great deal of further information is required. Even in Europe and Canada, where sufficient information has been gained about crossing structures to demonstrate that the majority of target species use them, there is still little information regarding effectiveness at population and genetic levels (van der Ree *et al*. 2010). At the least, monitoring of animal movements and road mortality is necessary before the mitigation measure is installed to provide baseline information, as well as monitoring afterwards to determine whether the goals have been achieved (e.g. actual speed limit is reduced; crossing structure is used; family parties, males, females are using and breeding is occurring; road mortality in the area is reduced). When coupled with monitoring of a site where the measure has not been installed to examine yearly and seasonal variability, effectiveness of the measure can be demonstrated.

Monitoring programs for ecological effectiveness need to:

1) Establish baseline data about road mortality and movements of animals, and, preferably, population structure and genetic diversity;
2) Evaluate the effectiveness of measures and structures by monitoring mortality and movements: for example:
    - establishing whether structures are commonly used;
    - establishing use by all sections of the population;
    - establishing degree of mortality post-implementation;
    - preferably examining population structure and genetic diversity.
3) Implement any changes to design if measures are ineffective.
4) Report and publicise the effectiveness of the measures and the results of the monitoring program.

Long-term monitoring programs can be expensive and time-consuming (Lee *et al.* 2010). However, by designing the program so that volunteers from the community can undertake sections of the data collection, costs can be reduced substantially. Successful models have been developed in many areas where community members:

- Collect data, together with GPS locations of animal movements; or
- Submit data through an interactive Web-based mapping tool; or
- Report through a telephone hotline;

to a local project coordinator. The web-based mapping tool can use open-source free software that allows community participants to add their data directly to an airphoto-based layer and then use a pop-up tool to enter date, species, time of day, and other information such as age class etc. Alternatively or additionally, a systematic wildlife driving survey can be included that will provide information on species presence but also absence on a defined section of road that participants regularly drive. They enter start and end times and commit to recording data from driving that section of road twice a week (Lee *et al*. 2010). This type of community monitoring has proven very useful in a Canadian study. The value of this type of information for collection of data about mammals has been demonstrated in a study which compared professional scientist data with community data (Newman *et al.* 2003). Community data has been used to examine Lumholtz's Tree-kangaroo sightings and road mortality hotspots on the Tablelands (Izumi 2001; Kanowski *et al.* 2001). The C4 community ***cassowary*** sightings database provides a similar resource (Chapter 2), although more systematic recording of data and determination of locations, such as is currently occurring, could improve its application (Chapter 1). Particularly the inclusion of assigned road sections monitored twice weekly would greatly increase its value. Huijser et al. (2010b) suggest that mobile phones with integrated GPS can be equipped with software to record and transmit animal sightings and mortality data in real time. More complex data such as those for water quality assessments, have also be successfully collected by citizens, provided the techniques used do not require extensive training and interpretation (Nicholson *et al.* 2002).

Volunteers in Mission Beach could also be involved in monitoring of easily collected data from crossing structures, including cassowary droppings and track information, provided the disturbance to the crossing structure was kept to a minimum, due to the potential of human presence reducing attempts to access structures. This may require assigning monitoring of a structure to one to several community members who could ensure data was collected twice a week, complementing each other so that one person commits to monitoring once a week. Likewise, maintenance of structures must be funded over the lifetime of the mitigation measure. Experience in Far North Queensland has shown that structures such as purpose-designed culverts can be installed, but then when they need maintenance, the funding has not been available and the structures have remained in poor repair for long periods of time (Goosem *et al.* 2008).

5.5 CONCLUSIONS

The first and most important means of mitigating road impacts is by avoiding sensitive ecosystems. However this can only happen during road construction or upgrades and is not applicable to current roads. Secondly, habitat loss, weed invasions and edge effects can be reduced by minimising the width of clearing between forest edges to the narrowest that will satisfy safety concerns. However this strategy is unlikely to reduce road mortality.

5.5.1 Changing Cassowary Behaviour

5.5.1.1 Crossing Structures and Exclusion Fencing

The conclusions from overseas studies are that long bridges and tunnels, and wildlife fencing in combination with overpasses and underpasses or with animal detection systems are the most effective measures to substantially reduce collisions with large mammals and improve habitat connectivity for these species (Clevenger and Ford 2010; Huijser and McGowen 2010; Jones 2010). There is ample evidence to support the reduction of mortality of large mammals when wildlife fencing and underpasses or overpasses are installed. Animal detection systems do not have this body of evidence in support, so Huijser and McGowen (2010) contend that they are still experimental and further evidence is required. They also allow the animals to cross the road surface, so there is always likely to be mortality to some degree. Also, for a species where crossing locations cannot be pinpointed to within 100-200 metres along a relatively straight stretch of road, animal detection systems are unlikely to prove successful. No information about mortality and connectivity for large birds is available other than what is known about cassowaries from this study and anecdotal evidence.

Unfortunately, for cassowaries the structures that are proven or likely to encourage crossings and thereby reduce road collisions tend to be expensive. These include high bridges at stream crossings that allow growth of attractive vegetation underneath and at entrances. Relatively large vegetated overpasses with natural surfaces would also provide a likely crossing route. Long bridges, tunnels and viaducts would also be expected to register success as they retain habitat away from the road surface. Culverts have not been shown to be effective overall, although very occasionally used, probably because the road surface provides a quicker and more easily accessed crossing option and culverts are closer to the road surface than higher bridges. Overall, it appears likely that, like other solitary species using crossing structures, individuals would time their crossings to avoid each other and potential antagonistic encounters, so these should not be a large problem. Similarly, there is little evidence of predators using crossing structures as prey traps in North Queensland; however monitoring would be necessary to ensure that dogs were not a problem around structures. Crossings under bridges recorded thus far do not suggest that this is a likely scenario.

Numbers of crossings at underpasses, overpasses and possibly large culverts could be increased by exclusion fencing which directs cassowaries to the structures. However, fencing in a cyclone-prone and highly vegetated area incurs a variety of difficulties in maintenance to prevent gaps occurring and the possibility of birds becoming trapped on the road surface. Therefore means of escape in the form of returns would need to be provided should fencing be employed. The fence could not use the relatively cheap option of wire mesh because birds could damage themselves, but must ensure the birds cannot see across the road to the habitat except where underpasses and overpasses provide a crossing route. Shadecloth or other fencing that cannot be seen through is likely to be effective. Further trials with fencing are urgently required, should this option be undertaken.

Careful consideration concerning location and spacing of crossing structures would be required taking into account:

- Road mortality hotspots in the DERM cassowary road mortality database;
- Road crossing hotspots derived from the C4 visitor and local sightings database;
- Habitat linkage mapping;
- Topography, land tenure and human use;
- Landscape scale regional corridor networks (without dead-ends);
- Movement and home range data derived from other sources – experts, local community.

The option most likely to reduce road mortality would be to elevate the roads above the habitat, as has become more common in Europe, thereby removing the risk from the birds. This may be possible for sections of road where there are many small dips and rises. However the expense is likely to limit such a strategy.

5.5.1.2 Reducing Cassowary Visits to the Roadside

One means of reducing attractiveness of the roadside would be to remove fruit-bearing trees at the road edge. However, it is unlikely that this would reduce crossings substantially because there is still a requirement to access habitat on either side of the roads. It may also remove important seasonal food sources, so is not recommended overall. A more important strategy is to ensure that fruit farms do not have readily available fruit either on the ground or easily within reach that encourages crossings by the birds. Intercept feeding is not feasible in normal weather circumstances and may lead to dependence. Removal of small animal roadkill would reduce the potential for scavenging for this protein source but is also not feasible in the long term.

There appears to be no satisfactory means of scaring cassowaries from the roadside. None of the techniques that have been trialled overseas appear at all likely to succeed. These include light reflectors and mirrors (not effective for a diurnal species); whistles and audio scarers (no evidence of behavioural effects after a few days habituation); olfactory repellents (no effect on some species, need continuous replacement); and chasing animals (inhumane).

5.5.2 Changing Driver Behaviour

5.5.2.1 Reducing Vehicle Speed

There is evidence that reduction in speed of vehicles allows both wildlife and driver more time to avoid a collision. However, reduction of legislated speed limits must be accompanied by reductions in road design speed through the incorporation of constructed traffic calming structures (rather than psychological means) to influence the amount and severity of collisions. Otherwise, drivers will continue to move at the speed that appears safe from the design of the road. Structures that can achieve this end include:

- Chicanes and curved divided roads with planted centre islands;
- Roundabouts at intersections;
- Speed humps.

Chicanes and divided curved roads are commonly used in urban areas to ensure reduced speeds. Speed humps on council-controlled roads appear very successful in the Daintree lowlands in reducing speeds and cassowary deaths are much fewer than at Mission Beach. Roundabouts have been incorporated in higher design speed roads such as the Cook Highway in Cairns and can be effective provided safety concerns are adequately addressed.

It would also be expected that continual monitoring of speeds in a reduced legislated speed limit zone would have a similar effect in reducing number and severity of collisions. Such an opportunity arises with speed cameras or permanently visible signs that are activated by speeding vehicles to provide information regarding speed. Overall, enforcement of legislated speed limits must also be considered a cornerstone of ensuring that reduced speed limits are implemented effectively.

Psychological traffic calming in the form of road markings that aim to reduce the apparent width of road lanes or warn of a hazard has been trialled at Mission Beach without apparent success. Similarly rumble strips do not appear to be successful, unless included with constructed traffic calming or legislated speed limits and reduced road design speed.

Evidence suggests that passive signage and public information and education alone are unlikely to reduce traffic speed to any great extent. The first is unlikely to be successful because drivers become habituated to signs. The second does not appear to reduce speeds because driver education cannot predict when a hazardous situation will occur, so requiring a driver to be vigilant over a prolonged period. However, signage and public education programs play a valuable role in raising awareness of the problem, advising of current crossing locations, and increasing support for more expensive mitigation strategies. Highlighting recent cassowary death locations is an approach that could be trialled. Passive signs of unusual design that attract attention, such as the large cassowary collision signs, may alert drivers who do not travel the road regularly, so may be of some assistance in reducing speeds but overall reductions may not be significant if regular travellers form the major proportion of traffic volume.

Temporary signs that are only put in place when crossings are observed provide a much more specific warning signal to drivers and tend to have at least some effect in reducing driver speeds, particularly if drivers understand there is a hazard to themselves. These tend to be more effective if equipped with flashing lights or if they present active messages. Such signs need to be moved once there are no reports of crossings within a specific time frame. Permanently visible signs in fixed locations with active messages (variable message signs) also can result in significant reductions in vehicle speed if the messages are only illuminated when crossings have been recorded and otherwise remain switched off. Alternatively, moving a variable message sign on a trailer to areas of current crossings is likely to have some effect in reducing traffic speeds (and thus mortality).

5.5.2.2 Vegetation Clearing

Although wide road clearings may have some effect in reducing mortality in species such as deer and moose that are attracted to the roadside vegetation to forage on shrubs, it also increases mortality in species such as kangaroos and wallabies that are attracted to the roadside to forage on the low grassy vegetation left after clearing. For cassowaries there appears to be no advantage in wide clearings – although it has the potential to improve visibility along the roadside for drivers, this appears to be negated by the higher speeds driven along roads with wider clearings. Cassowaries are killed on areas of the Tully-Mission Beach road with wider clearings, and also on the El Arish-Mission Beach Road where visibility is affected more by curves, dips and crests than vegetation along the roadside. Wider clearings also result in greater loss of cassowary habitat, greater edge effects and longer distances to cross in stressful conditions away from habitat cover.

5.5.3 Integrated Strategy to Reduce Cassowary Mortality

An integrated strategy would include a variety of these measures, appropriately located, maintained and enforced where required, together with a monitoring programme to determine their effectiveness.

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MISSION BEACH ROAD IMPACTS ON CASSOWARIES AND OTHER VERTEBRATES

SECTION 6:

ROAD SECTIONS, CONNECTIVITY, CROSSINGS AND MITIGATION OPTIONS

6: ROAD SECTIONS, CONNECTIVITY, CROSSINGS AND MITIGATION OPTIONS

Leslie Moore and Miriam Goosem

Summary.

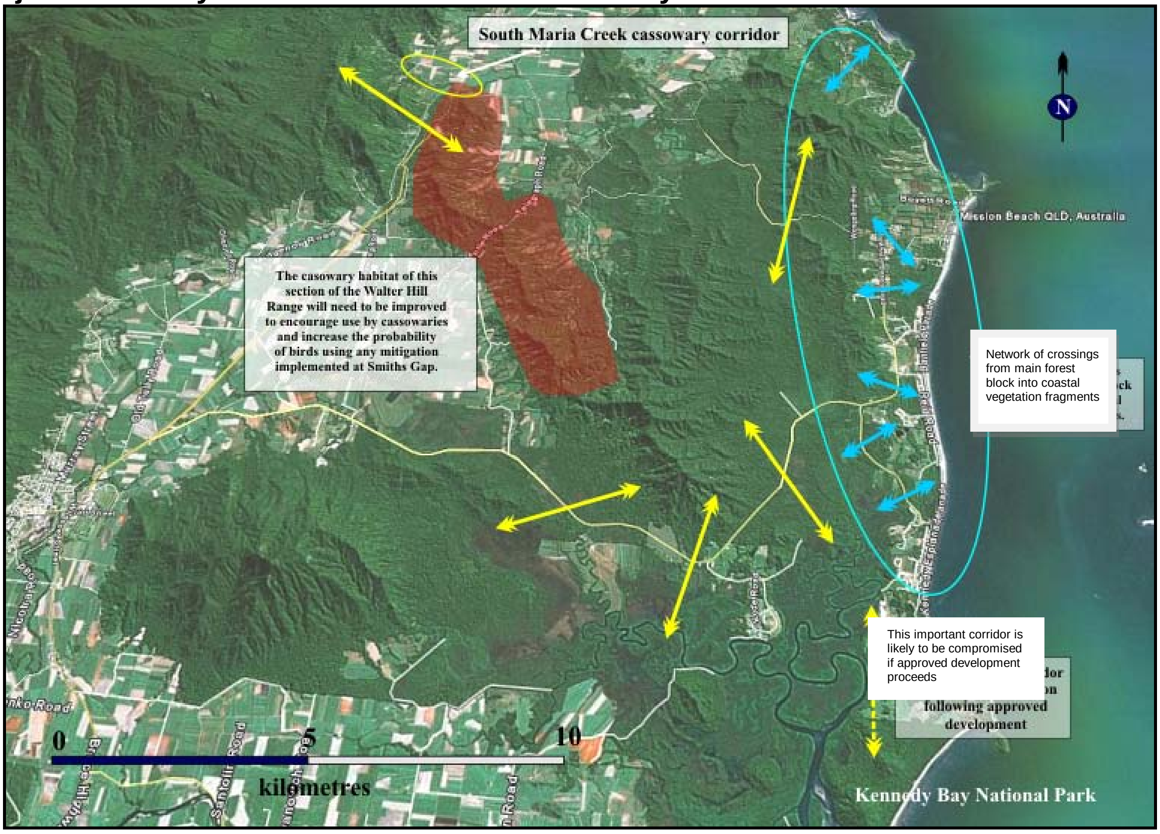
This chapter summarises the major road sections, general road crossing hotspots and potential mitigation measures that could be used at each site. The tables address each of the nine road sections discussed in Chapter 2. In many cases, application of mitigation measures to the complete road section may be the most appropriate approach, particularly in areas where road mortality is high, numbers of crossings are also high, and birds tend to cross in many areas or anywhere along the road segment. These include the major rainforested sections of the El Arish-Mission Beach Road, Tully-Mission Beach Road and South Mission Beach Road, together with Garners Beach Road. However, in these tables we also provide information about individual crossing zones, noting that in several road sections these are not discrete entities. A risk-based and ecological benefit analysis should be undertaken to determine the highest priority crossing zones and the most effective techniques to employ over particular road sections or individual road crossing zones. It is essential that consultation with all relevant stakeholders should form part of this assessment, including QTMR, CCRC, DIP, WTMA, EPA, SEWPAC, JCU, Terrain NRM, CSIRO, Traditional Owners, C4 and the local community. The next chapter describes potential options that should be considered by all stakeholders in an integrated road management strategy.

Brief comments on each crossing area are provided including identified threats and a range of mitigation techniques which may be appropriate at that site. Current risks were identified by personal observation (L. Moore). Information from the EPA Cassowary Road Mortality database and the C4 Cassowary Sightings database has been incorporated where appropriate, however, it should be noted that certain roads (e.g. Bingil Bay Road, Garners Beach Road, South Mission Beach Road) are likely to be driven less often by Mission Beach visitors than the main entry roads, so crossings and roadside sightings on those roads are likely to be less frequent in the visitor database.

6.1 INTRODUCTION

As we have seen in previous chapters, roads and highways have the potential to undermine ecological process through the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow and metapopulation dynamics (Lui and Zhao 2003). Many species of wildlife require large undisturbed tracts of land in order to meet their food; cover and reproduction needs and population sizes may drop below sustainable levels if these requirements are not met (Gibeau *et. al.* 1994). Large species like the cassowary are particularly affected due to their considerable home range sizes. The major cassowary movement areas that are bisected by roads at Mission Beach are indicated in Figure 6.1. They were compiled by Les Moore after consideration of movements (including road crossings and birds observed over many years), in conjunction with the major areas of cassowary habitat remaining. The yellow arrows represent critical movement areas which must be maintained as they are essential to the healthy functioning of the Mission Beach cassowary population (Moore 2003). They include crossing areas along the El Arish – Mission Beach and Tully – Mission Beach Roads and the Bruce Highway. These movement corridors are comprised of a varying number of cassowary road crossing zones which are identified and discussed in Chapter 2.

Figure 6.1
Major cassowary movement corridors bisected by roads at Mission Beach

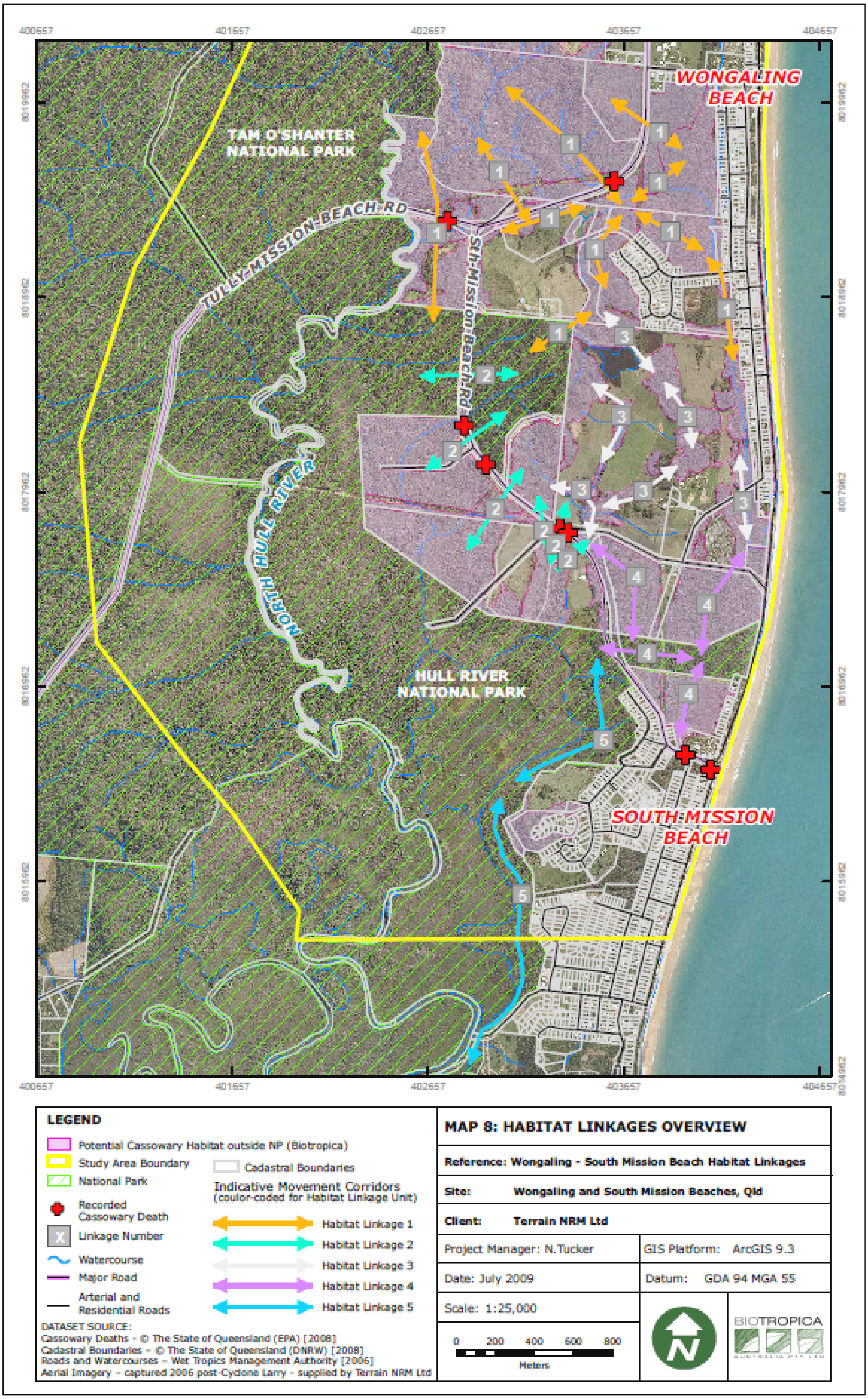


The blue arrows on Figure 6.1 represent an overview of permanent and ephemeral areas of movement across roads which allow cassowaries to access remnant coastal vegetation at Garners Beach, Bingil Bay, Cassowary Drive, and South Mission Beach Road. These crossings have a high local profile and crossing cassowaries are sighted regularly throughout the year. Unfortunately, from a management perspective cassowary use of these crossings could be problematic, not only from the increased risk of vehicle collisions, but also because birds are led further into urban areas where the potential for hand-feeding and dog attack is increased. Most of the vegetation on either side of these coastal roads is on freehold land, considerably reducing management options. The locations of many of these coastal cassowary movement corridors were mapped (by Les Moore) and provided to Terrain NRM to assist Biotropica Pty Ltd (2008; 2009) in preparation of reports concerning habitat linkages in the Wongaling Creek catchment and in the area of Wongaling Beach to South Mission Beach. The suggested habitat linkages were refined, checked and mapped in much greater detail during the Biotropica studies and overview maps are shown in Figures 6.2 and 6.3 taken from the Biotropica reports. The areas of Clump Point, Bingil Bay and Garners Beach have not been mapped in such detail.

