Identifying optimal greyhound track design for greyhound safety and welfare

Phase II – Progress Report

1 January 2016 to 31 December 2017

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1 INTERVENTIONS CONDUCTED BY GRNSW

Introduction

1.1 This chapter provides an updated summary of the interventions recommended to Greyhound Racing New South Wales (GRNSW) by the University of Technology Sydney (UTS). This summary discusses the progress of the Phase I interventions, a synopsis of the results obtained and recommended modifications to these interventions. This chapter will also discuss new interventions recommended to assist GRNSW improve the performance and welfare of greyhounds.

Lures

1.2 In the previous annual report, it was suggested that GRNSW collaborate with Greyhound Racing Victoria (GRV) on the new generation lure designs with a reach greater than 2.0 m, by incorporating a travelling counter-balance into the design. This was suggested to reduce greyhound clustering as it would move the lure further from the rail to the centre of the track. GRNSW commenced installing and testing the 1.2 m quasi-extended lure on 13 TAB tracks across NSW in mid-2016 and throughout 2017. Currently, no non-TAB tracks have had the 1.2 m quasi-extended lure implemented.

1.3 As of the time of this report there are insufficient data to determine whether GRNSW's 1.2 m quasi-extended lure has had a relevant impact on reducing the number of racing related injuries. However, observations and comparative statistics suggest that the use of the wide looped lure by GRNSW has encouraged runners to spread out a little more and comments from greyhound community members suggest that the 1.2 m quasi-extended lure has reduced both non-chasing and fighting convictions.

1.4 There is also anecdotal evidence that the elevated lure (chain linked to arm) is encouraging the running greyhound to run in an unnatural stance and that this unnatural running stance is leading to an increase in the injury rate. We understand that GRNSW is addressing this with the roll-out of a flexible pipe retrofit across all TAB tracks.

1.5 The primary reason for extending the lure toward the centre of the track is to encourage the centroid of the running pack toward the centre of the track and in so doing provide more, and less congested, real estate for the racing greyhounds to run. A secondary reason is to increase the line of sight for the racing greyhounds. The wider on the track the lure sits the easier it is for more of the runners to observe and follow, particularly as they go around the bend. This means there are potentially 8 different viewing angles to the lure as different greyhounds have different ideas about the angle at which they like to chase the lure. However, it should be noted that all tracks have varying shapes and it can be difficult to create a universal lure. More circular tracks make it harder for the greyhounds to keep an eye on the lure as they fall back from the lead greyhounds in the pack.

1.6 It is also important to note that individual greyhounds place themselves differently on the track, either running against the rail, centre of the track or out wide. This can be attributed to their running style, perception and knowledge of the track or whether they are left or right footed. It can also be noted, through anecdotal and observational evidence, that when the lure leaves the greyhounds' line of sight they either begin to follow the track or run in a pack mentality, thus losing the thrill of chasing the lure. This can be attributed to the varying nature of interest greyhounds have in finding the lure.

1.7 Implementing the 1.2 m quasi-extended lure by GRNSW was considered a step in the right direction. However, to improve the performance of the runners on all tracks, each track must have a unique lure to match the specific track design.

Starting boxes

1.8 UTS previously recommended increasing the grill height of the box gates to 400 mm similar to Victoria. UTS believes that this intervention would allow the greyhounds to adopt a more natural stance prior to the jump.

1.9 This intervention is beneficial as prior to the boxes opening, when the greyhounds hear the lure they lower their heads in an attempt to observe the approach of the lure through the grille. This forces the greyhounds to adopt an unnatural stance immediately prior to the gates opening. Injury location data collected provide some evidence that non-congestion related injuries may be attributed to the awkward pre-start crouching position of the greyhounds.

1.10 GRNSW has stated they will investigate the matter by installing CCTV cameras within the boxes to monitor the greyhounds and their pre-race conditions. At the time of this report there has been no development presented to UTS.

1.11 Because of the variations in TAB race tracks, the design of the starting boxes and their alignments should be tailored to correlate with each specific track design. The location of the boxes should depend on the width of the track as having more widely positioned starting boxes can produce a cleaner earlier run.

1.12 The second recommendation made was to implement a delayed starting box opening trial, which was to be conducted at a track that has an upgraded lure and braking system. It was proposed that conducting trials, in which the box openings were delayed and the speed of the lure increased from 50 to 70 km/hr, would reduce interference between the runners. The perception from the greyhounds' perspective will be that they first observe the lure further down the rail providing them more time to disperse along the track before veering towards their preferred racing position.

1.13 GRNSW stated that they would work closely with GRV to determine a plan to trial delayed box openings. At the time of this report no developments have been presented to UTS. GRV was in the early stages of exploring delayed box openings and indicated that it could possibly be done without moving the trip starts and by manipulating the lure speed and associated driving approach. Again no

developments have been presented.

1.14 The third recommendation was to conduct trials using 'moveable' box starts that can be lowered onto the track at the start of a straight. The reason for this intervention relates to paragraph 1.7. This intervention would avoid the need for a permanent alteration to the track, reduce the cost of implementation and allow the testing of box alignment and starting distances. GRNSW stated it will investigate the installation of a similar system in Bulli. However, At the time of this report no developments have been presented to UTS.

Reduction of runners

1.15 From the evidence obtained from the injury reports and race data given to UTS, a recommendation was made in the 2017 UTS Report to limit the number of racing greyhounds from 8 to 6. The reasoning for this recommendation was that reducing the pack size would reduce the probability of clustering, particularly clustering that occurred at the beginning of the first turn which had been causally linked to higher injury rates.

1.16 The objective of the preliminary experiment, consisting of 6 greyhound races, was to determine whether the number of dogs in a race affects the injury rate and if so whether further trials should be conducted. Two investigations were undertaken. The first was a comparative retrospective analysis of the injury data for all GRNSW tracks over a two year period reviewing the data for 6, 7 and 8 dog starts. The second was a control study at the Grafton track that investigated 6 and 8 dog races where boxes 3 and 6 were specifically not used during the races with 6 greyhounds.

1.17 In NSW the majority of the races held consist of 8 greyhounds followed by races consisting of 7 and 6 greyhounds. Although races consisting of 4 and 5 greyhounds were held, the number of total races was too small compared to other races held. The data collected from January 2016 to December 2017 show that the number of Level 2 injuries obtained from races with 6 greyhounds was lower than races with 7 and 8 greyhounds.

1.18 Data from the first investigation indicated that the normalised injury rate for 6 start races was approximately half the rate for both 7 and 8 start races.

1.19 The results show a reduction in the number of total injuries in races with 6 dog starts, regardless of the arrangement of box positions.

1.20 For the second investigation the preliminary 6-dog trial initially began at Lismore, in 2017, but was transferred to Grafton after Lismore was temporarily closed due to flood damage. The preliminary 6-dog trial has now been moved completely to Lismore and is expected to continue until the end of the 2018 financial year.

1.21 Data from the second investigation indicated that the overall normalised injury rate was less than half the rate for the 8 start races.