Much of the coastal vegetation utilised by cassowaries is within an urban context. However, more natural areas such as Reserve 214 (R214) east of Cassowary Drive and adjoining Porters Creek may play a vital role in the maintenance of those cassowaries that have traditionally made use of this coastal area. Preventing access to the area could have significant impacts on the individual birds concerned and adversely impact the viability of the local cassowary population. It is appropriate, therefore, to ensure that adequate ecological information is available with which to evaluate the importance of these areas to the long term viability of the Mission Beach cassowary population.

Figure 6.2 Habitat Linkages in the Wongaling Creek catchment. After Biotropica Pty Ltd (2008).

Figure 6.3 Habitat Linkages in the Wongaling – South Mission Beach area. After Biotropica Pty Ltd (2009).



Ecological benefit and risk based analysis can readily form part of the recommended assessment of site-specific mitigation options for most of the crossings identified at Mission Beach. However, in the case of Reserve 214 and the remnant vegetation east of South Mission Beach Road, the following additional information would assist in risk analysis aimed at mitigation decisions:

1. An evaluation of the ecological role of the cassowary in maintaining coastal (and regional) biodiversity within the remnant vegetation at the site;
2. An evaluation of the importance of the vegetation for those cassowaries making use of the habitat;
3. Finally, an analysis of the costs of potential mitigation options in terms of value to cassowaries and habitat – i.e. matching the cost of particular solutions aimed at providing safe cassowary crossing with respect to their benefit both to cassowaries and to the areas of coastal habitat concerned.

6.2 ROAD SECTIONS – CROSSINGS AND BROAD MITIGATION APPROACHES

The cost of mitigating cassowary-vehicle collision will be relatively high, both financially and in terms of community behaviour change. However, the cost of not mitigating such collisions is also extremely high, both for cassowaries and vehicle occupants involved in collisions, and also for the environment if the ecological functions provided by cassowaries are lost.

A range of potential mitigation options are provided for the road sections identified in this report. In many cases, consideration and application of mitigation measures to the complete road section may be the most appropriate approach, particularly in areas where road mortality is high, numbers of crossings are also high, and birds tend to cross in many areas or anywhere along the road segment. However, in these tables we also provide information about individual crossing zones, noting that in several road sections these are not discrete entities. It is recommended that a risk-based and ecological benefit analysis be undertaken to determine the highest priority crossing zones and the most effective techniques to employ over particular road sections or individual road crossing zones. It is essential that consultation with all relevant stakeholders should form part of this assessment, including QTMR, CCRC, DIP, WTMA, EPA, SEWPAC, JCU, Terrain NRM, CSIRO, Traditional Owners, C4 and the local community.

The following tables address each of the nine road sections discussed in Chapter 2 (see Figure 2.7). Individual road sections and the cassowary road crossing zones located along them are shown Figures 6.5 – 6.13. Brief comments on each crossing area are provided including identified threats and a range of mitigation techniques which may be appropriate at that site. Current risks were identified by personal observation. Information from the EPA Cassowary Road Mortality database and the C4 Cassowary Sightings database has been incorporated where appropriate, however, it should be noted that certain roads (e.g. Bingil Bay Road, Garners Beach Road, South Mission Beach Road) are likely to be driven less often by Mission Beach visitors than the main entry roads, so crossings and roadside sightings on those roads are likely to be less frequent in the visitor database. Locals may observe crossings at these zones more often but not report them; similarly locals may not report crossings on the main roads. It is important to note that the recommended stakeholder and researcher risk and benefit analysis may conclude that some road crossing points cannot be mitigated or are best modified to discourage use by cassowaries. An example of such a road crossing is Crossing #13 near James Street on the Bingil Bay to Mission Beach Road. At this location in 2008, a family party crossed the road to feed on fallen fruit from a small number of trees along the foreshore. Both crossings, east and west across the road, occurred in areas of limited visibility. Decisions regarding mitigation options at all sites, but in particular, these difficult sites, will require the combined expertise of stakeholders and consensus amongst them. Local government planning and tenure information will be required to assist in that determination e.g. presence of conservation covenants, Wildlife Crossing Points.

It should be noted that these tables are not an exhaustive list – several crossing areas known to the community (e.g. Pioneer St/Bingil Bay intersection and Cuttle Bay/Wee Beach) have since been indicated to be active, but the authors did not have this information at the time of field study. Chenoweth (2008) suggested a number of mitigation options for the Cassowary Drive section (i.e. section of road between the El Arish – Mission Beach Road and South Mission Beach Road turnoff). The authors provided input to the study but do not incorporate all options suggested in the report from that study in these tables. We recommend that the options from Chenoweth's report for that road section should also be examined in terms of risks and benefits in the stakeholder and researcher consultation, together with all other road crossing areas. One mitigation method to reduce traffic speed has recently been trialled along this road after consultation with stakeholders. Overall, we believe that mitigation options along all the major Mission Beach Roads should be prioritised in the stakeholder consultation with the aim being consensus. However particular consideration should be given to those crossing areas with greatest road mortality and/or observed crossings by birds.

6.2.1 Mitigation Options Considered

In the following tables a variety of mitigation options have been considered. Several are generic and apply to all crossing zones e.g. warning signage or other forms of alert for driver education purposes (e.g. road painting) and temporary passive signage when birds are known to be in the area. Others have been suggested as options for particular areas for discussion in risk management assessments and consultation with stakeholders. Those case-specific options are considered to be viable for the crossing zone described based on its road design characteristics, the importance of the site in terms of road mortality (Figure 2.4), the traffic volume and speed characteristics of the area, and the number of crossings recorded in the area (Chapter 2). For example an option of flashing signage when vehicles approach is suggested for sites where crossings are relatively frequent and which have higher traffic volumes than local streets.

It is not suggested that each of the alternative options should be installed at each crossing zone. The cassowary road management plan must be integrated so that drivers do not become either blasé about, or irritated by, similar installations at crossing zones throughout the Mission Beach main roads. Too much signage or other forms of alert could thus be counter-productive, particularly if used in areas where crossings are infrequent. For example, for the main roads, speed reduction could be combined with enforcement and/or speed cameras, speed-activated signs or vehicle-activated message signs rotated around several locations. In particular hotspots for crossings or cassowary deaths, flashing signage might also be deployed, while other known mortality hotspots might have warning signs, normally inconspicuous, but which are able to be switched on by rangers when crossings have been recorded. A variety of signage is recommended, rather than maintaining one sign design for all occasions and settings. Any measures used should be complementary rather than overloading the driver with messages, and should not be repeated at the next crossing zone.

At sections of Council-operated road with known cassowary crossing and mortality hotspots effective traffic calming devices such as chicanes, speed humps, or planting of vegetation close to road and within road islands should be employed. Main roads in the Mission Beach area should also be considered as appropriate for such traffic calming options, as the area is recognised as an area of high populations and road mortality of an endangered species, making it very important for cassowary conservation. Policies that allow such traffic calming on main roads in highly sensitive ecosystems need to be implemented.

Large crossing structures should be implemented on main roads with high traffic speeds and volumes. Funding should be earmarked for these installations including high bridges at stream crossings, which have been proven to be used by cassowaries when furnished and vegetated appropriately. Trials of a large overpass should be considered where possible, but in particular the Bruce Highway.

Figure 6.4
Road Section 1 – Bruce Highway to Bingil Bay Road

Red icons = active crossings   Blue icons = past crossings   Green icons = past sighting

NOTE: This table refers to known crossings on State – controlled roads (El Arish – Mission Beach Road, Cassowary Drive, Tully – Mission Beach Road), together with the main CCRC – controlled roads of Bingil Bay Road, Garners Beach Road, Alexander Drive and South Mission Beach Road. Several local streets are also mentioned where cassowaries commonly cross, although these were not examined in this study.

PC = Past crossing point

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
1. Bruce Highway to Bingil Bay Road	45	• Narrow riparian corridor • No significant functional connectivity role • Crossing birds are a rare occurrence only • Birds may have moved down from the range via the western tributary to Big Maria Creek • Low potential as connectivity corridor and potentially could lead cassowaries out into agricultural land • No deaths recorded in EPA database (since 1992) • No crossings or roadside sightings in visitor database (since 2000)	• State-controlled road • Very high speeds • Private property • Fences • Proximity of dogs • Little refuge vegetation	• Standard warning signage • Temporary warning signs placed at the site when birds are known to be in the area
	PC16	• Probable that cassowaries still cross at this location although it was not identified as being used during the study. • Birds have been sighted crossing here for many years • Potential connectivity links with swamps to the north and also Maria Creek NP • No deaths recorded in EPA database (since 1992) • No crossings or roadside sightings in visitor database (since 2000)	• State-controlled road • Very high speeds • Private property • Fences • Proximity of dogs? • Forest/matrix corridor, so birds may be led into agricultural areas	• Standard warning signage OR • Non-standard warning signage OR • Short sections of psychological traffic calming (rumble strips, painted indicators) to alert drivers • Temporary passive signage when animals are sighted crossing the road • Speed reduction signs for road past the aquaculture farm

Figure 6.5
Road Section 2 –Bingil Bay Road to Garners Beach Road

Red icons = active crossings Blue icons = past crossings Green icons = past sighting

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
2. Bingil Bay Road to Garners Beach Road	1	• Narrow riparian corridor • Connectivity role needs to be assessed although landowners comment that they see cassowaries crossing in the area • Creek would require rehabilitation to increase corridor width and quality • Crossing birds are occasional only • No cassowary deaths recorded in database • No crossings or roadside sightings in visitor database	• Medium speed road • Currently low traffic volume • Private property • Fences • Proximity of dogs • Little refuge vegetation • Forest – matrix corridor, could lead birds away from forest • Relatively poor driver visibility	• Standard warning signage OR • Non-standard signs • Short sections of road painting indicators to alert drivers • Temporary warning signs placed at the site when birds are known to be in the area • Flashing lights triggered by vehicle
	2	• Narrow riparian corridor with discontinuous vegetation • Creek would require extensive rehabilitation to reconnect to northern swamp • No cassowary deaths recorded in database	• Medium speed road • Currently low traffic • Private property • Fences • Proximity of dogs • Little refuge vegetation • Forest – matrix corridor, could lead birds away from forest	
	PC1	• Probable that cassowaries are still crossing in this general location although it was not identified as being used during the study • Birds have been sighted crossing here for many years • Significant connectivity role allowing cassowaries access to the coast, Garners Beach NP, and Maria Creek NP • No cassowary deaths recorded in database	• Medium speed road • Currently low traffic volume • Private property • Residences • Fences • Proximity of dogs • Poor driver visibility	• Standard warning signage • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Road-based traffic calming (rumble strips, painted road surface) • Flashing warning signs that react to vehicle presence • Speed reduction signs

Figure 6.6
Road Section 3 – Garners Beach area

Red icons = active crossings   Blue icons = past crossings   Green icons = past sighting

Road Section	Crossing	Comments	General Risk Analysis	Mitigation Options
3. Garners Beach Area	3	• Cassowaries cross anywhere along Garners Beach Road • Birds in National Park also cross road at Crossing 11 on Bingil Bay Road (Road Section 4) • Cassowary deaths shown on EPA map (Fig 2.7), and recorded at Cedar Creek	• Low speed dirt road • Currently very low traffic nos. • Private property, residences • Fences • Proximity of dogs • Frequent crossings	• Road-based traffic calming (e.g. speed humps • Keep road unsealed to maintain low-speed environment • Flashing warning signs that react to vehicle presence • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing road • Speed reduction signs
	4	• Cassowaries cross south and north of the Garners Beach Road junction • Birds often cross at top of small hill • Cassowaries have been crossing in the general area for many years • Has significant connectivity role allowing cassowaries access to the coast, Garners Beach NP, and Maria Creek NP • Cassowary death recorded in database • Frequent crossings in this area in database: 6 + 1 roadside sighting	• Medium speed road • Currently low traffic volume • Very poor line of sight • Private property, residences • Fences • Proximity of dogs	• Standard warning signage OR • Non-standard warning signage OR • Road-based traffic calming (rumble strips, painted road surface) • Temporary passive signage when animals are sighted crossing road • Flashing warning signs that react to vehicle presence turned on when crossings have been recorded • Speed limit 60 kph or less • Revegetate the matrix in a safer location to encourage cassowaries to cross there
	5	• Cassowaries cross frequently anywhere along Garners Beach Road • Birds in National Park also cross road at Crossing 11 on Garners Beach-–Mission Beach Road (Road Section 4) • Cassowary deaths recorded on Garners Beach Road • 5 crossings & 6 roadside sightings at this end of Garners Beach Road	• Low speed road • Currently low traffic volume • Private property, residences • Fences • Proximity of dogs • Frequent crossings	• Road-based traffic calming (e.g. speed humps • Keep road unsealed to maintain low-speed environment • Flashing warning signs that react to vehicle presence • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when

Road Section	Crossing	Comments	General Risk Analysis	Mitigation Options
3. Garners Beach Area	6	• Cassowaries cross anywhere along Garners Beach Road • Birds in National Park also cross road at Crossing 11 on Garners Beach-– Mission Beach Road (Road Section 4) • Cassowary deaths recorded on Garners Beach Road • 11 crossings and 4 roadside sightings at this section of road	• Low speed road • Currently low traffic volume • Private property, residences • Fences • Proximity of dogs • Frequent crossings	animals are sighted crossing the road • Speed reduction signs
	7 7.1	• Poor line of sight (near road bend) • Generally birds use driveway on east side to access road • Several crossings recorded in database	• Low speed road • Currently low traffic volume • Private property, residences • Fences, proximity of dogs • Frequent crossings • Poor line of sight	
	8	• Cassowaries cross anywhere along Garners Beach Road • Birds in National Park also cross road at Crossing #11 on Bingil Bay Road • Possible crossings in database	• Low speed road • Currently low traffic volume • Private property, residences • Fences • Dogs on beach • Crossing reports common	• Road-based traffic calming (e.g.speed humps). • Keep road unsealed to maintain low-speed environment • Flashing warning signs that react to vehicle presence • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Speed reduction signs
	9	• Cassowaries cross anywhere along foreshore road	• Low speed road • Currently low traffic volume • Poor line of sight • Private property, residences • Fences • Dogs on beach • Crossing reports common	
	10 Holt Rd	• Occasionally on road below The Sanctuary • 5 crossings in database	• Low speed road • Currently low traffic volume • Poor line of sight • Private property, residences • Fences	• Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Road-based traffic calming (rumble

Road Section	Crossing	Comments	General Risk Analysis	Mitigation Options
			• Proximity of dogs	strips, speed humps, painted road surface) • Speed reduction signs

Figure 6.7
Road Section 4 – Bingil Bay Road and Alexander Drive: Garners Beach Road to Mission Beach

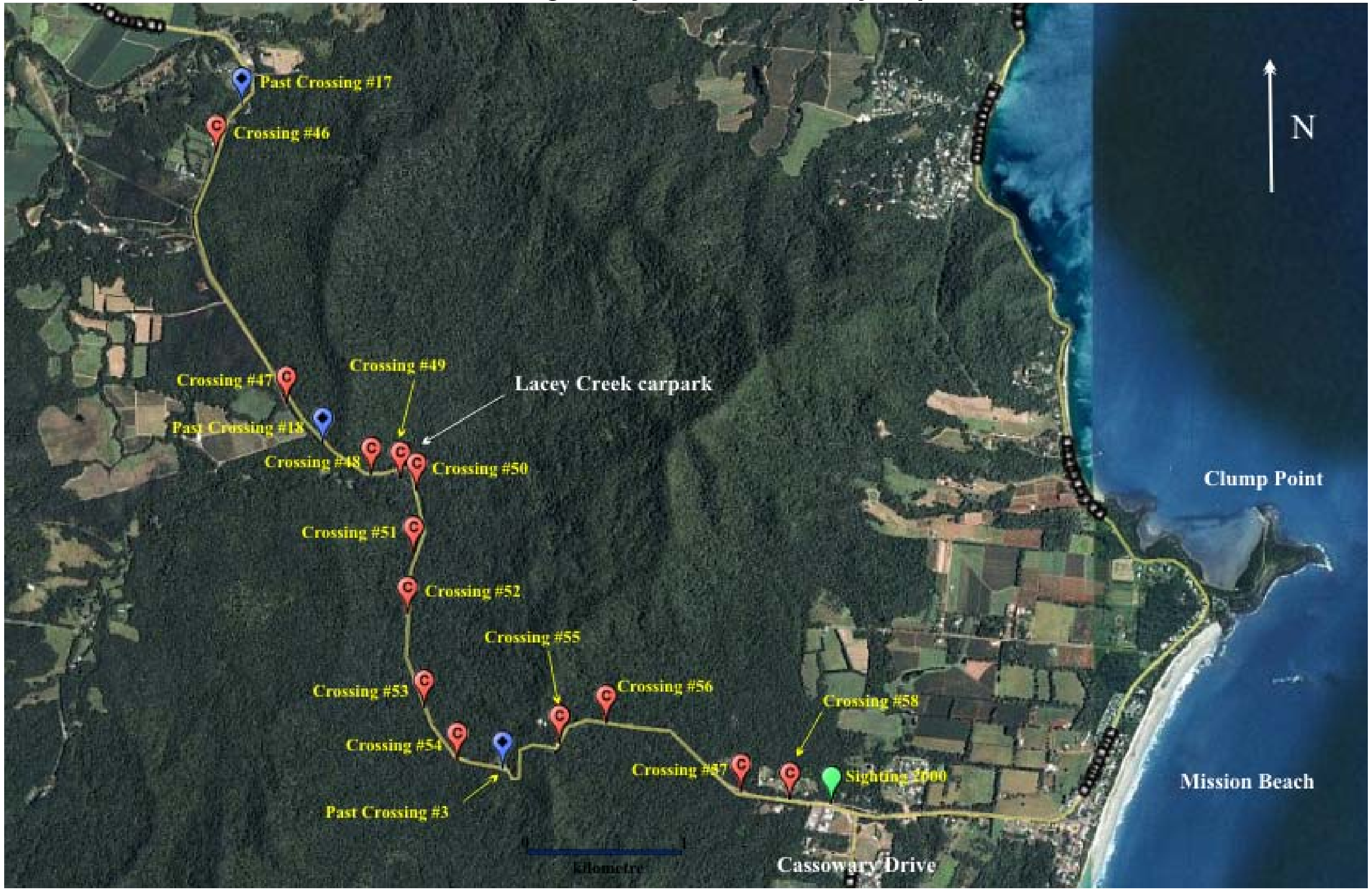
Red icons = active crossings Blue icons = past crossings
Green icons = past sighting

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
4. Bingil Bay Road and Alexander Drive: Garners Beach Road to Mission Beach and beyond to Cassowary Drive turnoff	11 Bingil Bay Road 11.1	• Riparian corridor • Connects Garners Beach National Park with Clump Mt & Tam O-Shanter NPs • Cassowaries known to move from Double Mt across into Garners Beach NP (Moore 2003) • There are 5 crossings recorded in this area in the visitor database • Comments from C4 describe another crossing zone approaching the Bingil Bay shop, • 10 crossings in the zone including the shop and beach in the visitor database	• Medium speed road • Currently low traffic volume • Private property, residences • Fences • Proximity of dogs • Frequent crossings • Council-controlled road	• Road-based traffic calming (speed humps, combined with rumble strips, painted road surface) • Standard warning signage OR • Flashing warning signs that react to vehicle presence when recent crossings are recorded • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Speed reduction on CCRC road • Speed limit enforcement
	12	• Local street • Past handfeeding history in this area • Several crossings/roadside sightings on Plantation Drive and adjacent Bingil Bay Rd in visitor database	• Low speed road • Low traffic volume • Private properties, residences • Fences • Proximity of dogs	• Standard warning sign • Temporary warning signs placed at the site when birds are known to be in the area
	PC2	• Local street • Handfeeding known in this area in the past • Several crossings recorded in visitor database on Cutten and Plumb Sts	• Low speed road • Low traffic volume • Private properties, residences • Fences • Proximity of dogs	
	PC3 Alexander Drive	• Cassowaries visit the entrance to Bicton Hill walking track to feed on mangoes etc • Birds sometimes wander on the road • Several crossings in visitor database	• Medium speed road • Currently low traffic volume	• Road-based traffic calming (speed humps, rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage • Temporary passive signage

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
				when animals are sighted crossing the road
	13 Alexander Drive 13.1	• Birds cross near James Street on Alexander Drive (Narragon Beach) to forage along foreshore in mangroves • Also attracted to fruiting *Syzygium* east of road • Some birds traced back to Bicton Hill • Handfeeding known for this area in the past • Often cross near blind bend north of James St. • There is a similar seasonal crossing for *Syzygium* fruit closeto the Clump Pt jetty (C4 pers. comm.) • Only a few crossings are noted in visitor database for these areas	• Medium speed road • Currently low traffic volume • Poor line of sight • Private property • Fenced properties • Proximity of dogs • Dogs on beach • Frequent seasonal crossings	• Road-based traffic calming (speed humps, combined with rumble strips, painted road surface) • Flashing warning signs that react to vehicle presence • Standard warning signage • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Speed reduction for CCRC road as recommended by JSC plan
	PC4	• Cassowaries cross road to access the arboretum at C4 (one record in visitor database) • Infrequent occurrence but may increase when trees are in fruit within the arboretum	• Medium speed road • Currently low traffic volume • Private property • Fences • Proximity of dogs • Dogs on beach	
	14 El Arish MB Road, North Mission Beach	• Cassowaries cross road either side of the small Wongaling Creek bridge • Parts of the banks have been rehabilitated but a higher bridge would facilitate movements under the road • 8 crossings and 5 roadside sightings recorded in visitor database • No cassowary deaths recorded in EPA database	• Medium speed road, recently reduced to 60 km/h • Private property • Fences • Proximity of dogs • Little refuge vegetation	• Raised bridge over Wongaling creek (underpass) with revegetation underneath • Purpose-designed cassowary fencing (e.g. shadecloth covered by vines) either side of underpass to funnel birds into crossing • Road-based traffic calming (speed humps, rumble strips,

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
	15 Nonda St	• Birds cross Nonda St either moving towards R214 or towards Wongaling Creek and Royal Palms estate • A crossing and narrow "corridor" was designed to facilitate bird movements towards R214 • 4 crossings and 1 roadside sighting in visitor database	• Low speed road with traffic calming at expected crossing point, however tyre mark evidence shows some vehicles ignoring the traffic calming • Private property, residences • Fenced developments are a problem in this area, causing entrapment • Proximity of dogs	painted road surface) • Roundabout at Cassowary Drive entry (El Arish-Mission Beach Road, Wongaling section) • Flashing warning signs that react to vehicle presence when speeding • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Speed limit enforcement on EAMB Rd • Speed cameras

Figure 6.8
Road Section 5 – El Arish Mission Beach Road between Bingil Bay Road turnoff and Cassowary Drive turnoff including Lacey Creek and Fenby Gap



Red icons = active crossings Blue icons = past crossings Green icons = past sighting

<table>
<tr><th>Road Section</th><th>Crossing Number</th><th>Comments</th><th>General Risk Analysis</th><th>Mitigation Options</th></tr>
<tr><td colspan="5">Mitigation for individual cassowary crossings along this road section is problematic as birds can and do cross anywhere along the road from the beginning of the Tam O'Shanter Forest (Past Crossing 18) to Clump Mt Cooperative (Crossing 58). This road section has high cassowary road mortality, comprising approximately 26% of all cassowary road-deaths at Mission Beach (DERM 2007).
It is a high design speed road managed by the Queensland Department of Transport and Main Roads. This management regime currently limits many road-based mitigation techniques due to legal safety requirements (e.g., speed humps, road narrowing). From the viewpoint of cassowary conservation, the road is best treated holistically rather than addressing individual crossings. The Queensland Government should consider declaring this road and other Mission Beach entry roads as roads passing through a high value ecological area so that special conditions could apply in terms of speed reduction. Another option that could be explored is the de-maining of the road or its reclassification as a 'Presentation (unrestricted) Road' under the Wet Tropics Management Plan with a subsequently greater scope for cassowary road mitigation. Funding from the State and Federal Governments should be sought by the Cassowary Coast Regional Council to maintain the road if this option were adopted.
In this section, care should be taken to implement different styles of mitigation at recent crossing points so that drivers do not become blasé or irritated by a series of similar techniques.</td></tr>
<tr><td rowspan="2">5.

El Arish – Mission Beach Road: between Bingil Bay Road turnoff to Cassowary Drive turnoff (including Lacey Creek and Fenby Gap)</td><td>PC17</td><td>• Birds crossed from residential driveway in 1998-2001
• Cassowary killed near this location in late 1989
• Connects to Mt Edna vegetation (west)
• Alternative connection south to Banfield Road vegetation</td><td>• High speed road
• Moderate traffic volume, increasing
• Private property
• Fences
• Poor line of sight
• Proximity of dogs</td><td>• Alert traffic calming (rumble strips, painted road surface) OR
• Standard warning signage OR
• Non-standard warning signage
• Flashing warning signs that react to vehicle presence
• Temporary passive signage when animals are sighted crossing the road
• Speed reduction
• Dog control
• Speed limit enforcement</td></tr>
<tr><td>46</td><td>• 5 cassowary deaths in EPA database and on EPA map (Figure 2.7) in this area
• Cassowaries cross into fruit farm
• Birds have been sighted crossing here for many years
• Crossing at base of small hill and poor line of sight from the east
• Fence within forest on opposite side from</td><td>• High speed road, always greater than 80 kph limit
• Mean speed 82.6 kph just beyond Mt View Cl
• Extremely high maximum speeds recorded</td><td>• Reduce speed limit to 60 kph
• Speed limit enforcement
• Speed camera OR
• Road-based traffic calming (rumble strips, painted road surface, and/or speed humps, chicanes, depending on safety) OR</td></tr>
</table>

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
		farm towards Mission Beach does not prevent crossings at farm, but may reduce crossings at blind corner opposite Mt View Close entry. Unproven – fence was fixed in 2008, but vegetation density makes monitoring of cassowary sign very difficult. • 3 crossings and 6 roadside sightings in visitor database, local owner reports that crossings are very common	• Moderate traffic volume, increasing • Private property • Fences • Poor line of sight • Frequent crossings and roadside sightings	• Flashing warning signs that react to speeding vehicle • Temporary passive signage when animals are sighted crossing the road OR • Variable message sign switched on by rangers after recent crossings • Potential to trial animal detection system in this area as crossing site is relatively well-known and of fairly short length • Open bridge type underpasses if road upgrade allows road to be elevated through this low area
	47	• Crossing near *Pandanus* swamp • Birds occasionally cross in several places between 46 and 47	• High speed road • Moderate traffic volume • Increasing traffic volume • Private property • Fences • Poor line of sight • Frequent crossings	• Speed limit reduced to 60 kph • Standard warning signage OR • Non-standard warning signage • Temporary warning signs placed at the site when birds are known to be in the area OR • Variable message sign switched on by rangers after recent crossings • Open bridge type underpasses if road upgrade allows road to be elevated through this low area • Speed limit enforcement
	PC18	• Used by Lacey Creek birds during 2000 study • Cyclone damage and subsequent road work makes crossing at this point difficult now.	• High speed road • Moderate traffic volume, increasing • Batters	• Reduce speed limit to 60 kph • Speed limit enforcement

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
	48	• Used by Lacey Creek birds during 2000 study • Cyclone damage and subsequent road work makes crossing at this point difficult now • Family party regularly seen to cross June-August 2008 • 1 crossing and 3 roadside sightings in this area in C4 cassowary sightings database	• High speed road • Moderate traffic volume • Increasing traffic volume • Batters	• Reduce speed limit to 60 kph • Speed limit enforcement • Speed cameras OR • Flashing warning signs that react to vehicle presence • Road-based driver alerts (rumble strips, painted road surface) • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road OR • Variable message sign that rangers switch on only when birds have crossed • Culverts at Lacey Creek currently not effective as underpasses – a more open higher bridge design, rather than the current relatively narrow box culverts could be trialled as a replacement during road upgrade,together with means of preventing easy crossings at grade would also need to be considered. • Exclusion fencing associated with underpass not feasible in current configuration of entry to Lacey Creek picnic ground – birds would be trapped on road • Animal detection systems if vehicle and person movements can be electronically screened
	49	• Located at Lacey Creek carpark • Used by old adult female (killed on road September 2008), young adult female, and family party June-October 2008. • High max vehicle speeds through this area • 2 cassowary deaths in Lacey Ck area in EPA database and 3 shown on map Fig. 2.7 • 9 crossings and 20 roadside sightings in Lacey Ck area in C4 cassowary sightings database • Rumble strips leading to area, painted road edge traffic calming has been trialled • Eye-catching signage present	• High speed road • Speeds average 73 kph • Moderate traffic volume • Increasing traffic volume • Handfeeding • Frequent crossings and roadside sightings	
	50	• Located on bend 100m east of Crossing #49 • Same history as crossing 49 • Rumble strips, painted road edge traffic calming has been trialled • 9 crossings and 20 roadside sightings in Lacey Ck area in C4 cassowary sightings database	• High speed road • Moderate traffic volume • Increasing traffic volume • Poor line of sight • Frequent crossings and sightings	

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
				out as part is relatively flat and movements likely
	51	• Long potential crossing area (~600m) • Dips in road reduce visibility • Rumble strips, painted road edge traffic calming has been trialled	• High speed road • Moderate traffic volume • Increasing traffic volume • Reduced line of sight • Crossings common	• Reduce speed limit to 60 kph • Speed enforcement • Speed cameras OR • Flashing warning signs that react to vehicle presence • Road driver alerts (rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road OR • Variable message sign that rangers switch on only when birds have crossed • Open bridge type underpasses if road upgrade allows road to be elevated through the low dips
	52	• Long potential crossing area (~400m) • Dips in road reduce visibility • One cassowary death in EPA database • 4 crossings and 6 roadside sightings in 4 cassowary sighting database in crossing zone 52-53	• High speed road • Moderate traffic volume • Increasing traffic volume • Reduced line of sight • Frequent crossings and roadside sightings	
	53	• Long potential crossing area (~100m) • Dip in road reduces visibility • 4 crossings and 6 roadside sightings in 4 cassowary sighting database in crossing zone 52-53	• High speed road • Moderate traffic volume • Increasing traffic volume • Reduced line of sight • Frequent crossings and roadside sightings	• Reduce speed limit to 60 kph • Speed cameras OR • Flashing warning signs that react to vehicle presence • Speed enforcement • Road-based driver alerts (rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Underpass using creek line and

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
				elevated bridge
	54	• Located at El Arish MB Rd – Licuala walking trail (Bean Tree Track) • Multiple crossings of adults, family parties • Used frequently by cassowaries 1990-2009 • 7 crossings and 12 roadside sightings in C4 cassowary sighting database around crossing zone 54 • 1 cassowary death recorded in EPA database and 2 shown on map (Fig 2.7)	• High speed road • Moderate traffic volume • Increasing traffic volume • Reduced line of sight • Handfeeding • Frequent crossings and sightings	• Reduce speed limit to 60 kph • Road-based driver alerts (rumble strips, painted road surface) • Flashing warning signs that react to vehicle presence • Animal detection systems at the Bean Tree Track entrance if vehicle movements can be screened out • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road OR • Variable message sign that rangers switch on only when birds have crossed • Speed enforcement • Vehicle-based speed cameras at Bean Tree Track entrance
	PC19	• Was the old supplementary-feeding site after Cyclone Winifred 1986 • Significantly modified on north side of road now dominated by introduced grass and weeds (some fruiting weeds) • Steep roadside batters	• High speed road • Moderate traffic volume • Increasing traffic volume • Reduced line of sight	
	55	• Located at the saddle of Fenby Gap • Appears to be seasonally used • 4 crossings and 5 roadside sightings in C4 cassowary sightings database • Traffic travels relatively slowly through Fenby Gap hairpins but speeds increase towards Mission Beach after summit	• High speed road • Moderate traffic volume • Increasing traffic volume • Reduced line of sight • Crossings frequent	
	56	• ~300m east of Fenbys Gap • Used mainly by two adults but use reduced significantly after two adults (likely to be this pair) were killed on Cassowary Drive 2001	• High speed road • Moderate traffic volume • Increasing traffic volume • Reduced line of sight	
	57	• In dip 250m west of entrance to Clump Mt Camp	• High speed road • Moderate traffic	• Reduce speed to 60 kph • Speed enforcement

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
		• Regularly used • 4 crossings and 3 roadside sightings in C4 cassowary sighting database • 2 cassowary deaths recorded in EPA database and map (Fig. 2.7) • Rumble strips present in this area	volume • Increasing traffic volume • Reduced line of sight • Frequent crossings and sightings	• Speed camera OR • Flashing warning signs that react to speeding vehicle • Road-based driver alerts (rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road OR • Variable message sign that rangers switch on only when birds have crossed • Underpass (open bridge type if road design allows road to be elevated in this low dip)
	58 58.1	• East of entrance to Clump Mt Camp • Road currently marked to highlight cassowary crossings • Rumble strips present • Birds occasionally sighted at Dewar Street corner (Mitre 10) • Department of Transport and Main Roads has recently reduced speed limit to 60 km/hr from approximately this point • 1 cassowary death recorded in C4 cassowary sightings database	• High speed road • Moderate traffic volume • Increasing traffic volume • Possible proximity of dogs? • Medium speed road	• Road-based driver alerts (rumble strips, painted road surface) • Flashing warning signs that react to vehicle/cassowary presence • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road OR • Variable message sign that rangers switch on only when birds have crossed • Reduce speed limit to 60kph till reach new speed zone • Reduce road design speed further to west

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
				• Speed enforcement • Speed camera OR • Flashing warning signs that react to speeding vehicle

Figure 6.9
Road Section 6 – Cassowary Drive
(from El Arish – Mission Beach Road to South Mission Beach Road turnoff)

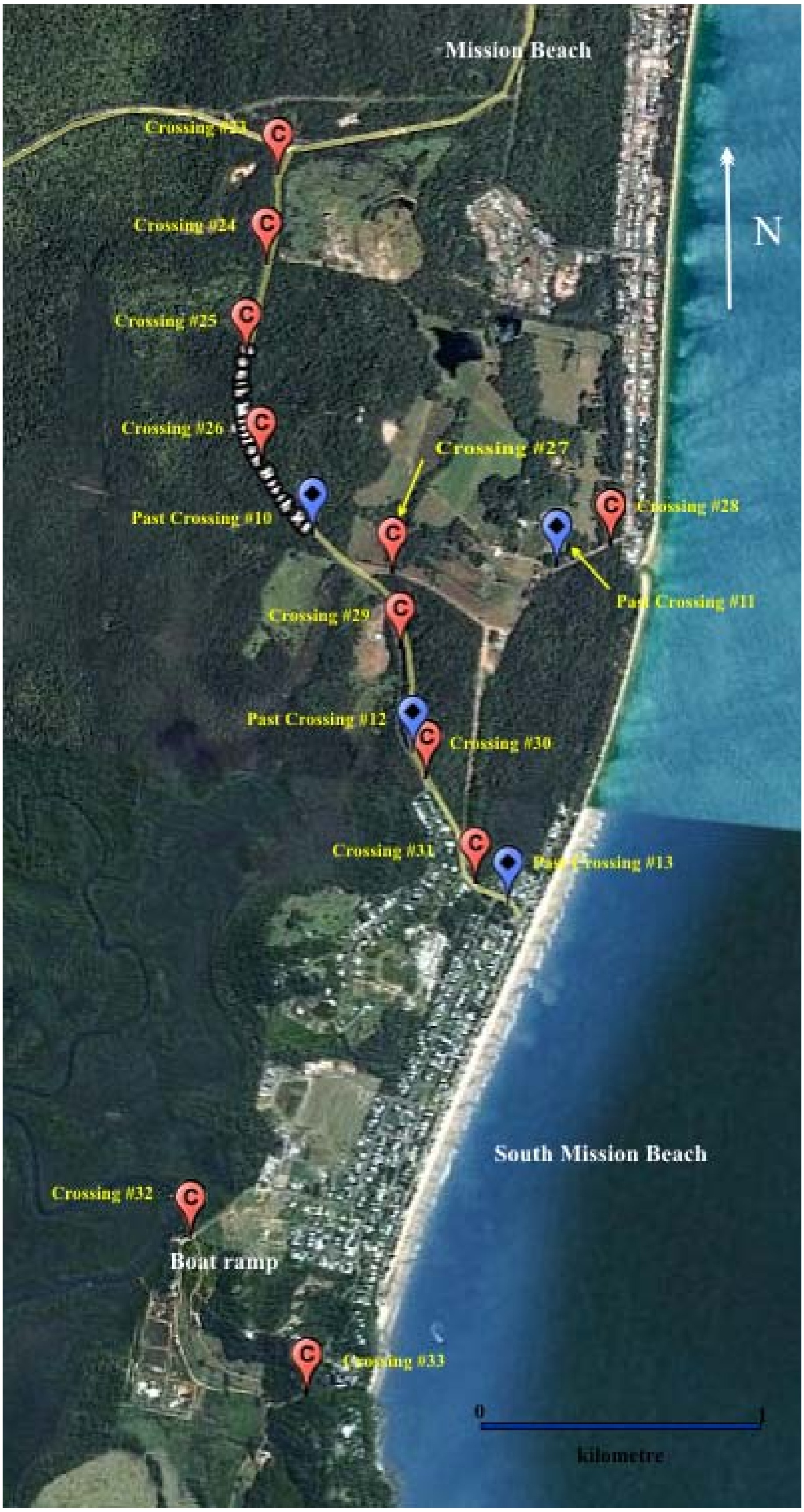
Red icons = active crossings Blue icons = past crossings Green icons = past sighting

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
In this section, care should be taken to implement different styles of mitigation at recent crossing points so that drivers do not become blasé or irritated by a series of similar techniques.				
6. Cassowary Drive	PC6	• Probable that cassowaries are still crossing at this location although it was not identified as being used during the study. • Birds have been sighted crossing here for many years • 6 crossings and one roadside sighting in C4 cassowary sightings database	• High speed road • High traffic volume • Increasing traffic volume • Private property • Fences • Proximity of dogs	• Road-based traffic calming (speed humps, rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage OR • Variable message signs when recent crossings are recorded • Temporary passive signage when animals are sighted crossing the road • Reduce road design speed (roundabouts or chicanes) • Speed limit enforcement • Speed camera OR • Flashing warning signs that react to vehicle presence
	PC7	• Probable that cassowaries are still crossing at this location although it was not identified as being used during the study. • Birds have been sighted crossing here for many years • 2 crossings in C4 cassowary database	• High speed road • High traffic volume • Increasing traffic volume • Private property • Fences • Proximity of dogs	
	16	• Frequently used crossing • Two cassowary deaths in EPA road mortality database • 8 road crossings and 2 roadside sightings in C4 visitor database	• High speed road • High traffic volume • Increasing traffic volume • Frequent crossings • Private property • Fences • Proximity of dogs	• Road-based traffic calming (speed humps, rumble strips, painted road surface – these have been trialled recently at crossing #17 but the humps were removed due to noise affecting residents) • Standard warning signage OR • Non-standard warning signage • Flashing warning signs that react to vehicle presence • Temporary passive signage when animals are sighted
	17	• Mission Circle area • Wide potential crossing area (~200m) • Cassowaries habituated to people • 4 road crossings and 3 sightings in C4 visitor database for Mission Circle and	• Medium speed road • High traffic volume • Increasing traffic volume • Frequent crossings	