1.22 The second investigation findings showed that the absolute injury rates for Euthananized and Major injury categories for 6* start races were both zero.

1.23 A more rigorous control study is proposed which will extend the 6 dog experiment sample size. This proposed experiment involves conducting 6 dog races at all Non-TAB tracks for a period of 12 months.

1.24 For more details on this topic please refer to the separate UTS report titled 'A preliminary investigation into the injury rate for 6 and 8 dogs starts'.

Track variations and alterations

1.25 It was recommended that GRNSW and the Australian Greyhound Industry reconsider their aversion to straight tracks and consider developing purpose-built straight tracks. Using a straight track would eliminate all injuries associated with greyhounds needing to negotiate their way safely around the bend. The low number of spectators does not warrant or justify the continued usage of oval-shaped tracks.

1.26 It is believed that a straight track would provide an additional pathway to racing, particularly for those greyhounds suited to straight track racing and sprint race distances. These types of races may facilitate eight greyhounds per race, possibly ten if deemed safe. Consideration could also be given to incorporating straight tracks into the Centres of Excellence model in the medium to long-term.

1.27 To commence the transition to safer tracks, GRNSW conducted a competitive expression of interest (EOI) process to identify a straight track where greyhound racing could occur. However, at the time of this report no data have been presented to UTS on the outcome of the EOI.

1.28 Another recommendation was the progressive removal of race distances with starting boxes currently located on the turn. This intervention was suggested based on evidence of injuries occurring in the turns. Home turns are too flat and this causes problems for all runners over all distances.

1.29 GRNSW suggested an assessment be undertaken on a regional basis, and where possible, modification of starting positions and associated distances should be considered to ensure sprint greyhounds have an opportunity to continue their racing careers. At the time of this report no assessment has been presented to UTS regarding the progressive removal of race distances with bend starts.

Future Interventions

1.30 GRNSW and UTS began talks of using the Cessnock greyhound race track as a research track. Having Cessnock as a research track would allow UTS to begin implementing interventions at a faster rate, allowing for more precise experimental control, improved rate of data collection, fewer logistical issues, im-

proved control over the interventions and less cost for GRNSW. This would also allow trial runs to be held at the track.

2 INJURY GRAPHS

INTRODUCTION

2.1 In this section the injury graphs generated from a twenty four-month injury data set are presented.

2.2 Only the 'post-race' and 'race-related' injuries are considered for data analysis i.e. injuries due to disease, dehydration etc. are not considered.

SEVERITY OF INJURY CATEGORY

2.3 Throughout the Report the severity of injury category contained within Figure 1 will be used.

Rating	Incapacitation period	Typical injury types
Minor injuries-1 (MINa)	0 days	Mild skin abrasion/grazes
Minor injuries-2 (MINb)	1-10 days	Grade 1 muscle injury Mild skin laceration
Medium injuries (MED)	11-21 days	Joint/ligament sprain skin laceration Grade 2 muscle injury
Major injuries (MAJ)	Greater than 21 days	Grade 3 muscle injury Bone fracture
Catastrophic (CATb)	Euthanased post-race	Euthanased post-race, unable to be retired or unable to race NB: may not include all data (deaths)
Catastrophic (CATa)	Deceased or euthanased on race day	Severe skull or spinal trauma complex/open/join fracture

Figure 1: Severity of injury category

INJURY LEVELS

2.4 Throughout this Report the following levels of injury will be used:

2.5 Level 1 = CATa + CATb

2.6 Level 2 = CATa + CATb + MAJ

2.7 Level 3 = CATa + CATb + MAJ + MED

2.8 Level 4 = CATa + CATb + MAJ + MED + MINa + MINb

ABSOLUTE AND NORMALISED INJURIES FOR ALL NSW TRACKS IN 2016 AND 2017

2.9 Figure 2 to 3 present histograms of the absolute injuries on a track-by-track basis for both TAB and non-TAB tracks within NSW.

2.10 The *absolute* number of injuries histograms provide the magnitudes of the number of injuries while the *normalised* histograms present the same data adjusted per number of 1000 starts at each track. Both the *absolute* and the *normalised* data are presented herein as they provide different perspectives and information.

2.11 The *absolute* histograms depict the raw total number of injuries for each track.

2.12 The normalised histograms depict the same data for each track after adjustment to account for the number of 1000 starts held at each track. This is important as tracks such as Wentworth Park, where many races are held, will have more injuries on average than tracks that have fewer races but that may be more dangerous.

2.13 The injury plots for Jan 2017 to Dec 2017 are presented and compared with those of 2016.

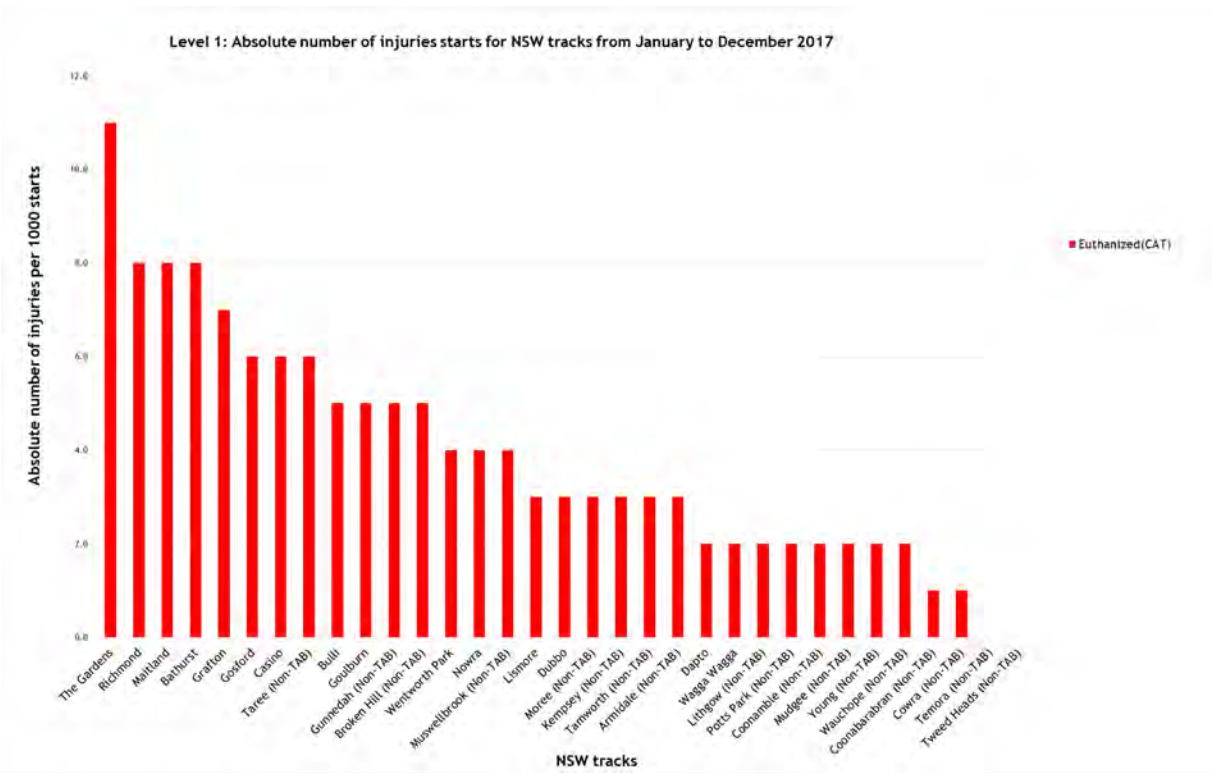

Figure 2: NSW Level 1 absolute injury rates – 1 Jan to 31 Dec 2017.

2.14 Figure 2 depicts the *absolute* Level 1 injury rates ranked from worst to best for 2017.

2.15 The worst five NSW tracks in **2017** were: The Gardens; Richmond; Maitland; Bathurst; and Grafton.

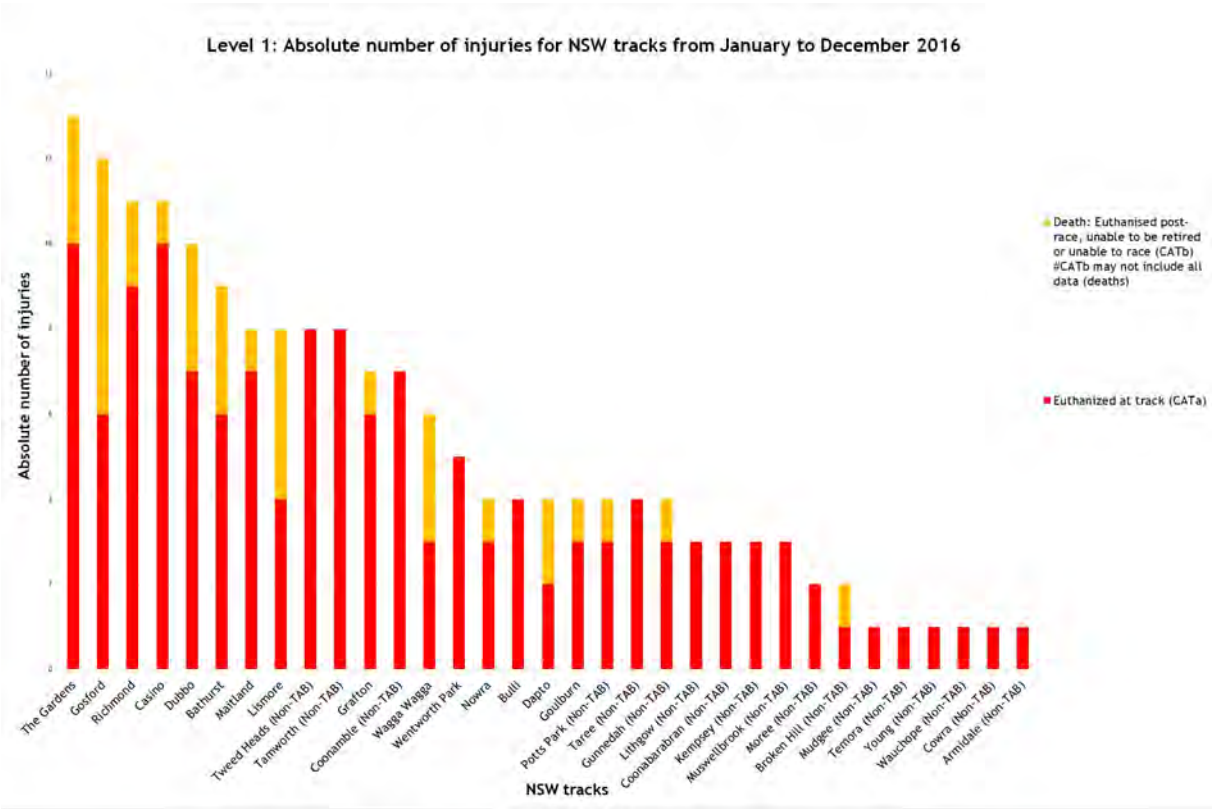

Figure 3: NSW Level 1 absolute injury rates – 1 Jan to 31 Dec 2016.