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
		melaleuca swamp area (crossing 18) • 1 cassowary death in EPA database	• Private property • Fences • Proximity of dogs • Handfeeding	crossing the road OR • Variable message signs when recent crossings are recorded • Speed limit has been reduced in Mission Circle area recently, but should be extended to Porters Creek crossing area • Roundabouts, chicanes, revegetated islands in road, narrow road verges are alternative measures to speed humps that could be trialled • Underpasses (elevated bridge type if road design allows road to be elevated in the creek crossing areas) • Speed limit enforcement • Speed camera OR • Flashing warning signs that react to speeding vehicle
	19	• *Melaleuca* swamp/ Garrett's corridor area • Cassowaries generally move down creek to access road • Cassowaries habituated to people • 4 road crossings and 3 sightings in C4 visitor database for Mission Circle and melaleuca swamp area (crossing 18) • 1 cassowary death in EPA database for Mission Circle / *Melaleuca* swamp area	• Medium speed road • High traffic volume • Increasing traffic volume • Frequent crossings • Private property • Fences • Proximity of dogs • Handfeeding	
	PC8	• This crossing was used occasionally <2000 • Clearing for residential development has made it unsuitable for cassowaries		
	20	• Connects Luff Hill cassowaries to South Mission Beach coastal vegetation. • 4 road crossings and 5 roadside sightings in C4 cassowary sightings database • 2 cassowary deaths in EPA road mortality database and on map (Fig 2.7)	• High speed road • High traffic volume • Increasing traffic volume • Frequent crossings • Private property • Proximity of dogs • Very restricted line of sight	• Reduce speed limit to 60 kph • Speed limit enforcement • Speed camera OR • Flashing warning signs that react to speeding vehicle • Road-based traffic calming (speed humps, rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage
	21	• Connects Luff Hill cassowaries to South	• High speed road	

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
		Mission Beach coastal vegetation. • Use of this crossing possibly affected by nearby development south of road • 6 road crossings and 4 roadside sightings in C4 cassowary sightings database • 2 road deaths in this vicinity in EPA mortality database and 1 on 2007 map (Fig. 2.7)	• High traffic volume • Increasing traffic volume • Frequent crossings • Private property • Proximity of dogs • Very restricted line of sight	• Temporary passive signage when animals are sighted crossing the road OR • Variable message signs when recent crossings are recorded • Reduce road design speed – narrower verges, chicanes, • Roundabout at SMB Rd entrance
	22	• Connects Luff Hill cassowaries to South Mission Beach coastal vegetation. • Use of this crossing possibly affected by nearby development south of road • Traffic may slow for SMB Rd turnoff • 10 road crossings and 9 roadside sightings in C4 cassowary sightings database	• High speed road • High traffic volume • Increasing traffic volume • Frequent crossings • Private property • Proximity of dogs • Restricted line of sight	

Figure 6.10
Road Section 7 – South Mission Beach Road



Red icons = active crossings Blue icons = past crossings Green icons = past sighting

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
The main South Mission Beach Road section has high mortality and cassowaries can cross anywhere, although crossings at the locations described below are frequent. Care should be taken to implement different styles of mitigation at recent crossing points so that drivers do not become blasé or irritated by a series of similar techniques.				
7. South Mission Beach	23	• Cassowaries using this crossing are generally moving from or towards Crossing 22 i.e., moving in/out of Hull River NP and South Mission Beach • High mortality along entire road (~17.5% of known road deaths 1992-2010: EPA mortality database) • Three crossings and 2 roadside sightings in C4 cassowary sighting database	• High speed road • Moderate traffic volume • Increasing traffic volume • Private property • Fences • Proximity of dogs	• Reduce speed limit to 60kph • Speed limit enforcement • Speed camera OR • Flashing warning signs that react to speeding vehicle • Road-based driver alerts (speed humps, rumble strips, painted road surface, chicanes) • Roundabout at SMB/TMB Rd intersection • Standard warning signage OR • Non-standard warning signage • Flashing warning signs that react to vehicle presence • Temporary passive signage when animals are sighted crossing the road OR • Variable message signs turned on by rangers when recent crossings recorded
	24	• Probable that cassowaries are still crossing at this location although it was not identified as being used during the study. • Birds have been sighted crossing here for many years • 1 crossing and 2 roadside sightings in C4 cassowary sightings database		
	25	• Frequently used crossing • 2 cassowary deaths in EPA mortality database and on map (Fig 2.7) • 4 crossings and 3 roadside sightings in C4 cassowary sightings database	• High speed road • Low-moderate traffic volume • Increasing traffic volume • Frequent crossings	• Reduce speed limit to 60kph • Speed limit enforcement • Speed camera OR • Flashing warning signs that react to speeding vehicle • Road-based driver alerts (rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage • Flashing warning signs that react to vehicle presence • Temporary passive signage when animals are sighted crossing the
	26	• Frequently used crossing • 4 crossings and 4 roadside sightings in C4 cassowary sightings database • 1 cassowary road death in EPA mortality database and on map (Fig 2.7)		
		• Probable that cassowaries are still crossing at this location although it was not identified	• High speed road • Low-moderate traffic	

	PC10	as being used during the study. • Birds have been sighted crossing here for many years • 2 cassowary road deaths in EPA mortality database and on map (Fig 2.7)	volume • Increasing traffic volume • Frequent crossings • Private property	road OR • Variable message signs turned on by rangers when recent crossings recorded
	27	• Crossing on Wheatley Road 100m from junction with South Mission Beach Road • Birds have been sighted crossing here for many years • 2 road deaths recorded in vicinity of creek crossing and transfer station in EPA mortality database • 3 road crossings in C4 cassowary sightings database	• Low speed road • Low-moderate traffic volume • Frequent crossings • Private property	• Speed limit enforcement • Speed camera OR • Flashing warning signs that react to speeding vehicle • Standard warning signage OR • Non-standard warning signage • Flashing warning signs that react to vehicle presence • Temporary passive signage when animals are sighted crossing the • Road-based traffic calming (speed humps, rumble strips, painted road surface, chicanes) OR • Roundabout at Wheatley Road/SMB Road intersection
	28	• Used by cassowaries visiting houses along the Esplanade • Several crossings and roadside sightings in C4 cassowary sightings database	• Low speed road • Low traffic volume • Increasing traffic volume • Frequent crossings • Private property • Handfeeding • Proximity of dogs	• Road-based traffic calming (speed humps, chicanes) • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road
	29	• Crossing at Frog's Hollow community hall • Birds using this crossings also #27 and #30 • Birds have been sighted crossing here for many years • 2 road deaths recorded in EPA mortality	• High speed road • Low-moderate traffic volume • Increasing traffic volume	• Reduce speed limit to 60 kph • Speed limit enforcement • Speed camera OR • Variable message signs turned on by rangers when recent

		database • Deaths also related to those at PC10 as crossing birds use R306 • 8 crossings and 2 roadside sightings recorded in C4 cassowary sightings database	• Frequent crossings	crossings recorded • Roundabout at Wheatley Road intersection • Standard warning signage OR • Non-standard warning signage • Flashing warning signs that react to vehicle presence • Temporary passive signage when animals are sighted crossing the road OR • Variable message signs turned on by rangers when recent crossings recorded
	30	• Birds using this crossing also #27 and #29 • Birds have been sighted crossing here for many years • Known road deaths (EPA road mortality map (Fig. 2.7) • Several roadside sightings and one crossing in C4 cassowary sightings database • Also several sightings of birds walking along Mission Drive, SMB	• High speed road • Low-moderate traffic volume • Increasing traffic volume • Frequent crossings • Private property • Proximity of dogs	
	31	• Infrequently used by birds visiting adjacent houses	• Medium speed road • Low-moderate traffic volume • Increasing traffic volume • Private property • Proximity of dogs • Handfeeding	• Temporary passive signage when animals are sighted crossing the road OR • Variable message signs turned on by rangers when recent crossings recorded
	PC13	• Used prior to 2000 • Probably still infrequently used by birds visiting adjacent houses • 1 road death recorded in EPA mortality database • 1 sighting of a crossing bird in C4 cassowary sightings database		
	32	• Hull River Boat Ramp • Area has long history of use by cassowaries: 5 crossings and 3 roadside sightings in C4 cassowary sighting database • Possible development south of the road threatens continued use by cassowaries • Cassowaries have been attacked at this site by unrestrained dogs (in boats or utes) • Main movement corridor between Kennedy Bay NP and South Mission/ Mission Beach	• Low speed road • Low traffic volume • Increasing traffic volume • Potential development with increasing human population • Private property • Proximity of dogs • Handfeeding	• Road based traffic calming (speed humps, rumble strips, painted road markings, chicanes) • Standard warning signage • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Educational signage for boat ramp visitors

		• 1 road death recorded in EPA cassowary mortality database		
	33	• Birds can cross anywhere along Explorer Drive: 4 crossings and 6 roadside sightings in C4 cassowary sightings database • History of handfeeding throughout area • Problem birds have been relocated away from this location in the past • Home range of some birds includes Kennedy Bay NP	• Low speed road • Low traffic volume • Private property • Proximity of dogs • Handfeeding	

Figure 6.11
Road Section 8 – Tully – Mission Beach Road from South Mission Beach turnoff to Bruce Highway

Red icons = active crossings Blue icons = past crossings Green icons = past sighting

<table>
<tr><th>Road Section</th><th>Crossing Number</th><th>Comments</th><th>General Risk Analysis</th><th>Mitigation Options</th></tr>
<tr><td colspan="5">Individual mitigation for cassowaries along this road section is problematic as birds can cross anywhere along a five kilometre stretch east of the junction with South Mission Beach (Crossing 34). Tully to Mission Beach Road, although possessing wide clear road verges, accounts for about 39% of all cassowary road-deaths at Mission Beach (EPA database 2010). It is a high speed road managed by the Queensland Department of Transport and Main Roads. From the viewpoint of cassowary conservation, the road is best treated holistically rather than addressing individual crossings i.e. a whole-of-road approach. Reduced speed limits and road redesign to reduce vehicle speed through cassowary crossing hotspot zones should be considered. Care should be taken to implement different styles of mitigation at recent crossing points so that drivers do not become blasé or irritated by a series of similar techniques</td></tr>
<tr><td>8.

Tully-Mission Beach Road</td><td>34-39</td><td>• Cassowaries can cross anywhere along this section of road
• Birds have been sighted crossing here for many years
• Known road deaths
• In C4 cassowary sighting database and EPA mortality database:
1 death, 3 crossings, 7 roadside sightings near Hull R
1 death, 7 crossings, 10 roadside sightings in vicinity of Licuala turnoff
5 crossings, 1 roadside sighting near Limbo Creek
6 crossings, 3 roadside sightings near Stony Creek
3 crossings, 4 roadside sightings near #38
2 deaths, 3 crossings, 2 roadside sightings in vicinity of #39</td><td>• High speed road
• High traffic volume
• Increasing traffic volume
• Frequent crossings all along this forested section of road</td><td>• Reduce speed limit to 60 kph
• Speed enforcement
• Speed cameras OR
• Flashing warning signs that react to speeding vehicle along sections from Hull River to Carmoo
• Road-based driver alerts at Licuala turnoff and #39 (rumble strips, painted road surfaces) (Painted road edges have been trialled along this section without notable success)
• Temporary passive signage when animals are sighted crossing road OR
• Variable message signs turned on by rangers when recent crossings recorded
• Reduce road design speed – could be achieved with narrower verges, traffic slowing features
• Underpasses – there is a functioning cassowary underpass at the North Hull River bridge
• The culvert at Stony Creek does not appear to function satisfactorily for cassowaries, due to its dimensions – altering to an open bridge structure could assist in use.</td></tr>
</table>

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
				• Standard warning signage OR • Non-standard warning signage
	40	• Major location of cassowary mortality (11 deaths 1992-2007 in EPA cassowary mortality database, 1 recent death • 18 crossings and 10 roadside sightings recorded in C4 cassowary sightings database • Road is high speed and sight lines are very poor for that speed environment • Deaths and crossings commonly occur either near banana farm or in narrow riparian strips close to Lindsay Road turnoff	• High speed road • High traffic volume • Increasing traffic volume • Private property • Fences • Very poor line of sight • Frequent crossings • Proximity to dogs • Fruit farm attractive to cassowaries	• Reduce speed limit to 60 km/hr • Enforce reduced speed limit • Roundabout at Lindsay Road • Reduce road design speed e.g. road-based traffic calming (speed humps, chicanes) • Ensure farm fruit is not available to cassowaries – cassowary exclusion fencing • Speed camera OR • Flashing warning signs that react to speeding vehicle presence along nearby sections • Temporary passive signage when animals are sighted crossing the road OR • Variable message signs turned on by rangers when recent crossings recorded • Updatable sign that lists number of road deaths • Chicanes at entry road if new development goes ahead
	PC14	• Sightings of cassowaries using the grassy paddock to cross the road (2000)	• High speed road • High traffic volume • Increasing traffic volume • Private property • Fences • Poor line of sight	
	41-43	• Road mortality is known in this zone (2 birds shown on EPA map (Fig 2.7) and deaths may not get reported • Cassowaries can cross anywhere in 3km stretch between #41 and PC15 • Sugarcane Creek (42) is a major crossing location • Banana farms south of road provides probable crossing motivation • Several crossings and roadside sightings reported in C4 cassowary sightings	• High speed road • High traffic volume • Increasing traffic volume • Private property & NP • Fences • Frequent crossings	• Reduce speed limit to 60 km/hr • Enforce speed limit • Speed camera OR • Flashing warning signs that react to speeding vehicle • Reduce road design speed (reduce width of vegetation clearing by planting low vegetation • Underpasses (elevated bridge type if road upgrade allows road to be elevated in creek crossing areas)

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
		database for this area		• Road-based driver alerts (rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage • Temporary passive signage after recent cassowary crossing OR • Variable message signs turned on by rangers when recent crossings recorded
	PC15	• Cassowaries crossed in this area in 2000	• High speed road • High traffic volume • Increasing traffic volume • Private property	• Road-based driver alerts (rumble strips, painted road surface) • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road • Reduce speed limit • Reduce road design speed • Enforce speed limit • Speed camera OR • Flashing warning signs that react to speeding vehicle
	44	• Two sightings of cassowaries crossing at this location in 2008 • records of road crossings and 6 sightings on roadside were recorded in this zone in the C4 cassowary sighting database	• High speed road • High traffic volume • Increasing traffic volume	

Figure 6.12
Road Section 9 – Smiths Gap

Red icons = active crossings Blue icons = past crossings Green icons = past sighting

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
Smiths Gap is a potential linkage corridor that could reconnect the Mission Beach cassowary population back to the WHA west of the Bruce Highway. The barrier to cassowary movement at this point comprises the Bruce Highway and the rail line and cane tram. There have been sightings of cassowaries crossing the road but these are rare, possibly due to the isolated nature of the area and transient nature of traffic causing difficulties with reporting such observations. .				
8. Smiths Gap	PC22	• Adult cassowary sighted on November 2000 standing on the eastern roadside next to formed driveway. Bird moved back into the forest without attempting to cross • Cassowaries were sighted in the same general area in 1988 (Crome and Moore 1988) • Steep terrain and many deep gullies restrict cassowary movement • Local landowner has never sighted cassowaries or droppings on his property in six years	• Very high speed Highway • High traffic volume • Increasing traffic volume • Rail line • Secondary road west of rail line • Private property	• Speed reduction signs • Reduce road design speed • Wildlife overpass above the road • Increase dimensions of potential underpass to a bridge design • Standard warning signage OR • Non-standard warning signage • Temporary passive signage when animals are sighted crossing the road
	61	• Big Maria Creek • Footprints located east of Bruce Highway along creek heading towards bridge (12 July 2008) • Birds have been reported previously crossing the highway at the bridge		• Underpass at bridge – a higher bridge would improve effectiveness when highway is upgraded • Riparian rehabilitation to enhance corridor • Standard warning signage • Variable message signs turned on by rangers when recent crossings recorded OR • Temporary passive signage when animals are sighted crossing road OR • Signs with flashing lights when recent crossings recorded
	PC21	• A cassowary was reported crossing at this location in 1988 (Crome & Moore 1988) • No other known records		• Road-based driver alerts (rumble strips, painted road surface) • Standard warning signage

Road Section	Crossing Number	Comments	General Risk Analysis	Mitigation Options
				• Temporary passive signage when animals are sighted crossing road OR • Variable message signs put in place when recent crossings recorded • Underpass would assist with connectivity issues

6.2.2 Connectivity across the Bruce Highway at Smiths Gap for Rainforest – dependent Species including Cassowaries

The Bruce Highway is predominantly a two-lane road between Townsville and Cairns which provides a 340 km link between the cities. Approximately 99% of the sub-link between Townsville and Innisfail has a posted speed limit of 100kph (GHD 2005) and the majority of this transport sub-link has a capacity of approximately 20,000 vehicles per day (vpd). In 1998 the average annual daily traffic (AADT) in the Tully-Cairns section of the Bruce Highway was approximately 11,000 -12,000 AADT (GHD 2005). Growth over the past decade means current traffic level would be substantially greater. A traffic volume of this size would cause great difficulty for any cassowary that might attempt to cross the highway in the Smiths Gap area. Highways in Europe with 10,000 vehicles a day are considered complete barriers, with little or no wildlife surviving crossing attempts (Bank *et. al.* 2002). This conclusion is supported by other studies that showed high volume roads had the greatest impact in blocking animal movements (Brody and Pelton 1989, Rondinini and Doncaster 2002, Chruszcz *et. al.* 2003). Reduced landscape connectivity ultimately results in smaller populations and lower population viability (Ruediger 2000), highlighting the need to restore the movement of cassowaries across the Bruce Highway. To facilitate effective and safe cassowary movement across such a significant barrier is difficult. However, the development of safe wildlife corridors, either under and/or over the road corridor, provides the potential to restore some degree of natural cassowary movement, and reduce the worst impacts of habitat fragmentation. As a keystone species provision of connectivity should assist in maintenance of ecological communities. Requirements for cassowary connectivity also might be expected at the least to assist movements of other mobile rainforest-dependent faunal species. In this section the opportunities to reconnect the cassowaries east and west of the Bruce Highway using an effective cassowary movement corridor are explored.

4.2.2.1 Faunal movement corridor options at Smiths Gap

Although wildlife movement corridors can increase population persistence, an understanding of the species' requirements is critical in encouraging species use. The probability that an animal will utilise a corridor is directly correlated to the biological cost, time, and behavioural motivation the animal must expend crossing it (Rosenberg, 1997). The most effective corridors provide a safe travel route for an animal by providing a path with high habitat visibility and potential to escape from threats (Gibeau *et. al.* 1994). To encourage confidence and thus constancy of use, the structure of a corridor should resemble the actual habitat of the target species, as animals generally favour moving across familiar landscapes (Rosenberg *et al.* 1997; Goosem *et al.* 2001).,The effectiveness of a movement corridor depends on its location in the landscape, its connectedness to surrounding habitats, whether the vegetation reflects species-specific habitat preferences, and if there are acceptable opportunities to cross unimpeded elsewhere (Clevenger *et. al.* 2002). Many of the best examples of effective movement corridors incorporate riparian systems. In this case, we examine potential movement corridor options for cassowaries. Other options for movements of large animals include ridgelines, as was planned in the Kuranda Range road upgrade (Goosem *et al.* 2004).

The Walter Hill Range is separated from the majority of the World Heritage Area to the west by a narrow valley running north-south. The valley is approximately four kilometres in length and 0.7 kilometres at its widest point. It is traversed by the Bruce Highway and the main north-south rail line, as well as the Old Tully Road running along the base of the western part of the range. Also bisecting the valley is Hogan Creek which runs parallel to and west of the rail line, joining Big Maria Creek near the road bridge at the north end of the valley. Topography is generally steep to the east of the road, flattening out to the west of the road for a short distance (~500m) before rising once more into ranges. Although Smiths Gap is the name generally coined for the area, the actual location of Smiths Gap is at the south end of the valley and represents the narrowing of the valley floor at that point. Cassowaries are known to use the Walter Hill Range east of the road and cassowaries regularly visited a banana farm to the west of Old Tully Road from 1988-2001. Birds have occasionally been seen crossing the highway from east to west (Crome and Moore 1988, Moore 2000, 2003, Westcott pers. comm. 2009).