2.16 Figure 3 depicts the *absolute* Level 1 injury rates ranked from worst to best for 2016.

2.17 The worst five NSW tracks in **2016** were: The Gardens; Gosford; Richmond; Casino; and Dubbo.

2.18 Figure 4 depicts the *absolute* Level 2 injury rates ranked from worst to best for 2017.

2.19 The worst five NSW tracks in **2017** were: The Gardens; Gosford; Richmond; Casino; and Wentworth Park.

2.20 Figure 5 depicts the *absolute* Level 2 injury rates ranked from worst to best for 2016.

2.21 The worst five NSW tracks in **2016** were: Richmond; The Gardens; Grafton; Wentworth Park; and Gosford.

2.22 Figure 6 depicts the *absolute* Level 3 injury rates ranked from worst to best for 2017.

2.23 The worst five NSW tracks in **2017** were: The Gardens; Richmond; Grafton; Wentworth Park; and Gosford.

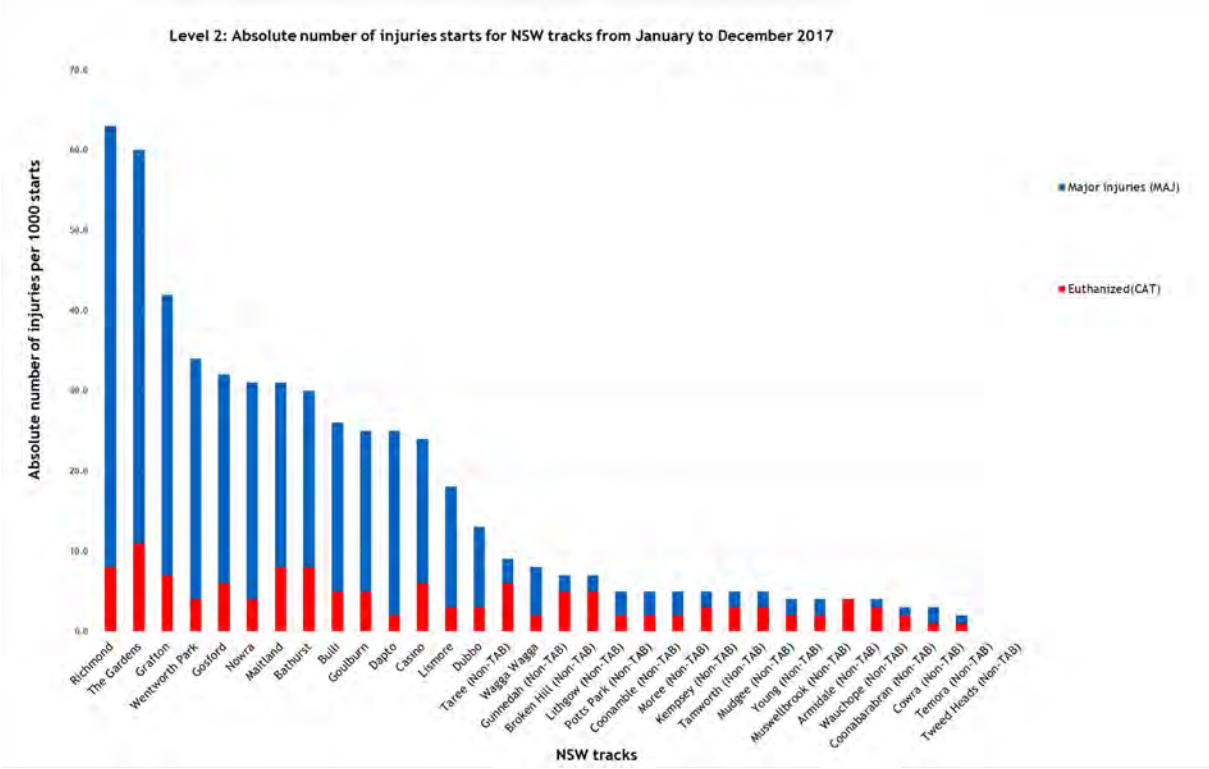

Figure 4: NSW Level 2 absolute injury rates – 1 Jan to 31 Dec 2017.

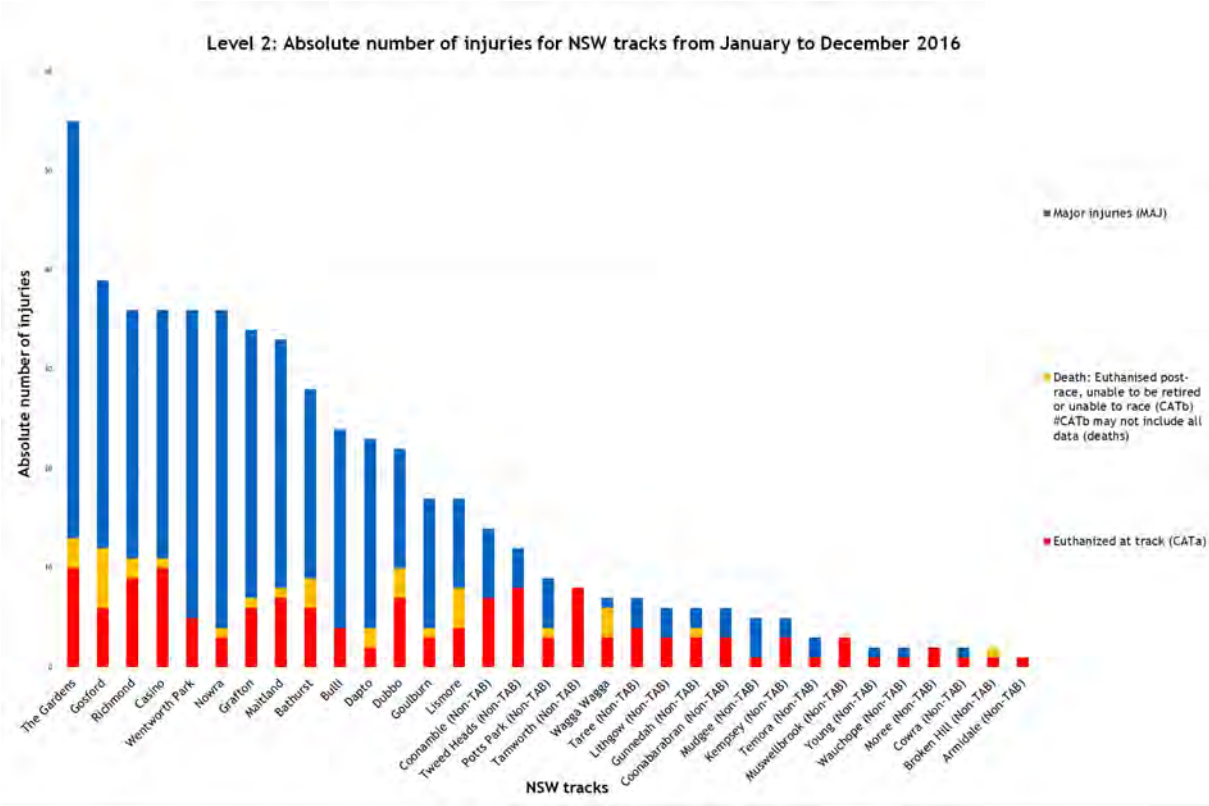

Figure 5: NSW Level 2 absolute injury rates – 1 Jan to 31 Dec 2016.

2.24 Figure 7 depicts the *absolute* Level 3 injury rates ranked from worst to best for 2016.

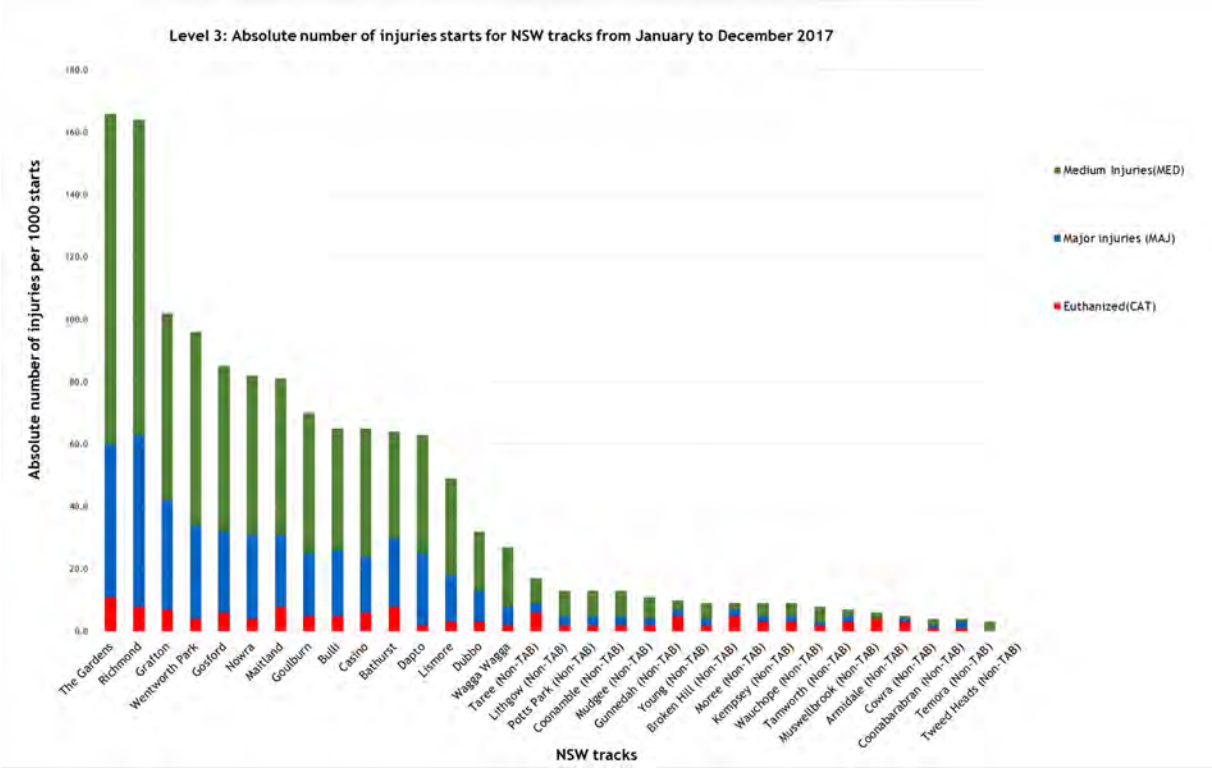

Figure 6: NSW Level 3 absolute injury rates – 1 Jan to 31 Dec 2017.