There has been uncertainty as to whether cassowaries could use existing large culverts to cross under the Bruce Highway. The field survey revealed that a number of culverts crossed under the Bruce Highway and the adjoining rail line, necessitating at least two journeys for cassowaries through the wide culverts to access the rainforest along Hogan Creek. Observations in Chapter 3 show that cassowaries, like some other large animals, do not like entering closed spaces, and it is highly improbable they would ever attempt such long and complex crossings at Smiths Gap. The external and internal views of the largest culvert under the Bruce Highway are shown in Figure 6.13. This culvert measured approximately 2.1m x 2.1 m with an arched profile and flat base internally. The length of the culvert was approximately 45 m; this distance would discourage use by cassowaries and most other larger vertebrates. The height of the culvert is considered insufficient for cassowaries (even the 2.5 – 3.5 m high culverts studied at Stony and Lacey Creek did not appear to be sufficient in height). Entry requires access via wading through a two metre deep pool.

Historically, observations of cassowary movement across the Bruce Highway at Smiths Gap are rare, but this may be a function of the general isolation of the area from potential places where drivers could report observations and the fact that crossing birds may not be reported because many drivers are likely to be long distance travellers. Cassowaries were sighted crossing the highway in 1988 (Crome and Moore 1988), and Bentrupperbaumer (1992) recorded birds crossing in the Smiths Gap area in 1992. Three crossing points were used by cassowaries to cross over the road from 1988-2001 (Moore and Moore 1988, 2003) with a fourth crossing located near Big Maria Creek bridge. More recently an adult cassowary was seen crossing the highway in the general area of Past Crossing #22 (D. Westcott pers. comm. 2009).

The Walter Hill Conservation Park, Warrubullen Conservation Park, and the railway reserve east of the Bruce Highway in the Smiths Gap area were surveyed for cassowaries in 2008-2009 as part of the Mission Beach cassowary road project. The objective of the survey was to establish whether the area was currently being used by cassowaries, and to locate any active cassowary crossing points across the Bruce Highway. Cassowary use of vegetation surrounding the Smiths Gap area appeared to be low, probably due to a combination of the steep terrain and highly disturbed vegetation along much of the Walter Hill Range and its lower slopes. The cleared areas along Old Tully Road may discourage cassowaries moving into the Hogan Creek forest from the west. When approached in 2008, most landowners along the Bruce Highway and the Old Tully Road had never seen cassowaries on their properties or observed them crossing the Bruce Highway. Apart from fresh cassowary footprints found along Big Maria Creek in July 2008, no cassowary activity was observed in the immediate area of Smiths Gap. Birds were located, however, along Telegraph Road (three kilometres east of Smiths Gap) and near Banfield Road approximately four kilometres east of the Bruce Highway (Figure 6.14). Recent droppings were also found along a narrow section of Big Maria Creek which traversed cleared agricultural land two kilometres north of Friday Pocket Road (Figure 6.14).

Figure 6.13
External and interior views of the largest culvert under Bruce Highway

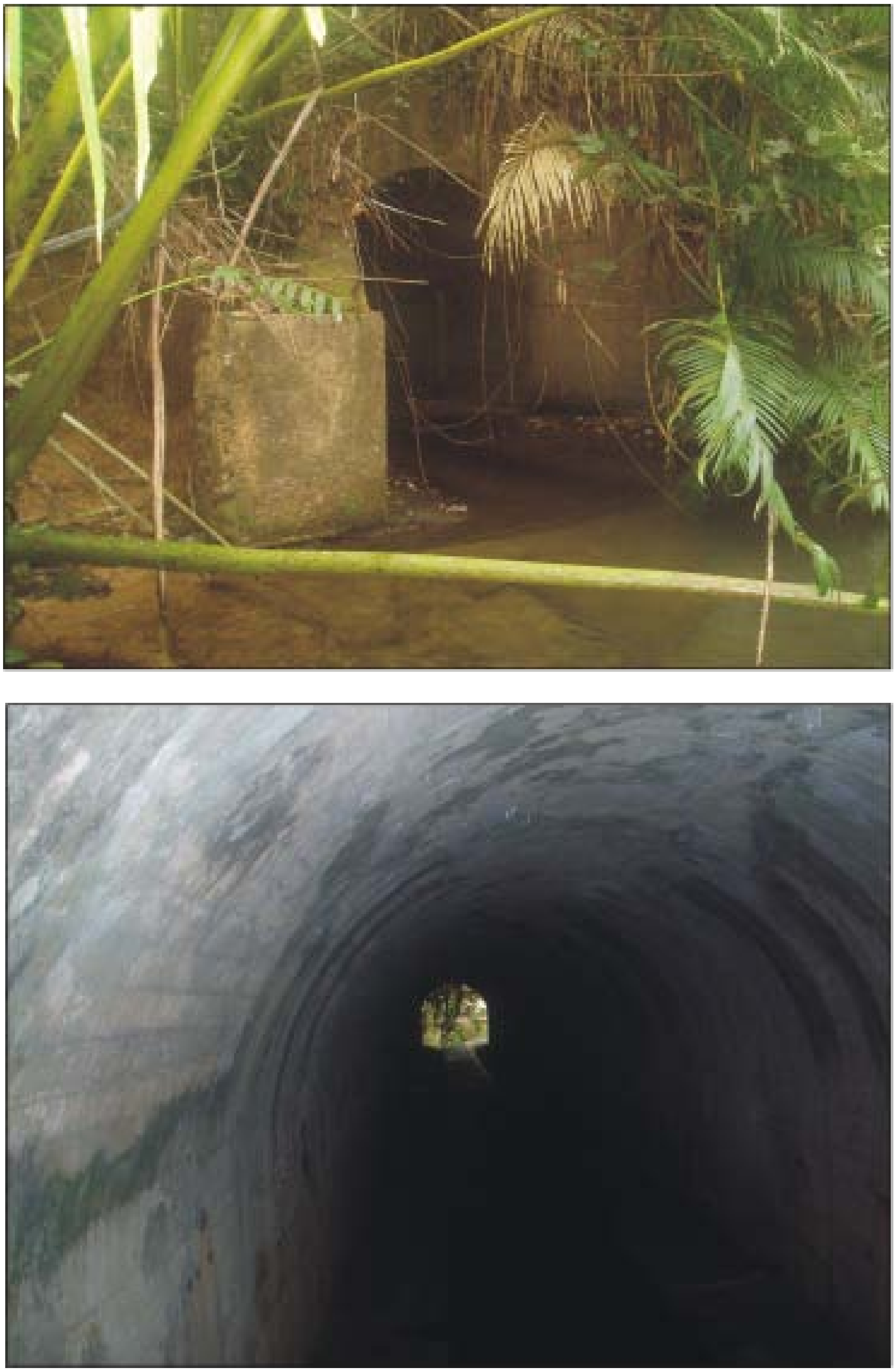
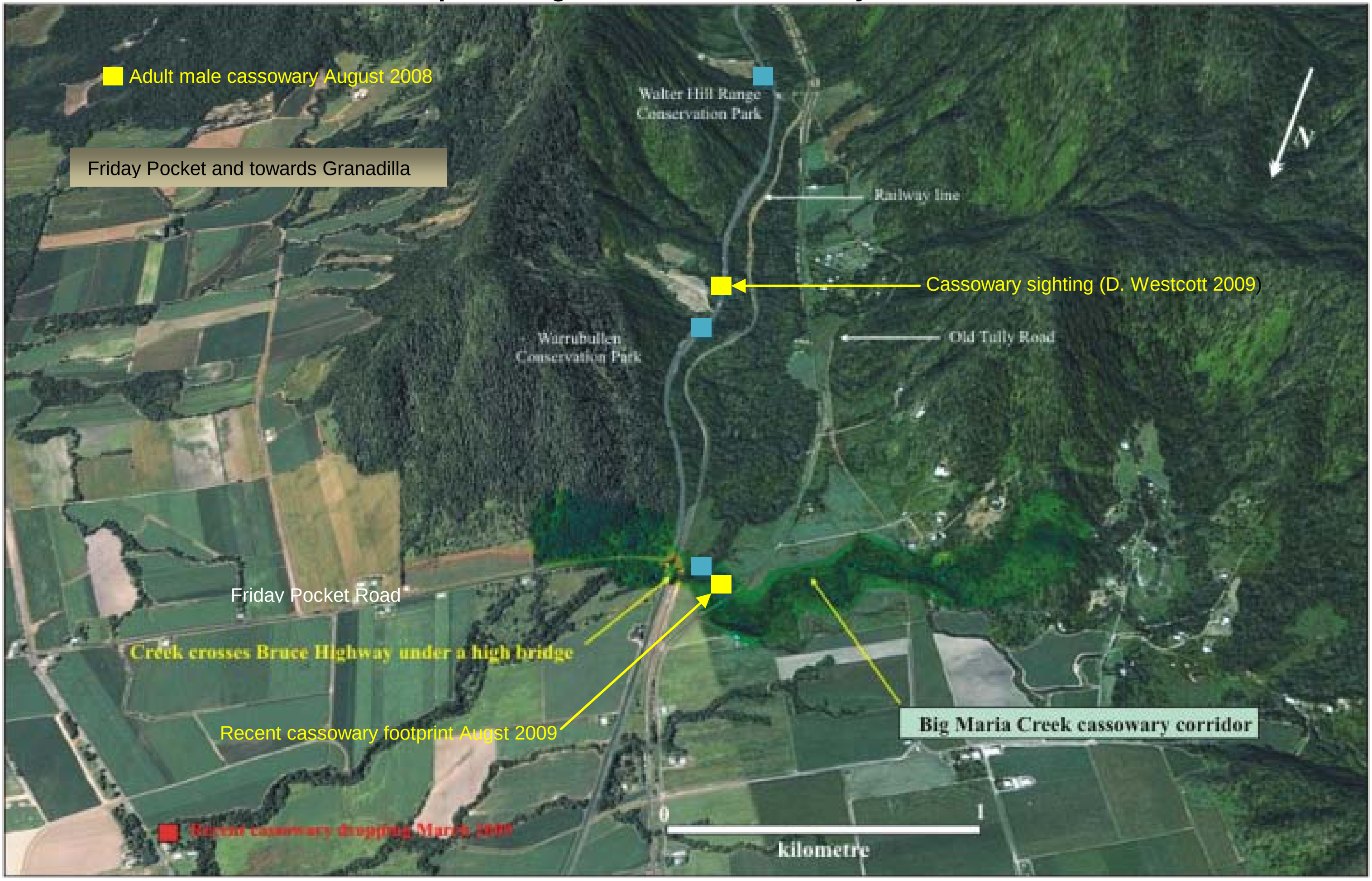
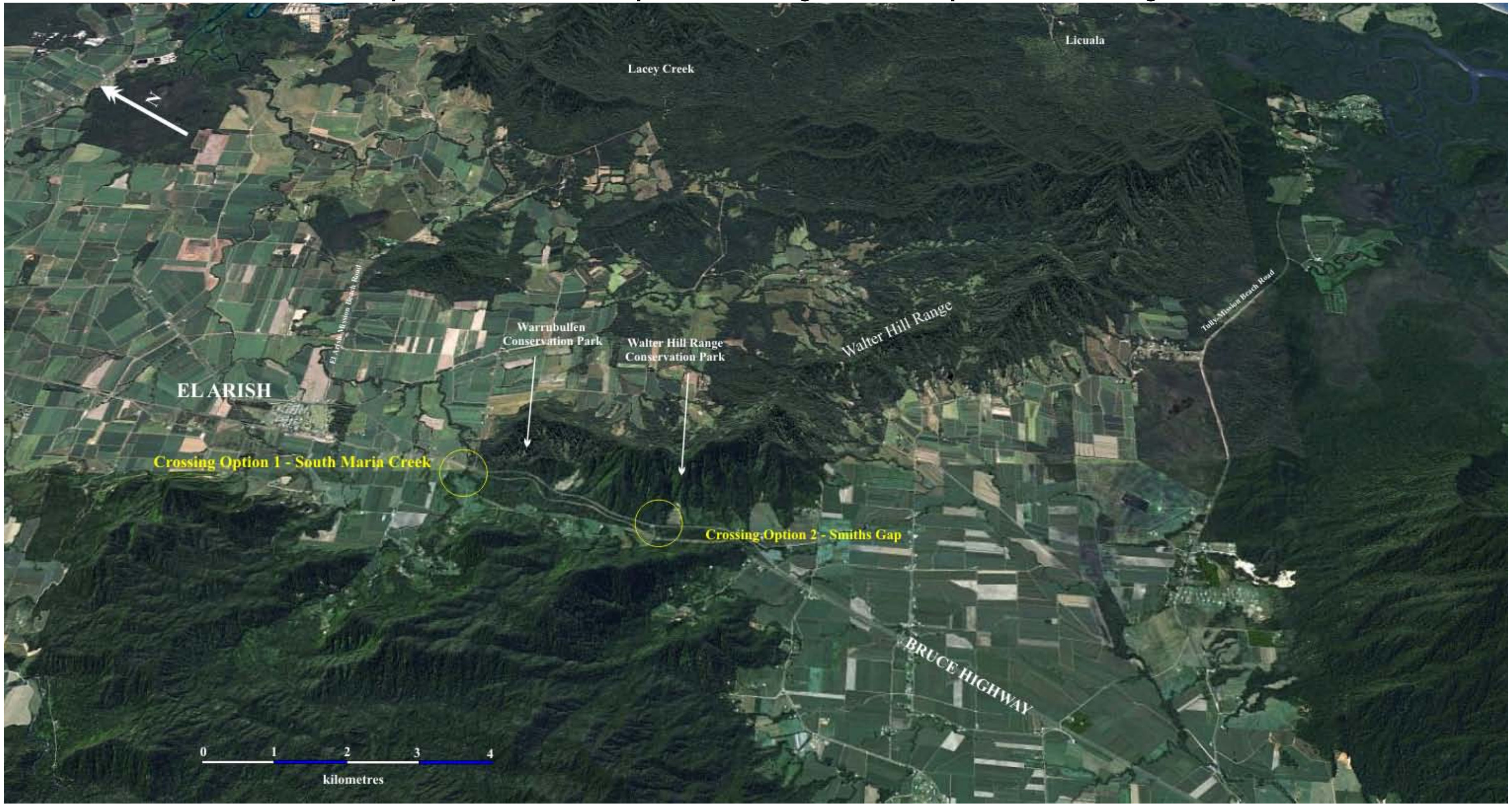


Figure 6.14
Proposed Big Maria Creek cassowary corridor



Blue squares = past crossing observations

Figure 6.15
Landscape view of Smiths Gap area showing location of potential crossing sites



6.2.2.2 Potential Crossing Points at Smiths Gap

Using the results of the 2008-2009 survey and historical data of sightings in the area, the potential for safe and permanent road crossing points was evaluated. The two most likely crossing locations are shown on Figure 6.15. The section of Big Maria Creek either side of Bruce Highway is proposed as the best option for an effective riparian cassowary movement corridor (Figures 6.14, 6.15 and 6.16). A second site, located at Smiths Gap at the southern end of the valley, is a possible site for a large wildlife overpass (land bridge) (Figure 6.15).

6.2.2.3 Big Maria Creek cassowary movement corridor option

The most promising location for a faunal movement corridor across the Bruce Highway is the riparian corridor of Big Maria Creek, at the north end of Smiths Gap (Figures 6.14, 6.15 and 6.16). Cassowary footprints were found along the creek near the Old Tully Road Bridge on 12 July 2008 and birds are known to have crossed the road in the past using the riparian corridor (Moore *pers. obs*. 1988-1998). The highway bridge area has been the site of Department of Environment and Resource Management and community rehabilitation efforts in the past. Big Maria Creek is permanent and connects to the uplands of the Walter Hill Range to the west; it is fed by the smaller tributary of Hogan Creek. Flooding occurs during the wet season and access under the bridge for cassowaries may be compromised at this time. This obstacle could be ameliorated by rehabilitation to widen the riparian strip allowing cassowaries to move along the creek banks as well as within the stream itself. Landholders who contribute to the corridor should be offered incentives to retain and enhance habitat such as through voluntary covenants and revegetation. Department of Transport and Main Roads should plan for upgrading the bridge to greater height for a more effective fauna crossing in future major works in the area. Implementation of those plans should form an essential part of any upgrade.

Figure 6.16
Location of Big Maria Creek bridges with place names discussed in the text

6.2.2.3.1 Creek vegetation near Bruce Highway

The following photographs (Figures 6.17 – 6.21) show the general state of the riparian corridor and its location in the landscape**.** They clearly illustrate the requirement for rehabilitation particularly under the Bruce Highway bridge and railway bridge, and along the creek bank near the Old Tully Road bridge and railway bridge

Figure 6.17
Big Maria Creek at the Old Tully Road Bridge - looking west

Figure 6.18
Big Maria Creek at the Old Tully Road Bridge - looking east towards highway

Figure 6.19
Big Maria Creek near Bruce Highway Bridge looking east along the creek

Figure 6.20
Big Maria Creek near Bruce Highway Bridge 2 looking west from same location as Figure 6.19 showing the two bridges

Figure 6.21
Views of Rail Line Bridge and Bruce Highway Bridge areas

Railway bridge on Big Maria Creek looking west

Railway bridge looking east with Bruce Highway bridge in background

Bruce Highway bridge looking east

Bruce Highway bridge looking west with railway bridge in background

Bruce Highway bridge showing the height above ground and large area for rehabilitation

6.2.2.3.2 Friday Pocket Road cassowary crossing

As cassowaries using Big Maria Creek would have to cross Friday Pocket Road to enter the Warrubullen Conservation Park, road mitigation will be required to get them across the road safely. Figures 6.22 and 6.23 show the vegetation adjoining the road at the probable crossing area. Currently the Big Maria Creek option represents the best opportunity for providing an effective east-west wildlife linkage across the Bruce Highway for large species in the southern Wet Tropics region. Accordingly, one option for consideration should be the feasibility of closing this end of Friday Pocket Road. Landowners have alternative access just south of the township of El Arish. This would consolidate and enhance the rare lowland – upland connectivity this Big Maria Creek linkage represents for larger species. However, it may be possible to use alternative options such as traffic calming if traffic volumes and speeds are established by monitoring to be low.

Figure 6.22
View of Friday Pocket Road looking east from the junction with Bruce Highway

Figure 6.23
View to the west with Bruce Highway in the far background

6.2.2.4. Walter Hill Conservation Park Crossing Option

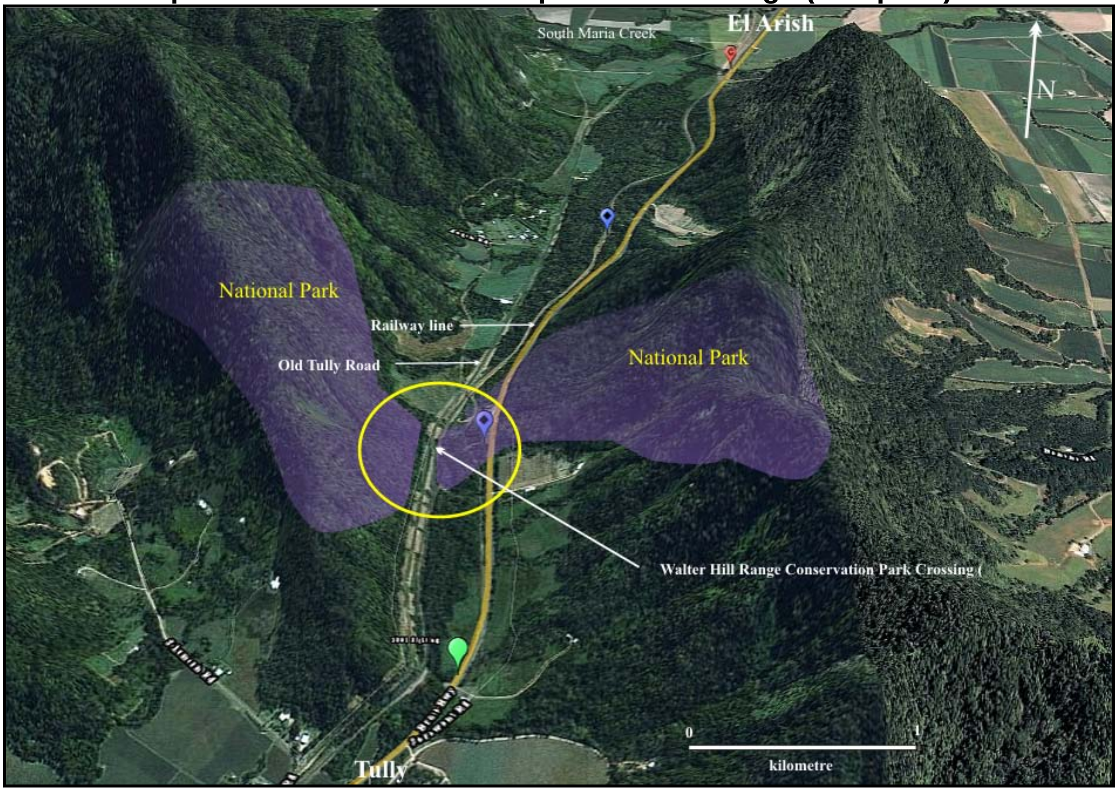
The Bruce Highway is a major highway with high traffic volumes and a posted road speed of 100kph. The width of the road corridor varies along its length through Smiths Gap but generally approximates 40-50 metres from canopy to canopy (Figure 6.24).

Figure 6.24
Typical view of road corridor along Bruce Highway in Smiths Gap area

Attempting to get cassowaries across the road surface itself is not realistic as the Bruce Highway is both a high speed road and a major north-south transport corridor for cars and trucks. Culverts under the road are not effective for cassowaries although retro-fitting those in existence may assist other species to cross the highway. For cassowaries, the only mitigation options likely to be effective are a raised bridge (underpass), or a wildlife overpass (land-bridge). Both strategies are expensive undertakings and a high expectation of success would be required before deciding on this mitigation approach. Raised bridge-style underpasses are known to be effective for cassowary movement if furnished and revegetated with cassowary food plants (Chapter 3), although means of ensuring birds could not access the highway would be required.

It also appears very likely that cassowaries would make use of wildlife overpasses, again ensuring that birds could not gain access to the highway and that noise barriers were in place on the overpass. These could take the form of a solid wooden fence. For wildlife overpasses the tenure of the land either side of the road is important. Overpasses require extensive earthworks at either end and will need to be maintained and monitored for many years following construction. The location should be informed by a study of surrounding tenure, landforms and habitat connectivity to east and west. Should this study identify a location including private property, voluntary acquisition may be an option. Otherwise, there appears to be only one suitable location within the Smiths Gap area where the ownership of the land either side of the highway is within the conservation estate (Figure 6.25). The overpass would also need to straddle the rail line, with road-based mitigation a possible option for the Old Tully Road. Given the high cost of constructing overpasses ($1-2 million dollars) this option would require a feasibility study to be conducted evaluating the probability that effective numbers of cassowaries will use the bridge.

Figure 6.25
Location of possible site at Smiths Gap for a land-bridge (overpass)



6.2.3 Summary of connectivity options at Smiths Gap

A long term plan needs to be developed for enhancing ecological connectivity across Smiths Gap. The area has a critical role in providing connectivity between the uplands and lowlands and remains the best opportunity south of the Daintree to achieve such connectivity. The Mission Beach – Southern Atherton Tablelands Rainforest Connection could provide connectivity for rainforest-dependent species, communities and ecological processes in the face of climate change; however Smiths Gap forms an important obstacle that must be overcome for this corridor to be effective in allowing rainforest biota to adapt to climate change. This corridor between uplands and lowlands is currently the subject of efforts to improve connectivity including Caring For Country initiatives of revegetation in the uplands and forms part of the Mission Beach Habitat Action Network Plan (Hill et al. 200.

6.2.3.1 Big Maria Creek riparian corridor

Given the support of local landowners and adequate funding, it is highly probable that effective connectivity can be achieved for cassowaries (and other species) between Walter Hill Range and the major sections of the Wet Tropics World Heritage Area west of the Bruce Highway using the riparian corridor of Big Maria Creek. The total length of this riparian corridor is approximately 1400 metres. Cassowaries have historically used the creek to cross the highway, both across the road and under the bridges, and evidence of recent usage was found in this study. The three bridges along Big Maria Creek are all suitable underpasses for cassowaries, being high structures with a relatively narrow width and bright visual profile. There are extensive opportunities for rehabilitation in the area surrounding the bridges (refer to Figures 6.17-6.21) and vehicle access is reliable for most of the year. The width of the riparian corridor varies from approximately 30 m at its narrowest point at Old Tully Bridge to approximately 170 m at the western end of the corridor. There is potential to widen the riparian corridor considerably at the Old Tully Bridge (Figure 6.18).

6.2.3.2 Smiths Gap crossing

Historically, records of cassowary movement across the Bruce Highway at Smiths Gap are rare, but this may be due to the isolation of the area and the fact that crossing birds are not reported by drivers who are generally long distance travellers. To restore or improve cassowary connectivity between Walter Hill Range and the World Heritage Area (WHA) to the west by constructing and maintaining a land bridge would be an expensive undertaking. Nonetheless, it would be worthwhile if there was a high probability of sufficient numbers of cassowaries locating the bridge and crossing it. In the current circumstances this outcome would appear unlikely. However, a feasibility study is required to provide the information necessary to fully evaluate the practicality and likely success of constructing this mitigation structure at Smiths Gap. A land bridge would be likely to assist in movements of many other faunal species, provided adequate vegetative cover and faunal furniture was established to allow faunal movements. Such a structure has proven successful in more open habitats in south-eastern Queensland (Bond and Jones 2008).

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MISSION BEACH ROAD IMPACTS ON CASSOWARIES AND OTHER VERTEBRATES

SECTION 7:

SYNTHESIS – TOWARDS AN INTEGRATED STRATEGY FOR ROAD MANAGEMENT IN THE MISSION BEACH REGION

7. SYNTHESIS – TOWARDS AN INTEGRATED STRATEGY FOR ROAD MANAGEMENT IN THE MISSION BEACH REGION

Miriam Goosem

Summary.

Options for mitigation of road mortality and barrier effects for cassowaries are first discussed at the level of government policy and manuals for road measures. Landscape level needs to improve connectivity across the Bruce Highway and the major Mission Beach entry roads have been considered. These include the need to reduce vehicle speeds on all the major Mission Beach Roads and potential means of achieving this described. Several examples of sites where mitigations are of high priority are then described in greater detail. All measures need to be integrated to avoid overload of particular measures and driver habituation. The best way to achieve an integrated strategy for road management in the Mission Beach region is through consensus obtained between stakeholders in a series of workshops that discuss these mitigatory measures.

7.1 INTRODUCTION.

There are two major reasons for mitigating the impacts of roads on cassowaries and other fauna in the Mission Beach area. The first requirement is to ensure habitat connectivity at both the landscape and individual home range levels, thereby reducing fragmentation. The second requirement is to reduce the toll of road mortality inflicted by road mortality on the cassowary and other species, itself a contributor to fragmentation of the faunal populations. The cassowary forms an excellent flagship species for consideration of means to reduce these impacts. Although road mortality is the road impact that has received the greatest amount of attention, there are reasons that landscape fragmentation by roads should be considered to be just as serious. These include the isolation of the Mission Beach population from the major rainforest habitats of the Wet Tropics to the west and the way that the major roads entering Mission Beach and servicing each village bisect the remaining large blocks of rainforest habitat on which the birds depend.

An integrated road management strategy must be determined through consultations between all stakeholders. These include those that will provide the policy and construction capabilities where necessary, those who will fund the strategies (not mutually exclusive) and those that will be affected by the implementation of the strategies, together with those that can provide advice. We propose that workshops be instigated between all stakeholders to consider the variety of options listed within the foregoing chapters and integrated below. Participation in these workshops should include Queensland Transport and Main Roads; Cassowary Coast Regional Council; Queensland Department of Environment and Resource Management; the Wet Tropics Management Authority; Federal Department of Sustainability, Environment, Water, PAC; Terrain Natural Resource Management; indigenous representatives; conservation and tourism group members and experts from research institutions. As this describes the participants in the Mission Beach Habitat Action Network, we would hope that this body could coordinate such workshops. Coordination by a group such as MBHAN representing all sectors will be preferable to ensure all views are heard and considered.

7.2 STATE GOVERNMENT POLICIES AND MANUALS

7.2.1 State Planning Cassowary Conservation Regulatory Provisions and State Government Supported Community Infrastructure Cassowary Conservation Policy in Mission Beach area

Because it is difficult for Transport and Main Roads to reduce speed limits or road design speed without explicit and clear reasons under current legislation, **State Planning Cassowary Conservation Regulatory Provisions for Mission Beach** and a **State Government Supported Community Infrastructure Cassowary Conservation Policy for Mission Beach** should be developed as an extremely high priority. State planning regulatory provisions are statutory instruments that can specify categories of development, require master planning, implement a regional plan or address a risk of serious environmental harm. They override all other State instruments and plans. State planning policies are 10 year policies which override local planning instruments.

The cassowary regulatory provisions and policy should be very similar to the State Planning Koala Conservation Regulatory Provisions and State Government Supported Infrastructure Koala Conservation Policy which were implemented in May 2010. These require State Government supported community infrastructure providers to minimise and mitigate threats to koalas and koala habitat associated with development, including, for example, car strike and dog attacks, unless complete compliance with the provisions would significantly impact on the State's ability to deliver important community infrastructure. The Policy statement and principles state that the planning, design and construction of State Government supported community infrastructure in the SEQ Koala Protection Area is to be carried out in a way that reduces adverse impacts to koalas and koala habitat and conforms with the Queensland Government's commitment to leadership on koala habitat protection in south-east Queensland. All government supported community infrastructure providers must ensure site design provides safe koala movement opportunities, including koala movement infrastructure, as appropriate to the development type and habitat connectivity values of the site. It appears that koala conservation policies allow at least trial speed reductions on main roads through designated koala habitat in parts of South East Queensland (Dique *et al.* 2003).

The State Government Supported Infrastructure Koala Conservation Policy describes similar policies for State Government infrastructure providers as required by the State Planning Policy for Koalas (DERM, May 2010). This is used to **inform land use planning** undertaken by state and local government, and infrastructure providers to ensure koalas and koala habitat conservation measures are reflected in planning schemes, structure plans, master plans, local area plans, community infrastructure designations and biodiversity development offset areas. Planning decisions made in the South East Queensland Koala Protection Area (SEQKPA)—the seven eastern local government areas of South East Queensland—must include strategies and measures to respond to potential conflicts between achieving koala conservation objectives and development. A key goal of the SPP is to maintain the viability of all major koala populations across the region by increasing the size of their habitat. To achieve this, the SPP requires that planning must identify koala habitat values; protect significant areas of koala habitat value; ***retain and enhance connectivity to maintain koala population viability; maximize koala safety and movement through design and layout of development;*** achieve a net gain in koala habitat through offsets and other mechanisms; ensure preferred dominant land uses are consistent with the policy aims.

These two statutory instruments would allow greater flexibility to State Government entities in providing for cassowary conservation measures associated with roads in areas of high density cassowary populations.

7.2.2 Draft Queensland Biodiversity Strategy

The Draft Biodiversity Strategy for Queensland which is currently before Cabinet contains several priority actions that may assist Queensland Government entities that wish to include provisions regarding cassowary conservation, such as improving connectivity and reducing road mortality.. These come under the heading:

Continue to monitor threatened species and populations and review the effectiveness of actions:
5. Identify and protect priority areas for species of iconic and cultural importance.
7. Develop a Cassowary Rescue Plan in collaboration with key stakeholders in the Mission Beach area.

One of the targets by 2020 is to recover or reduce further declines of 10 priority species. The cassowary is described as an iconic species. Figure 7.1 is the image attached to those targets. Another target is to establish a minimum of three viable populations for at least five of Queensland's iconic species with population levels considered to be 'at risk'.

Another target is to increase connectivity across the landscape – there is no question that roads decrease connectivity in the landscape by decreasing wildlife movements through barrier effects and/or road mortality.

Figure 7.1 Image from the Draft Queensland Biodiversity Strategy 2011

Photo: Draft Queensland Biodiversity Strategy (2011)

7.2.3 Queensland Transport and Main Roads Manual

Advice from Queensland Transport and Main Roads personnel is that there are provisions within the QTMR Manual for Uniform Traffic Control Devices (August 2011) for reducing speed environments, which can be applied in ecologically sensitive areas. Speed limits can be reduced for environmental reasons provided the case is made extremely clear. It appears that the policy and strategy sections listed above would serve this function.

7.3 BROAD-SCALE LANDSCAPE MITIGATION MEASURES

The first set of road mitigation measures comprise broad-scale landscape measures that aim firstly to reduce fragmentation of cassowary populations and secondly to reduce road mortality of individual cassowaries. Connectivity across the landscape is necessary to allow movements of individuals within the Mission Beach area and also to reduce isolation of the Wet Tropics population, allowing gene flow and providing for normal population recruitment and emigration, particularly in the face of catastrophes such as cyclones or disease. When viewed in relation to the best available population estimates, the numbers of individuals removed by road mortality in the Mission Beach area is high and mitigation against this population drain must be instigated to reduce this loss in a long-lived and slow-reproducing endangered species.

7.3.1 Reconnecting the Mission Beach population with major rainforest habitats to the west

To maintain a healthy and viable Mission Beach cassowary population in the long-term, landscape-scale habitat connectivity through the Walter Hill Range with the populations in the major rainforest habitats to the west must be re-established. Although there are several reports of crossings of the Bruce Highway in the past, the current level of population connectivity is unlikely to be sufficient to maintain genetic diversity, protect against stochastic events in demographics or to allow immigration to the population from elsewhere following catastrophes such as Cyclones Larry and Yasi. At the current traffic volume of >12,000 vehicles per day, there is unlikely to be a sufficient break in traffic flow to allow safe crossings. Therefore alternative means of providing connectivity for wildlife is required.

7.3.1.1 Mitigation strategies for immediate implementation

The Bruce Highway bridge over Big Maria Creek forms part of a connectivity corridor, the functionality of which is partially jeopardised by gaps in continuity. The most important current need is to undertake more revegetation to strengthen revegetation undertaken by DERM in the past. This should occur under the highway bridge, and also along the creek banks and under the railway and Old Tully Road bridge to create a vegetation strip along each of the creek banks of at least 50 m in width. The importance of this corridor has been emphasised in the Mission Beach Habitat Action Network Plan. Expansion of creekside vegetation to create a wider corridor should be the next step, as data from the Mossman Lowlands show that corridors should be at least 50 m wide on either side of a creek and wider (100 -200

m) corridors provide habitat or means of movement for the greatest variety of rainforest fauna (Lawson *et al.* 2007).

7.3.1.2 Mitigation strategies for consideration in the medium-term

Elevating the Big Maria Creek bridge to create a more open span would assist in improving the connectivity for cassowaries of the riparian vegetation and could form part of future road upgrades.

To provide an alternative connectivity route across the Bruce Highway, replacement of the large culverts currently installed under the highway with a second high bridge would create the level of openness under the highway that should encourage animal movements. Care would need to be taken to ensure the entrance points were functional (i.e. not too steep and revegetated) and that the rail and road line crossings were likewise suitable for cassowary use. Alternatively construction of a wildlife overpass to connect land under conservation tenure could be considered in future highway upgrades.

7.3.2 Reducing cassowary mortality through speed reductions along major Mission Beach Roads

Road mortality forms about two-thirds of known deaths within the cassowary population. Forested and nearby sections of the Tully-Mission Beach Road, the El Arish-Mission Beach Road and the South Mission Beach Road are the major areas where road mortality of cassowaries occurs in the Mission Beach area. Within the DERM cassowary mortality database between 1992 and 2010 these roads have recorded TMB: 22 (38.6%); EAMB: 15 (26.3%); SMB: 10 (17.5%) of total road mortality, with the Cassowary Drive section of the EAMB Rd also recording 8 (14.3%). More recent road deaths have also occurred on these roads.

The speed a vehicle is travelling has a large influence on the number of animal-vehicle collisions and their severity (Chapter 5). A reduction in vehicle speed allows both drivers and wildlife more time and distance to respond and possibly avoid a collision (Knapp *et al.* 2004; Forman *et al*. 2003; Huijser and McGowen 2010). The lowered speed also results in shorter stopping distance which assists in avoiding or reducing the severity of a collision. Reducing vehicle speed from 100 kph to 80 kph in Tasmania has been estimated to reduce overall road kill by 50%.

Therefore, reducing vehicle speed is the mitigation measure that should produce the greatest reduction in cassowary road mortality, until further upgrades of these roads occur which include incorporation of further crossing structures and some means of preventing access by cassowaries to the road surface whilst crossings occur above or below it.

Reducing vehicle speeds along the forested road sections from 100 to 80 kph and from 80 kph to 60 kph would be expected to reduce cassowary road mortality substantially. Calculations show that this would only increase the length of time taken to drive the 13.7 km forested section of the Tully-Mission Beach Road between South Mission Beach Road turnoff and Merryburn by about 2.8 minutes. Likewise the 8.2km forested section of the El Arish-Mission Beach Road between the current 80 kph sign near Mission Beach and the Bingil Bay Road turnoff would increase in travel time by less than 2.05 minutes. The increase of journey time along the South

Mission Beach Road would be only 40 seconds. The extra time on the Cassowary Drive section of the El Arish – Mission Beach Road (about 2.2 km) would be in the order of 30 secs.

To achieve this speed reduction would require:

1) Reducing the legislated speed limit in those forested sections by 20 kph;
2) Reducing the design speed of the road in those sections.

There is a large body of evidence which demonstrates that reducing speed limits alone will not result in actual reduced vehicle speeds if road design remains the same (Chapters 5 and 6). This is because many drivers will still perceive that the previous speed is safe and continue to drive at that speed. Additionally, those drivers who do reduce speed are likely to induce others to overtake, with ramifications for driver safety. So mitigation measures to reduce road design speed must also be included in a final strategy. These include traffic calming measures such as roundabouts at side entry roads, reducing wide roadside clearings by replanting with low vegetation, inclusion of chicanes and speed humps on low speed roads and greater speed enforcement including speed cameras or signs that provide information about speeds. Potential sites for inclusion of these measures are discussed under particular target areas of these roads.

7.4 SITE SPECIFIC MITIGATION MEASURES

Although decisions on the integrated road management strategy need to be a consensus of all stakeholders, some examples for specific high-priority sites are given below to provide a starting point for discussions. These do not negate the need to consider all the road sections and potential crossing zones described in Section 6 of this report.

One of the key considerations should be to avoid over-saturation of similar signage or mitigation measures that could just cause irritation in drivers and lead to drivers ignoring the majority of measures. Varying the type of measure used on a particular road stretch is therefore important.

7.4.1 Speed Reduction Measures

Major reductions in cassowary road mortality along the Mission Beach roads in the short-term could be achieved by reductions in speed limits and road design speed. This necessitates reduction inclusion of measures that will reduce road design speeds of the roads. In the long-term inclusion of road crossing structures must form part of the mitigatory measures in future road upgrades, which would also improve connectivity (See Section 7.3.2).

Potential speed reduction mitigation measures are suggested for discussion in the integrated road management workshop. Measures considered were discussed in Chapter 6 and include:

a) Speed limit reduction;
b) Road design speed reduction through:
    - Roundabouts
    - Speed humps or chicanes;

c) Speed limit enforcement through:
   - Policing;
   - Speed camera installations;
   - Active message signage that displays driver speed or recent cassowary crossing message when activated by a speeding vehicle;

d) Road-based driver alerts such as painted surfaces, painted crossing areas and rumble strips;

e) Temporary signs of three types:
   - Cassowary crossing signs currently in use;
   - Recent cassowary death signs in place for several weeks;
   - Variable message signs that can be moved into place and convey warnings of recent crossings or deaths.

f) Permanent signs of two types:
   - Standard warning signs;
   - Non-standard warning signs e.g. current large cassowary-vehicle collisions signs, signs produced by community members e.g. school children (Terrain NRM 2010).

7.4.2 Other Site-Specific Mitigations

Where the topography allows, crossing structures in the form of high bridge underpasses at creek crossings and an overpass trial over the Bruce Highway have been suggested for inclusion in future road upgrades. High bridge underpasses may be combined with specially-designed cassowary fencing that guides birds towards the structures, provided future trials demonstrate:

a) that the fence provides a satisfactory guidance measure;
b) that fencing does not encourage birds to cross at the ends of the fence in dangerous positions;
c) that return to habitat measures through the fence are effective and birds do not become trapped on the road;
d) that potential antagonistic encounters between individuals are avoided as expected; and
e) that predators do not associate with the structures – not observed for other crossing species at other Wet Tropics sites.

A trial of animal detection systems at one of the priority sites where topography is optimal for sensors may also be considered.

7.5 SITE-SPECIFIC MEASURES

There are several important sites that should be considered for particular mitigatory measures, based on one of four criteria (Clevenger and Ford 2010; Huijser and McGowen 2010):

a) Hotspot for cassowary mortality;
b) Large numbers of crossings observed in the area;
c) Road design currently encourages high speeds;
d) Landscape connectivity has been compromised by barrier effects of roads.

However, by discussing these in more detail, we do not signify any reduction in the importance of including an integrated system of measures along all the forested sections of the major roads. These provide examples of measures that could be achieved in the short term and are supplemented by other mitigations that would require a longer-term focus.

In all cases the temporary signage installed by DERM personnel when cassowary crossings are recorded should be a continuing measure. These could be alternated with temporary variable message signs on trailers moved to recent crossing sites. Similar temporary signage that denotes when and where a cassowary has died and is left in place for several weeks could extend this measure.