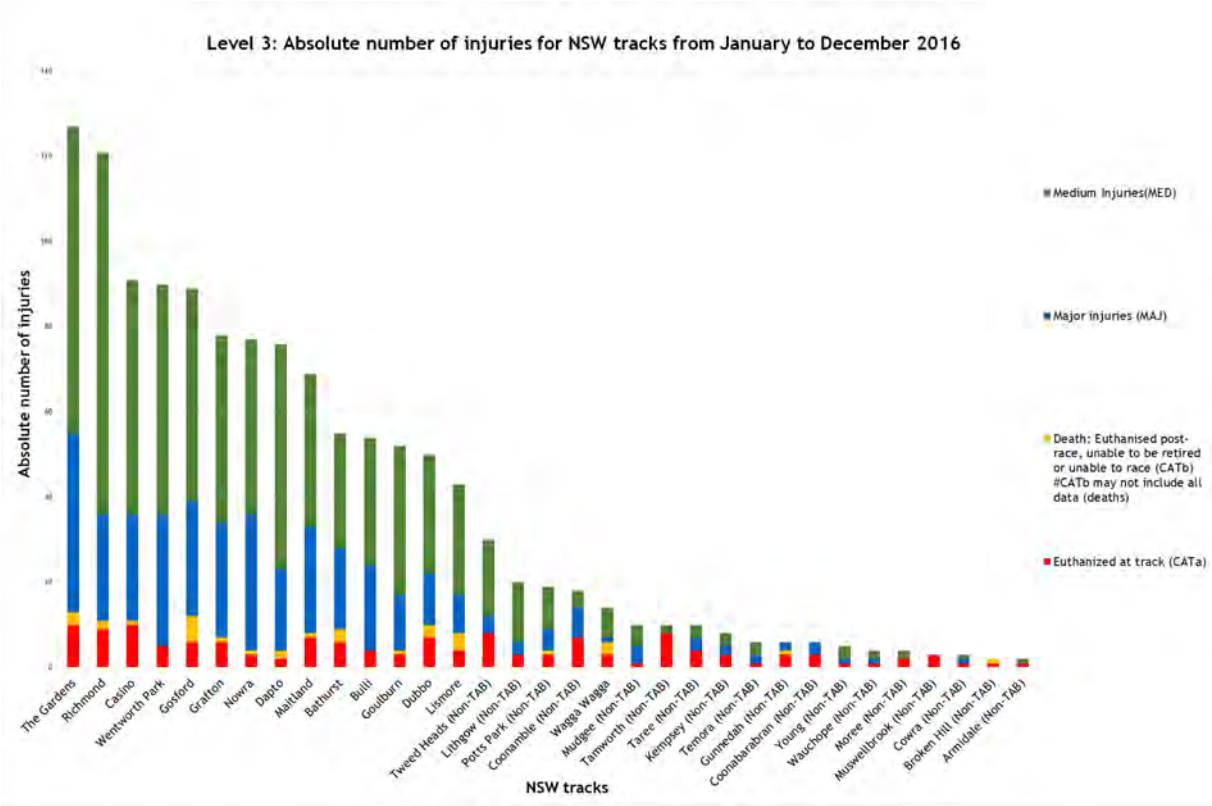

Figure 7: NSW Level 3 absolute injury rates – 1 Jan to 31 Dec 2016.

2.25 The worst five NSW tracks in **2016** were: The Gardens; Richmond; Casino; Wentworth Park; and Gosford.

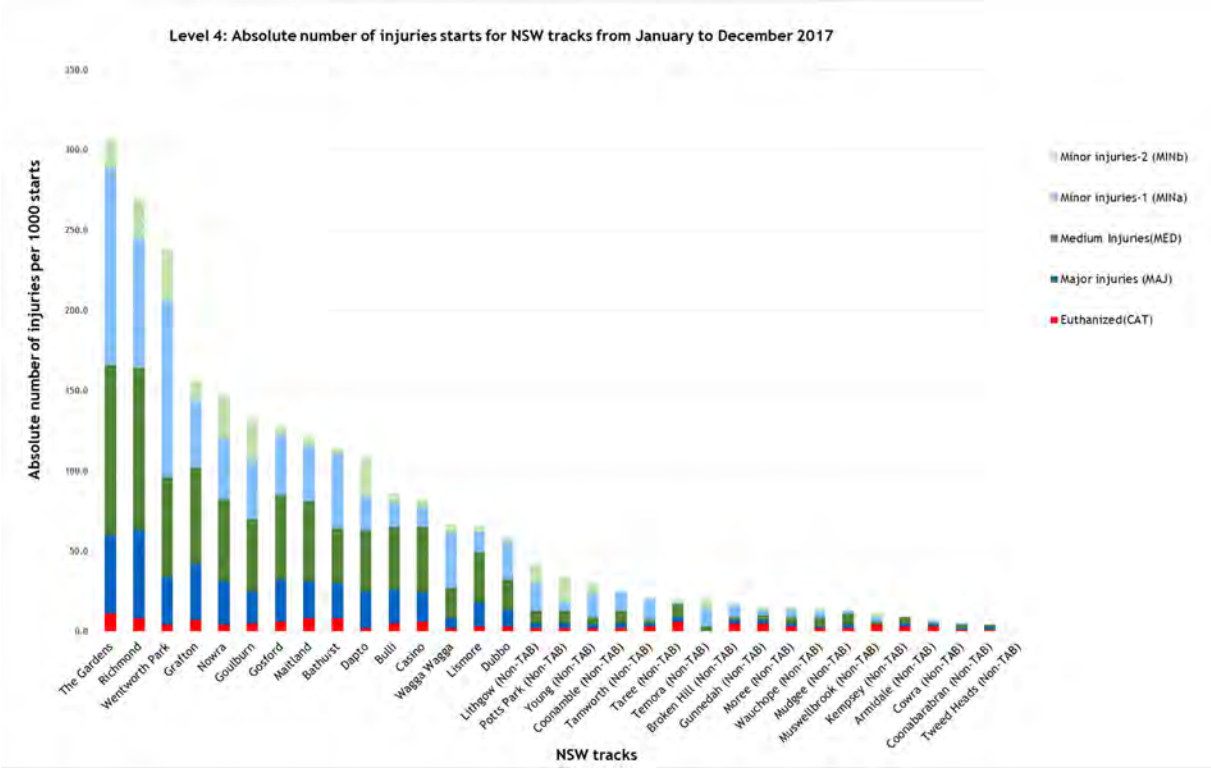

Figure 8: NSW Level 4 absolute injury rates – 1 Jan to 31 Dec 2017.