7.5.1 Carmoo - Lindsay Road area on Tully-Mission Beach Road (#40)

As the crossing zone with the greatest level of cassowary mortality (**12 cassowary deaths** recorded in DERM cassowary mortality database between 1992 and 2011), the Carmoo-Lindsay Road area becomes one of the highest priority sites for **immediate implementation** of mitigation measures. There are also **18 crossings** and 10 roadside sightings recorded in the C4 cassowary sightings database. A **recent death** from vehicle strike was recorded. Speeds are high in this area and sight lines are very poor because the road does a large, sharp curve in that position. Deaths and crossings commonly occur either near the banana farm east of Lindsay Road or in the narrow riparian strips close to the Lindsay Road turnoff.

Speed limits should be reduced immediately to 60 kph. The extremely high mortality level suggests that more expensive means of decreasing speeds and increasing sight lines are warranted. Inclusion of a roundabout at Lindsay Road would reduce the design speed and ensure that speed limits of 60 kph at the connectivity areas near the Lindsay Road turnoff and near the banana farm are observed. A roundabout could also provide increased visibility at the curve. Simply reducing the speed limit is extremely unlikely to result in those limits being observed (Chapters 4, 5).

An important consideration in this area is to ensure that bananas are not easily available to the cassowaries. A fence surrounding the banana farm, covered in shade cloth so that cassowaries cannot see through to the fruit source would assist with this. This fencing could be provided to the farmer as a conservation measure. Maintenance of fencing would be a priority to ensure breaches are fixed immediately.

These measures should be monitored and maintained to ensure that visibility is improved during implementation, that they remain in satisfactory condition and that vehicle speeds are reduced in the crossing areas.

7.5.2 El Arish – Mission Beach Road between Bingil Bay turnoff and Mountain View Close (PC17 and #46)

As the crossing zone with the second highest degree of cassowary mortality (**6 cassowary deaths** in DERM mortality database 1992-2011) and an area where crossings and roadside sightings have been recorded in the C4 database, with many more reported by nearby landowners, this zone is also afforded a very high priority for **rapid implementation** of mitigation measures. A **recent death** was recorded. This is a high speed road section with a very poor line of sight in most of the section due to curves, crests and dips in the road. A cassowary fence covered in shade-cloth was implemented within the forest several years ago to encourage birds not to cross near Mountain View Close and instead encourage crossings in the area with the greatest line of sight within the road section (near the lettuce and herb farm). The fence was repaired after Cyclone Larry but its current state of repair is unknown. The effectiveness of this fence before or after Cyclone Larry is unknown due to difficulties in monitoring.

Vehicle speed limits should be reduced to 60 kph immediately and some form of road-based traffic calming implemented to complement this if possible. In this section the poor line of sight may require careful consideration of safety factors for drivers, so provision of road-based traffic calming may be difficult. The implementation of speed enforcement in this section, possibly in the form of speed camera installations in which cameras are placed at unknown intervals, or signs that register the speed of a vehicle (Chapter 5) could provide a means of achieving a reduced speed in this area. Driver alerts in the form of rumble strips or painted crossings on the road surface could also increase awareness, although unlikely to cause reduced speeds in habituated drivers.

Assessment of the condition of the fence after Cyclone Yasi, and maintenance as required is recommended. Monitoring of effectiveness was not feasible in the past, so a greater distance cleared of undergrowth of >1 m adjacent from the fence would allow provision of larger sand tracking pads would assist in providing a more feasible monitoring scheme. If monitoring demonstrated that cassowaries are guided by the fence, extension towards Lacey Creek for another 50 m would encourage birds to cross further from the blind crest and curve at Mountain View Close.

***Future options**:*
The low spot and small creek may provide potential for a bridge underpass during road upgrades in future.
Alternatively the crest and Mountain View Close entry may be a site for alternative traffic calming options in future upgrades when removing visibility issues.
The crossing site near the creek also provides potential for trials of an animal detection system that reacts to cassowary presence as crossings tend to occur in a relatively short zone. However, care would need to be taken to ensure drivers did not depend on the system for warnings as the potential would remain for birds to cross elsewhere.

7.5.3 El Arish – Mission Beach Road near Lacey Creek (#48, 49, 50)

Lacey Creek crossing zone has seen ***at least two deaths*** (with more likely to have gone unrecorded) together with one noted during study surveys. There are many crossings and roadside sightings at this site, possibly due to the generally good habitat and more tourists being present in the area. Traffic currently travels at an average speed of 73 kph in this area, although much higher maximum speeds have been recorded (Chapter 4). The speeds at this site are possibly slower than other sections of the road that were monitored due to visitor vehicles entering and exiting the picnic ground and walking track, the large non-standard cassowary-vehicle collision sign attracting tourist interest, and the large curve necessitating slower speeds. Current rumble strips leading to the area and painting of road verges may have limited effectiveness, although the other reasons for slower traffic in the area are the more likely cause for slower speeds. Many visitors also cross the road at this site to access the walking track.

The speed limit should be reduced immediately to 60 kph. Speed enforcement by hand-operated radar is possible in this section of road due to pull-off zones. Other needs are a reduction in design speed which could be achieved by a variety of traffic calming options. One possibility is islands/chicanes allowing slow speed exit to the picnic ground. Safety for visitors could also be included with a pedestrian crossing and warning signage regarding this together with increased depth of rumble strips, with the concomitant effect of speed reduction assisting safe cassowary crossing.

Future Options:
As data show that the culverts at Lacey Creek do not function as effective underpasses, future road upgrades should consider creating a higher bridge providing more open under-road passage and vegetation underneath. Due to visitor access to the picnic ground, cassowary guiding fencing would not be able to be instituted at the site, unless configurations were changed. Fencing could only be considered if trials of 7.4.2 above were successful.
Lacey Creek provides a possible site for trials of animal detection systems in the future when reliability problems have been overcome and vehicles and people can be satisfactorily electronically screened out of the data.

7.5.4 Beantree Track entrance, El Arish – Mission Beach Road (# 54, 51-53)

This site registered a high number of crossings in the C4 cassowary crossings database with ***several deaths*** also recorded, one relatively recently. Speed limits are high, although the wide curve and climb to Fenby Gap probably restricts actual speeds somewhat. Driver sight lines are poor due to the curves, other than at the Beantree Track to Licuala entrance itself.

Speed limit should be reduced to 60 kph. This section also provides potential for enforcement in the form of vehicle-based speed cameras due to the track pull-off zone. In the road section between Lacey Creek and the Beantree Track (Crossings 51- 53, Chapter 6), a sign that detects speeding vehicles and alerts drivers to their speed could be installed at one of the crossing zones. Alternatively speed camera stands could be installed that allow random rotation of a camera between several stands. Rumble strips or painted crossing zones could alert drivers to this potential for enforcement.

Future Options:
Due to the numerous small dips with small streams and crests in the section between Lacey Creek and the Beantree Track entrance, the topography has potential for elevating sections of the road to provide connectivity with high bridge underpasses should be considered in road upgrades.
Animal detection systems may be able to be installed at Bean Tree Track entrance when they become more reliable and vehicles are able to be electronically screened out.

7.5.5 South Mission Beach Road intersection with Tully – Mission Beach Road(# 22,23)

This area and the adjacent Cassowary Drive section of the El Arish-Mission Beach Road, the beginning of the South Mission Beach Road and Hull River area of the Tully – Mission Beach road all have many road crossings and roadside sightings in the C4 cassowary sightings database. There have been at least ***4 cassowary deaths*** between here and the police station and ***another death*** near the Hull River bridge. Although traffic may slow for the South Mission Beach turnoff, this is not invariably the case.

Speed limit should be reduced to 60 kph. A roundabout at this major intersection would not only reduce speeds and increase driver reaction times and therefore reduce the potential for cassowary mortality but allow traffic flow from all three directions. It would also cause slowing of traffic from the Cassowary Drive section of El Arish-Mission Beach Road where a number of deaths have occurred.

7.5.6 South Mission Beach Rd intersection with Wheatley Road(# 26,27, 29)

This area has ***8 cassowary road deaths*** recorded in the DERM cassowary mortality database since 1992. One of these was a ***recent death***. This makes it one of the worst places for cassowary roadkill at Mission Beach and therefore has a ***very high priority*** for mitigation. There are also many road crossings and roadside sightings in this section of the South Mission Beach Road and Wheatley Road. The South Mission Beach Road is a high speed road

Reduce the speed limit to 60,kph. A roundabout at this intersection would ensure that vehicles had to slow in this area of high cassowary mortality, both on the South Mission Beach Road near the intersection and near Frog's Hollow, and also on Wheatley Road at the creek crossing. Signage and rumble strips would be included to alert drivers to the roundabout.

7.5.7 Tully-Mission Beach Road, Hull River to Carmoo (# 35, 36, 37, 38, 39)

Along this long road section it is recognised that cassowaries can cross almost anywhere and numerous crossings are recorded. One area where many crossings are recorded is in the vicinity of the Licuala turnoff, again possibly because of numbers of tourists visiting. There have been at least **4 cassowary deaths** along this section. It is a high speed road where almost all traffic is travelling significantly above the speed limit (average speed 83.4 - 86.9 for small vehicles and 85 - 89.5 for medium buses and trucks). Maximum speeds are well above these averages. The clearing for the road is very wide and this is probably part of the reason that vehicles travel so much faster than the speed limit – because the design speed with long straight sections of road with long distance visibility is higher than the speed limit.

Speed limit should be reduced to 60 kph. However, this would be unlikely to have much effect at all, unless road design speed is changed. This could be achieved by planting sections of the wide roadside clearing (probably along gullies) with low vegetation that would not obscure driver visibility of cassowaries but would make the road appear narrower. Vegetation clearance should still be maintained at safe distances. This would have the added benefit of providing more habitat of use to fauna. Additionally, inclusion of 3 or 4 signs along this long road section that react to speeding vehicles and tell drivers of their speed, with the potential to pass on information about speeding vehicles to the police would be expected to ensure that drivers slow down at least to some extent. Alternatively a system of speed camera stands that one or two cameras could be rotated between is likely to have a similar effect.

Future Options:
The Stoney Creek retrofitted culvert underpass is not effective for cassowaries, although there have been a few records suggesting that at one stage one bird or a family party used it. The functionality of the culvert is compromised by its length, lack of openness, lack of vegetation cover, and depth of water at one end. Replacing the culvert with a high bridge-style underpass would greatly improve connectivity. Similarly making the fences more functional by bringing the shadecloth down the fence to the ground or 10 cm above it would improve its guidance potential to a new bridge underpass.

7.5.7 Smith's Gap and Big Maria Creek, Bruce Highway

Descriptions and options for provision of connectivity between uplands and lowlands involving this road section are described in detail in Chapter 6. They include strengthening the corridor along Big Maria Creek with revegetation along the length between Old Tully Road and the Bruce Highway and potentially lifting the bridge in future highway upgrades. An overpass could be considered for future upgrades at the other end of Smiths Gap.

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APPENDIX 1
GPS locations for Mission Beach cassowary road crossings 2008-2009

Crossing Number	Location	Latitude	Longitude
1	Bingil Bay 1	17°49'31.47"S	146° 3'16.03"E
2	Bingil Bay 2	17°48'55.18"S	146° 3'54.18"E
3	Bingil Bay 3	17°48'59.49"S	146° 5'26.67"E
4	Garners Beach 4	17°49'0.89"S	146° 5'22.83"E
5	Garners Beach 5	17°49'0.00"S	146° 5'36.85"E
6	Garners Beach 6	17°48'59.98"S	146° 5'58.78"E
7	Garners Beach 7	17°48'57.62"S	146° 6'3.78"E
7.1	Garners Beach 7.1	17°49'0.63"S	146° 6'1.62"E
8	Garners Beach 8	17°48'51.06"S	146° 6'2.16"E
9	Garners Beach 9	17°48'41.10"S	146° 5'57.55"E
10	Holt Road 10	17°49'18.56"S	146° 6'8.41"E
11	Garners Beach 11	17°49'22.20"S	146° 5'32.51"E
12	Plantation Road 12	17°49'31.75"S	146° 5'40.31"E
13	James Road 13	17°50'39.64"S	146° 6'16.97"E
14	MB Creek 14	17°52'15.38"S	146° 5'39.30"E
15	Nonda Creek Corridor 15	17°52'23.20"S	146° 5'52.47"E
16	Porters Creek 16	17°52'48.84"S	146° 5'29.07"E
17	Mission Circle 17	17°53'8.65"S	146° 5'27.07"E
19	Mission Circle 19	17°53'18.48"S	146° 5'26.25"E
20	Police Station 20	17°54'28.64"S	146° 5'28.83"E
21	Development 21	17°54'37.62"S	146° 5'17.60"E

Crossing Number	Location	Latitude	Longitude
22	Development 22	17°54'41.99"S	146° 5'2.95"E
23	South Mission Beach 23	17°54'46.53"S	146° 4'59.00"E
24	South Mission Beach 24	17°54'57.40"S	146° 4'58.59"E
25	South Mission Beach 25	17°55'8.77"S	146° 4'57.19"E
26	South Mission Beach 26	17°55'21.92"S	146° 5'0.90"E
27	Wheatley Road 27	17°55'33.36"S	146° 5'18.82"E
28	Wheatley Road 28	17°55'26.91"S	146° 5'46.61"E
29	South Mission Beach 29	17°55'42.51"S	146° 5'20.99"E
30	South Mission Beach 30	17°55'57.94"S	146° 5'26.33"E
31	South Mission Beach 31	17°56'10.30"S	146° 5'33.85"E
32	Hull River Ramp 32	17°56'57.58"S	146° 5'2.03"E
33	Explorers Drive 33	17°57'14.36"S	146° 5'20.07"E
34	Hull River Bridge 34	17°54'40.76"S	146° 4'50.96"E
35	Licuala 35	17°54'50.60"S	146° 4'19.33"E
36	Stoney Creek 36	17°54'58.19"S	146° 4'10.05"E
37	Tully Road 37	17°55'14.62"S	146° 4'4.81"E
38	Tully Road 38	17°55'36.90"S	146° 3'58.80"E
39	Tully Road 39	17°56'8.95"S	146° 3'36.22"E
40	Lindsay Road 40	17°56'38.54"S	146° 3'3.82"E
41	Tully Road 41	17°56'15.60"S	146° 2'20.05"E
42	Sugar Cane Creek 42	17°56'12.88"S	146° 1'54.97"E

Crossing Number	Location	Latitude	Longitude
43	Sugar Cane Creek 43	17°56'11.04"S	146° 1'43.95"E
44	Tully Road 44	17°55'19.40"S	145°59'52.16"E
45	El Arish 45	17°48'35.24"S	146° 0'40.22"E
46	El Arish 46	17°49'48.38"S	146° 3'18.73"E
47	El Arish 47	17°50'50.07"S	146° 3'28.04"E
48	El Arish 48	17°51'4.79"S	146° 3'46.79"E
49	El Arish 49	17°51'5.63"S	146° 3'52.96"E
50	El Arish 50	17°51'7.91"S	146° 3'56.60"E
51	El Arish 51	17°51'21.08"S	146° 3'56.01"E
52	El Arish 52	17°51'33.49"S	146° 3'54.82"E
53	El Arish 53	17°51'52.76"S	146° 3'58.43"E
54	El Arish 54	17°52'3.44"S	146° 4'5.90"E
55	El Arish 55	17°51'59.51"S	146° 4'28.38"E
56	El Arish 56	17°51'55.58"S	146° 4'38.14"E
57	El Arish 57	17°52'10.02"S	146° 5'7.14"E
58	El Arish 58	17°52'11.94"S	146° 5'17.72"E
59	Smiths Gap 61	17°49'54.99"S	145°59'42.81"E
60	Past Crossing #1	17°48'39.71"S	1465°05'05.40"E
61	Past Crossing #2	17°49'41.85"S	146°05'35.95"E
62	Past Crossing # 3	17°50'18.53"S	146° 6'7.90"E
63	Past Crossing # 4	17°51'47.38"S	146° 6'32.52"E

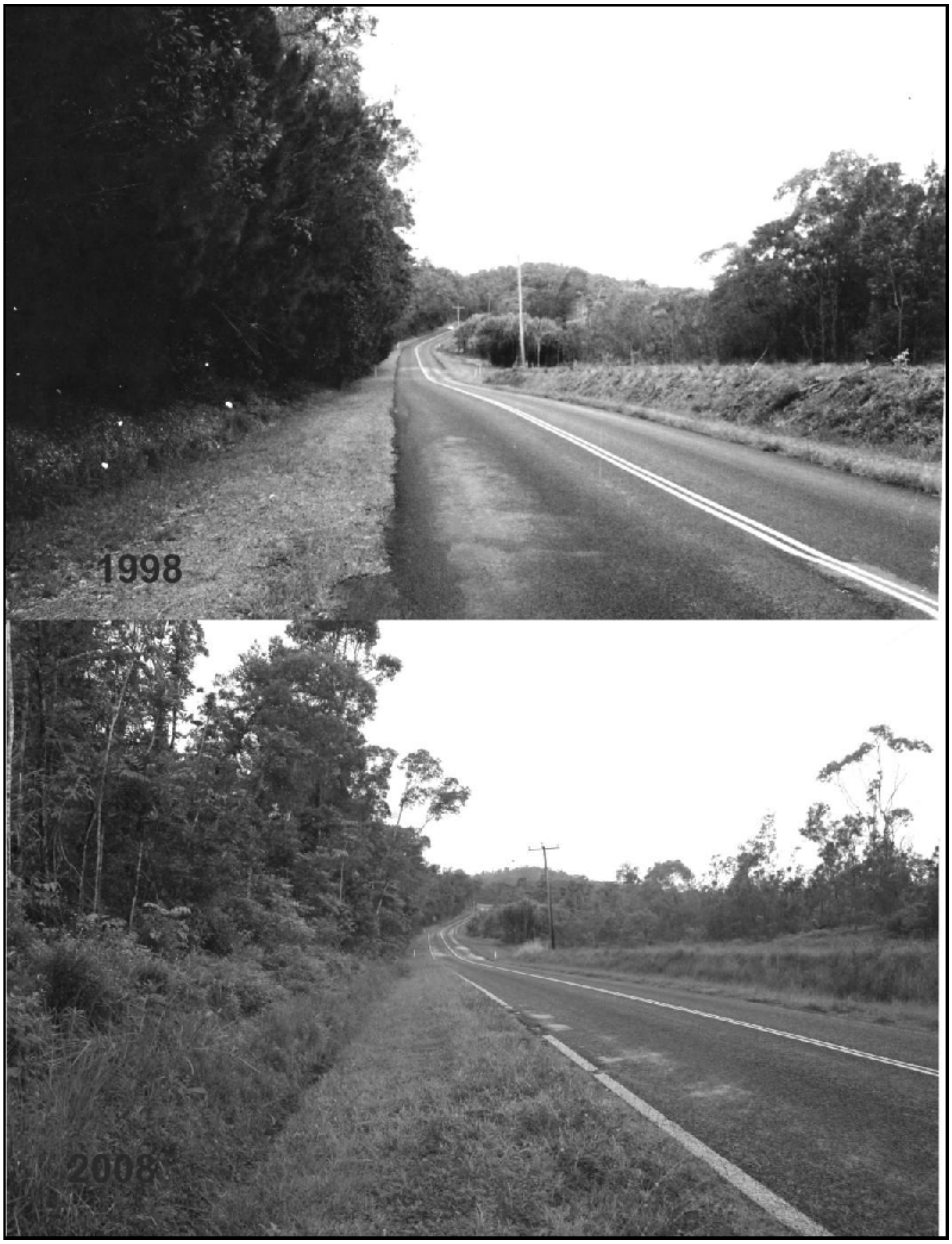
Crossing Number	Location	Latitude	Longitude
64	Past Crossing # 5	17°52'35.62"S	146° 6'10.73"E
65	Past Crossing # 6	17°52'32.18"S	146° 5'30.25"E
66	Past Crossing # 7	17°52'37.42"S	146° 5'30.02"E
67	Past Crossing # 8	17°53'30.78"S	146° 5'25.27"E
68	Past Crossing # 9	17°53'33.49"S	146° 5'40.50"E
69	Past Crossing # 10	17°55'29.76"S	146° 5'8.30"E
70	Past Crossing # 11	17°55'30.27"S	146° 5'40.06"E
71	Past Crossing # 12	17°55'55.05"S	146° 5'24.28"E
72	Past Crossing # 13	17°56'12.23"S	146° 5'38.35"E
73	Past Crossing # 14	17°56'33.53"S	146° 2'48.65"E
74	Past Crossing # 15	17°55'30.98"S	146° 1'2.83"E
75	Past Crossing # 16	17°48'53.47"S	146° 2'2.26"E
76	Past Crossing # 17	17°49'52.41"S	146° 3'13.85"E
77	Past Crossing # 18	17°50'58.66"S	146° 3'36.58"E
78	Past Crossing # 19	17°52'5.01"S	146° 4'15.98"E
79	Past Crossing # 20	17°51'31.30"S	146° 1'49.14"E
80	Past Crossing #21	17°51'5.79"S	145°59'8.95"E
81	Past Crossing #22	17°50'30.12"S	145°59'26.54"E
82	Sighting 2000	17°52'14.72"S	146° 5'48.50"E
83	Sighting 2000	17°52'12.70"S	146° 5'26.82"E
84	Sighting 2000	17°55'20.47"S	145°56'42.13"E

APPENDIX 2

Cassowary crossing photographs - 1998 and 2008 showing changes in crossing structure over a ten-year period

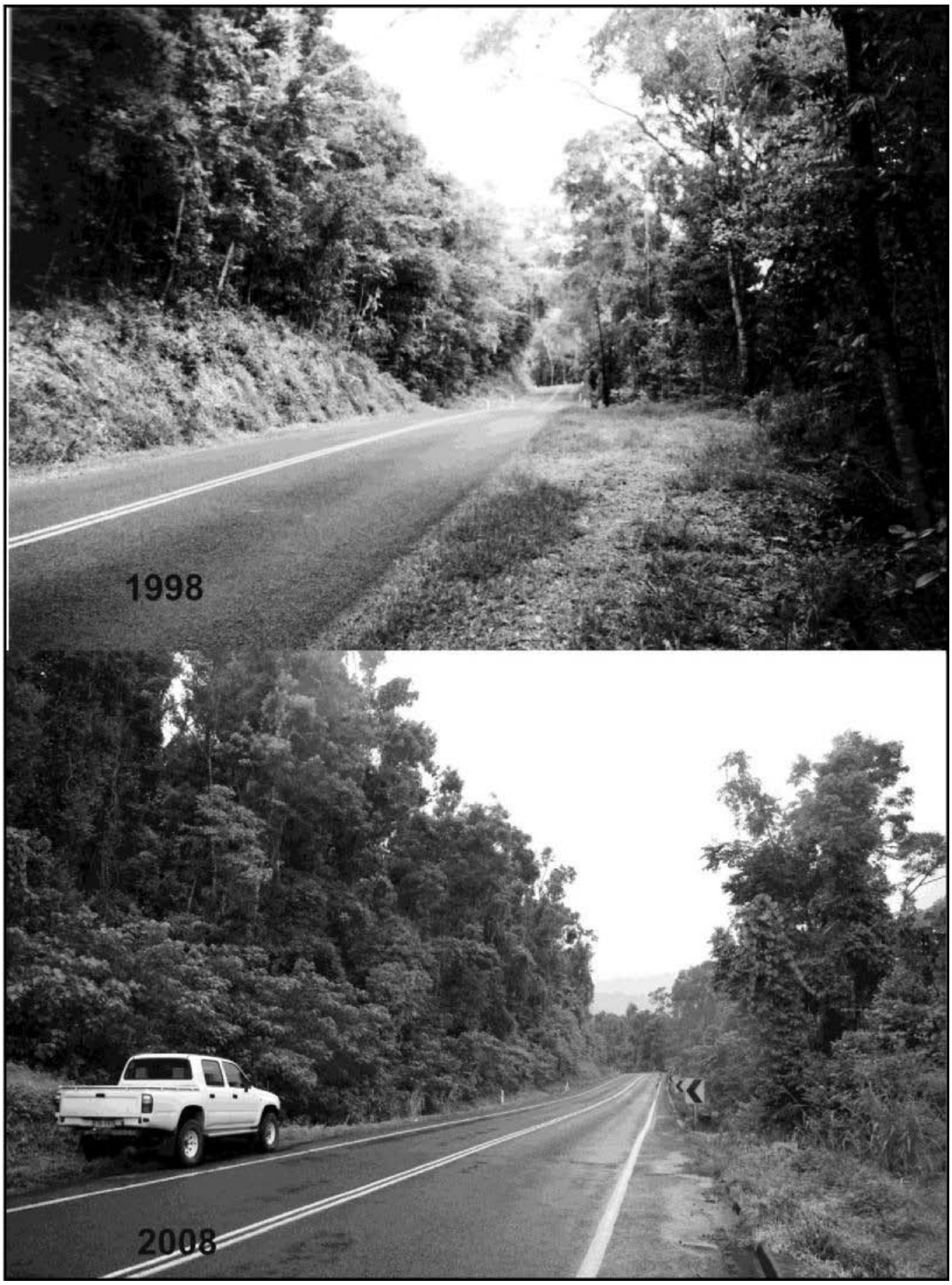
Crossing #46 (1998 - #1)

Crossing #47 (1998 - #2)

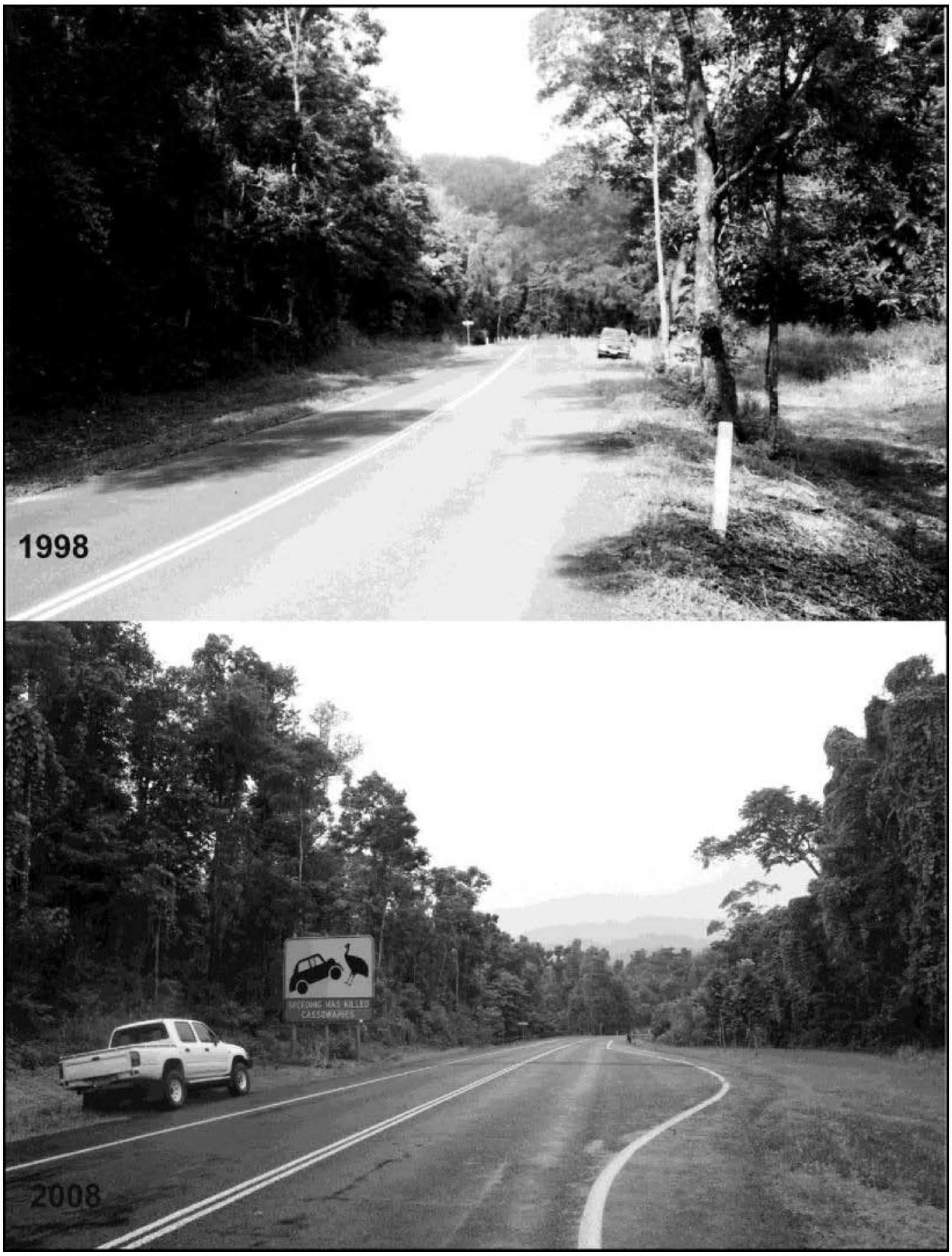


Past Crossing #18 (1998 - #3a)

Crossing #48 (1998 - #3b)



Past Crossing #49 (1998 - #4a)



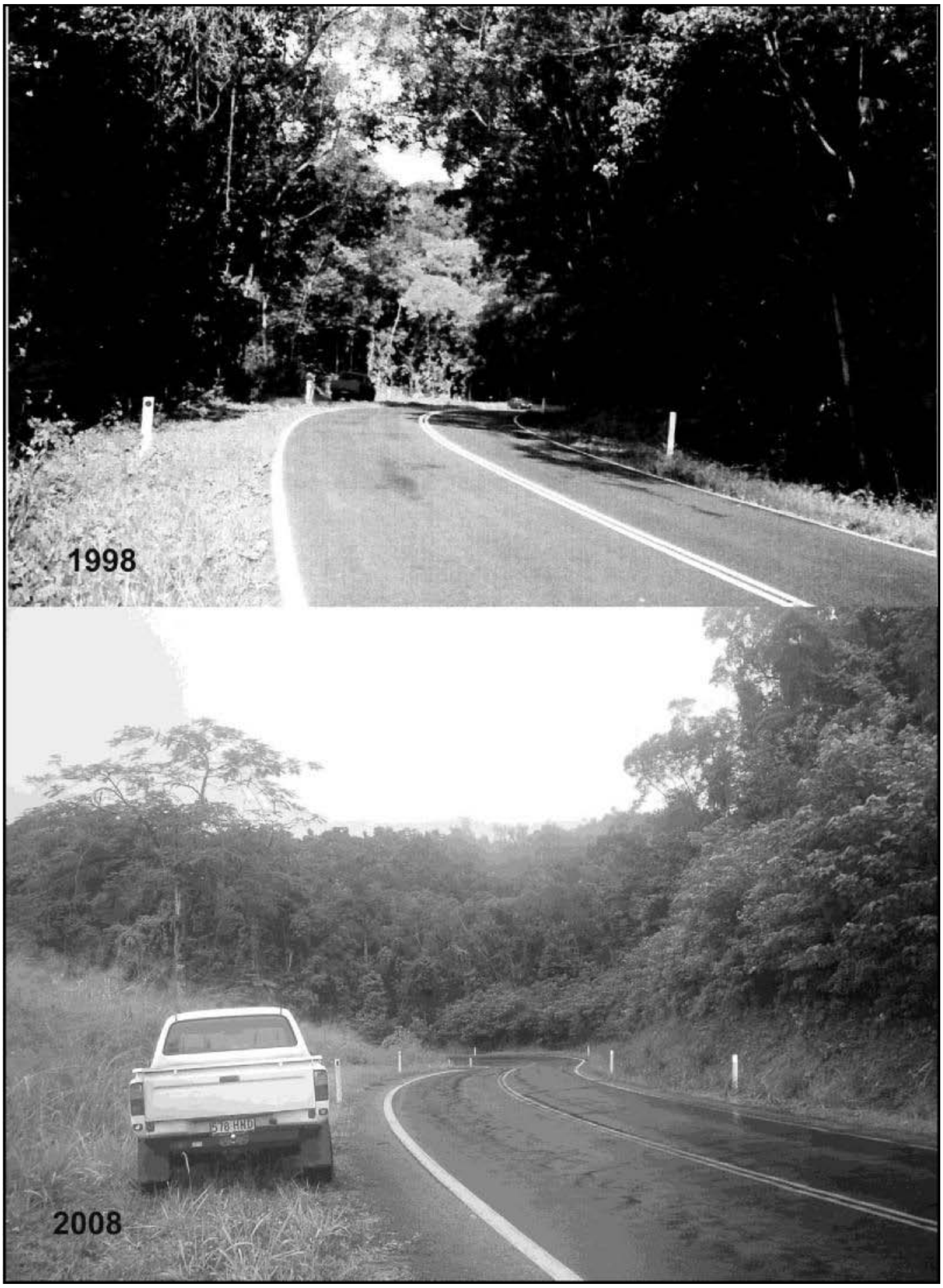
Crossing #50 (1998 - #4b)

Crossing #51 (1998 - #4c)

Crossing #51 (1998 - #5)

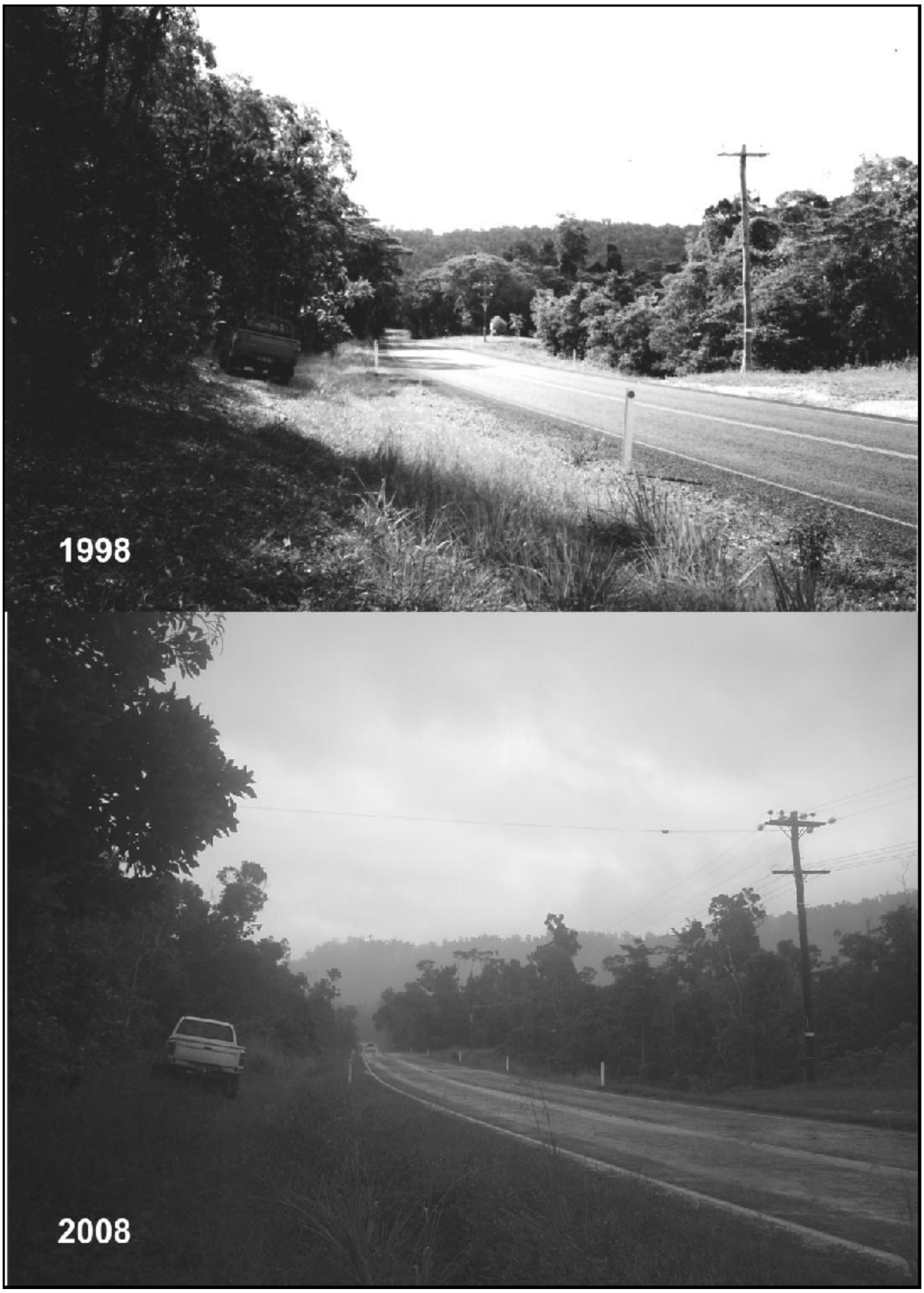
Crossing #52 (1998 - #6)

Past Crossing #3 (1998 - #7)



Crossing #56 (1998 - #8)

Crossing #58 (1998 - #9)



Crossing #14 (1998 - #10)

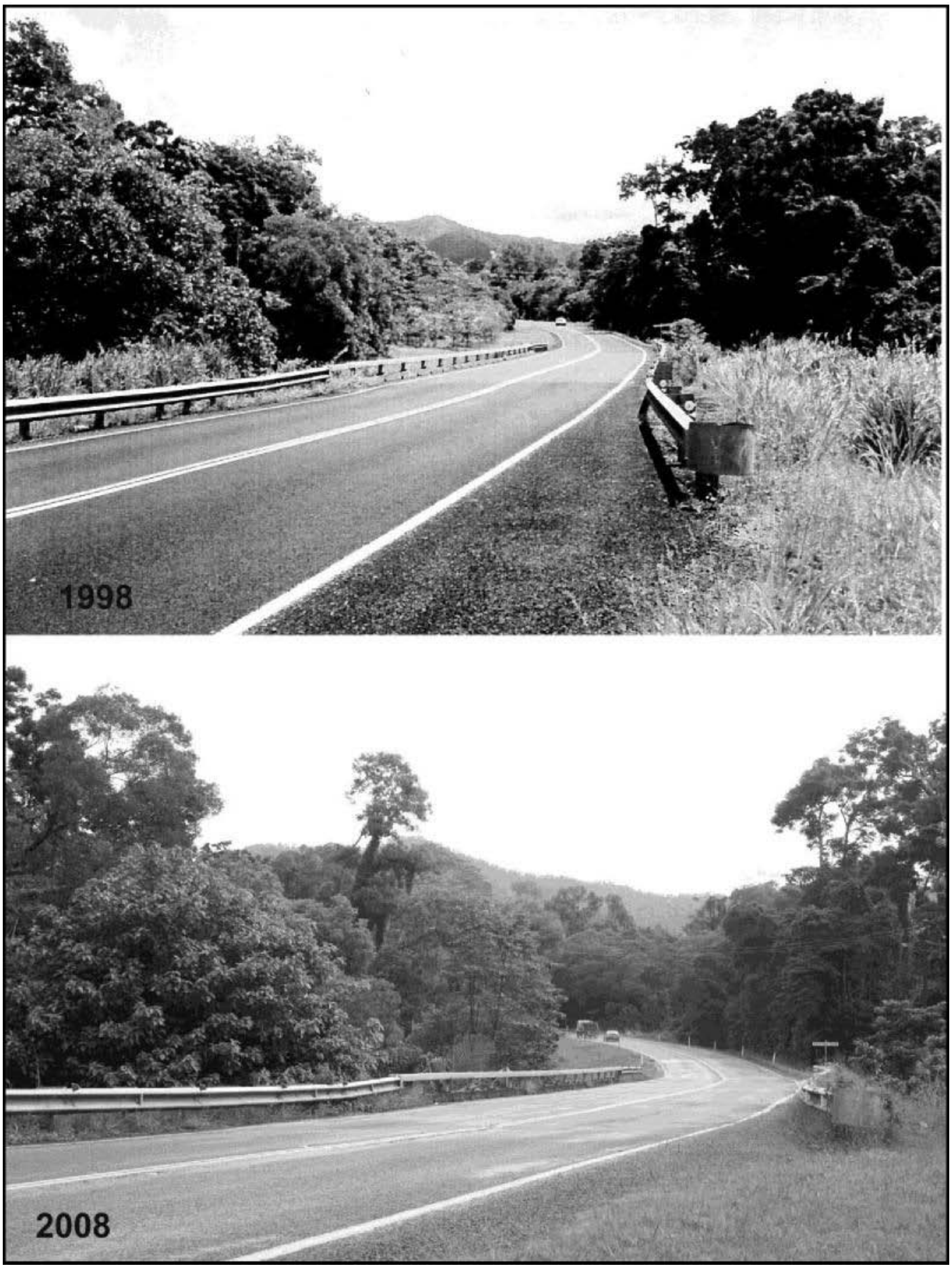
Crossing #16 (1998 - #12)

Crossing #17 and #19 (1998 - #12)

Crossing #20 (1998 - #13)

Crossing #21 and #22 (1998 - #14)

Crossing #34 - Licuala (1998 - #15)



Crossing #35 and #36 – Licuala (1998 - #16 and #17)

Crossing #38 and #39 (1998 - #17)

Crossing #40 (1998 - #18)

Crossing #41 – Sugarcane Creek (1998 - #19)

Crossing #42 (1998 - #20)