2.26 Figure 8 depicts the *absolute* Level 4 injury rates ranked from worst to best for 2017.

2.27 The worst five NSW tracks in **2017** were: The Gardens; Richmond; Wentworth Park; Grafton; and Nowra.

2.28 Figure 9 depicts the *absolute* Level 4 injury rates ranked from worst to best for 2016.

2.29 The worst five NSW tracks in **2016** were: The Gardens; Richmond; Wentworth Park; Nowra; and Gosford.

2.30 Figure 10 depicts the *normalised* Level 1 injury rates ranked from worst to best for 2017.

2.31 The worst five NSW tracks in **2017** were: Armidale; Broken Hill; Mudgee; Taree; and Gunnedah.

2.32 Figure 11 depicts the *normalised* Level 1 injury rates ranked from worst to best for 2016.

2.33 The worst five NSW tracks in **2016** were: Tamworth; Coonamble; Tweed Heads; Coonabarabran; and lismore.

2.34 Figure 12 depicts the *normalised* Level 2 injury rates ranked from worst to best for 2017.

2.35 The worst five NSW tracks in **2017** were: Gosford; Mudgee; Grafton; Nowra;

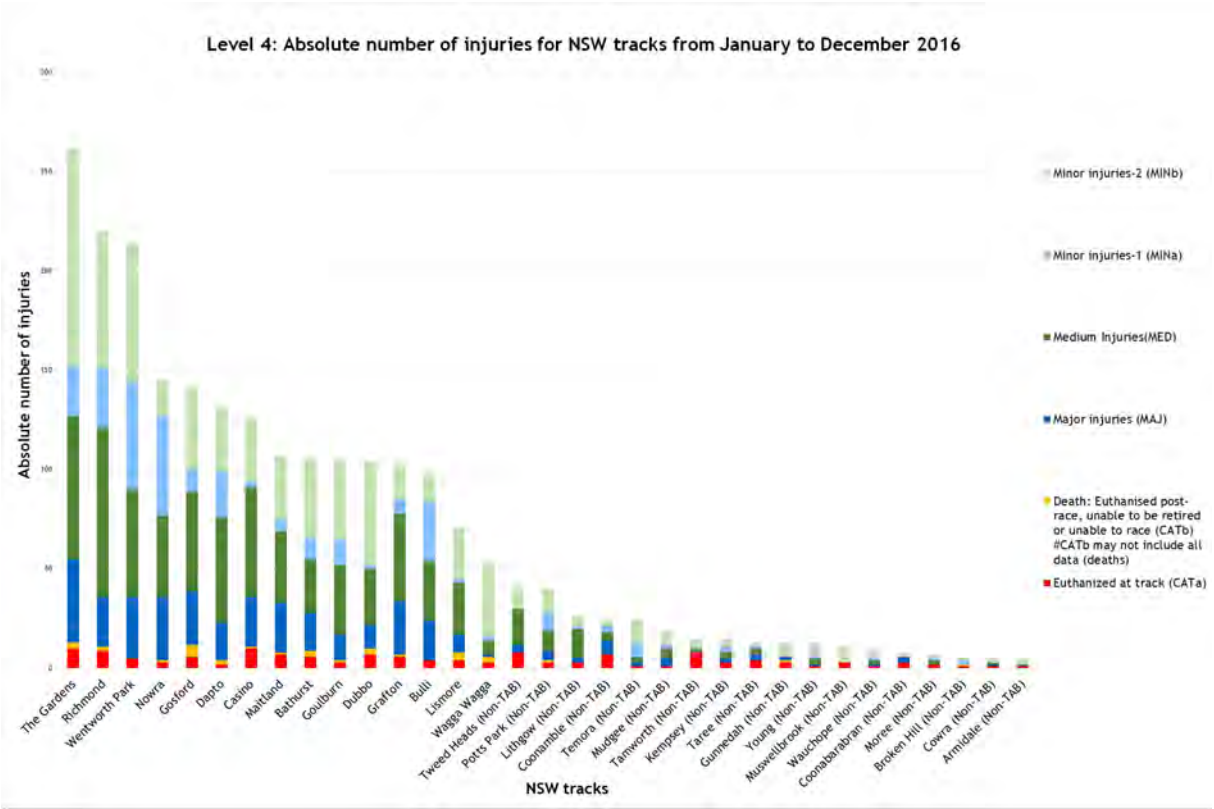

Figure 9: NSW Level 4 absolute injury rates – 1 Jan to 31 Dec 2016.

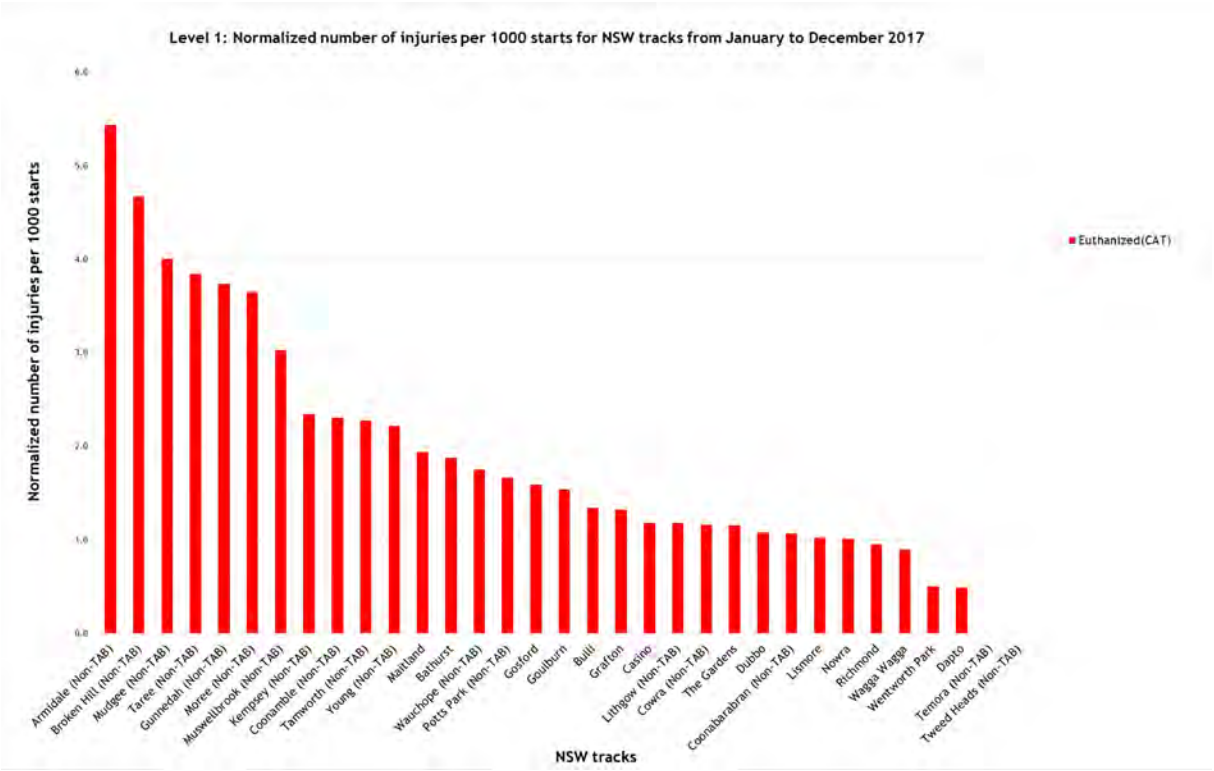

Figure 10: NSW Level 1 normalised injury rates – 1 Jan to 31 Dec 2017.

and Goulburn.

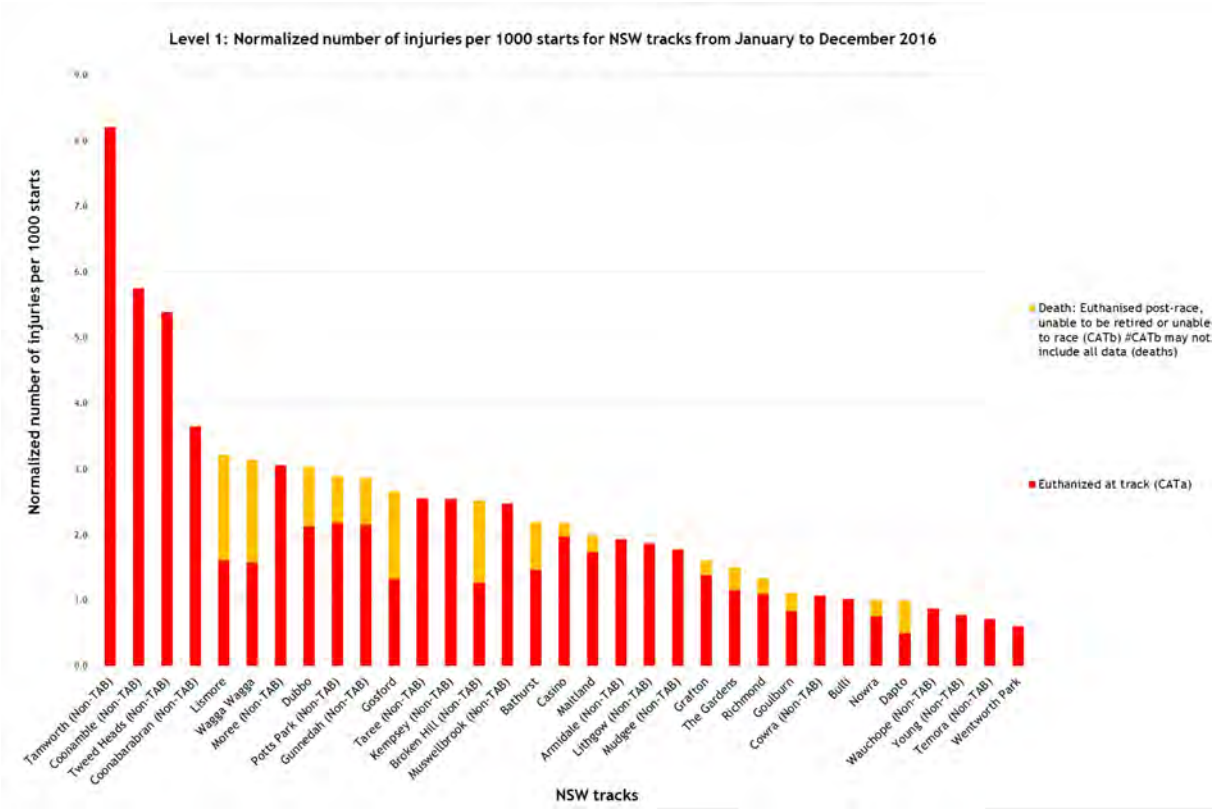

Figure 11: NSW Level 1 normalised injury rates – 1 Jan to 31 Dec 2016.

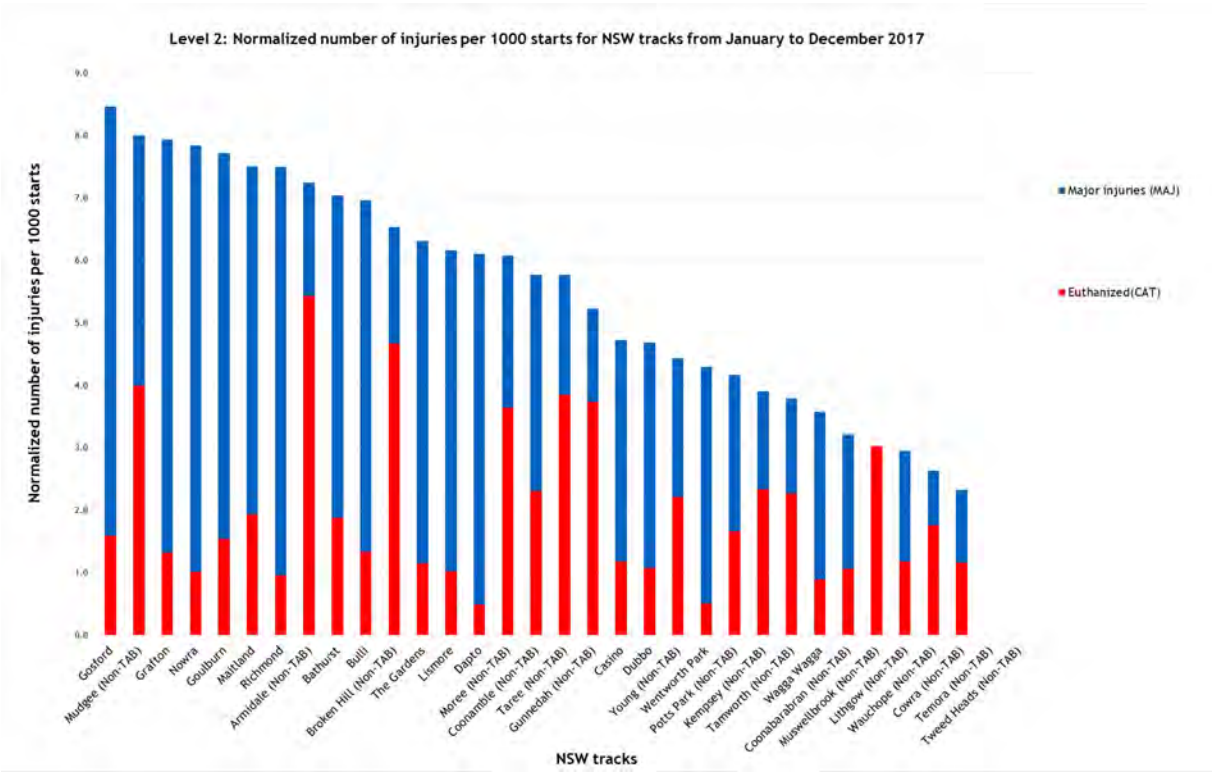

Figure 12: NSW Level 2 normalised injury rates – 1 Jan to 31 Dec 2017.

2.36 Figure 13 depicts the *normalised* Level 2 injury rates ranked from worst to best for 2016.

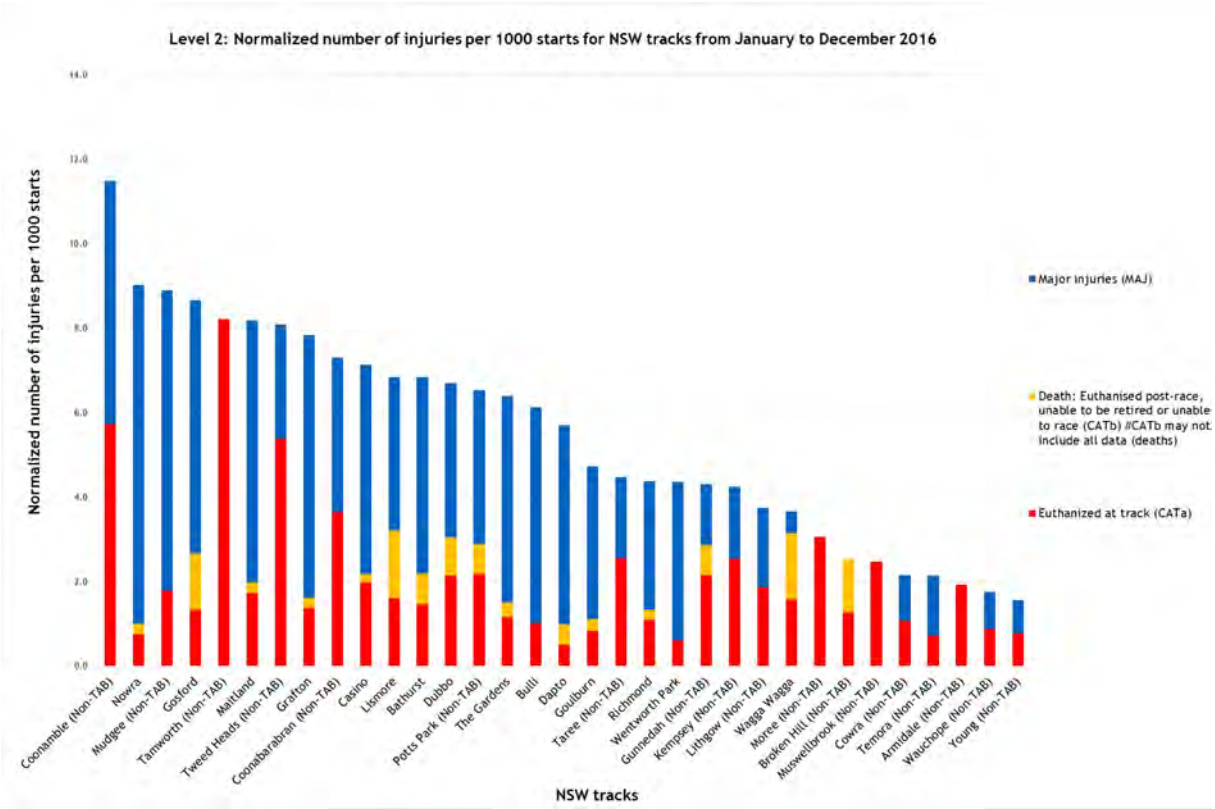

Figure 13: NSW Level 2 normalised injury rates – 1 Jan to 31 Dec 2016.

2.37 The worst five NSW tracks in **2016** were: Coonamble; Nowra; Mudgee; Gosford; and Tamworth.

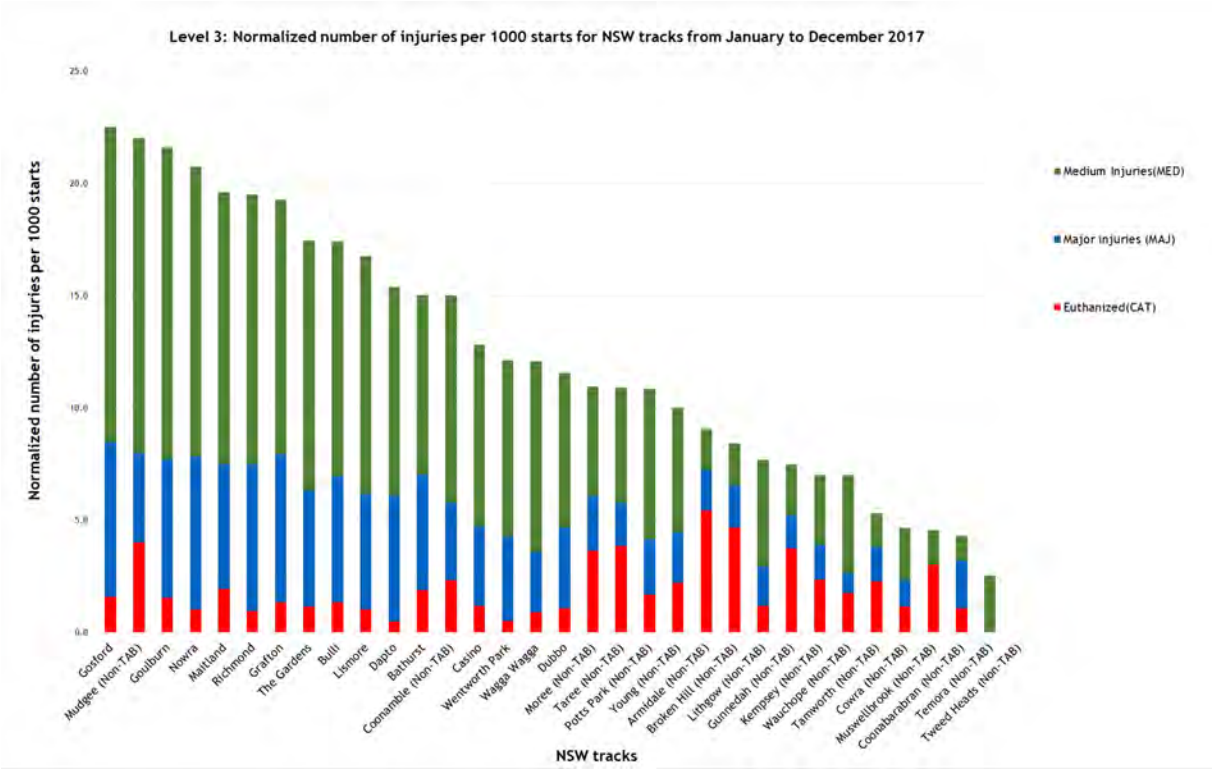

Figure 14: NSW Level 3 normalised injury rates – 1 Jan to 31 Dec 2017.

2.38 Figure 14 depicts the *normalised* Level 3 injury rates ranked from worst to best for 2017.

2.39 The worst five NSW tracks in **2017** were: Gosford; Mudgee; Goulburn; Nowra; and Maitland.

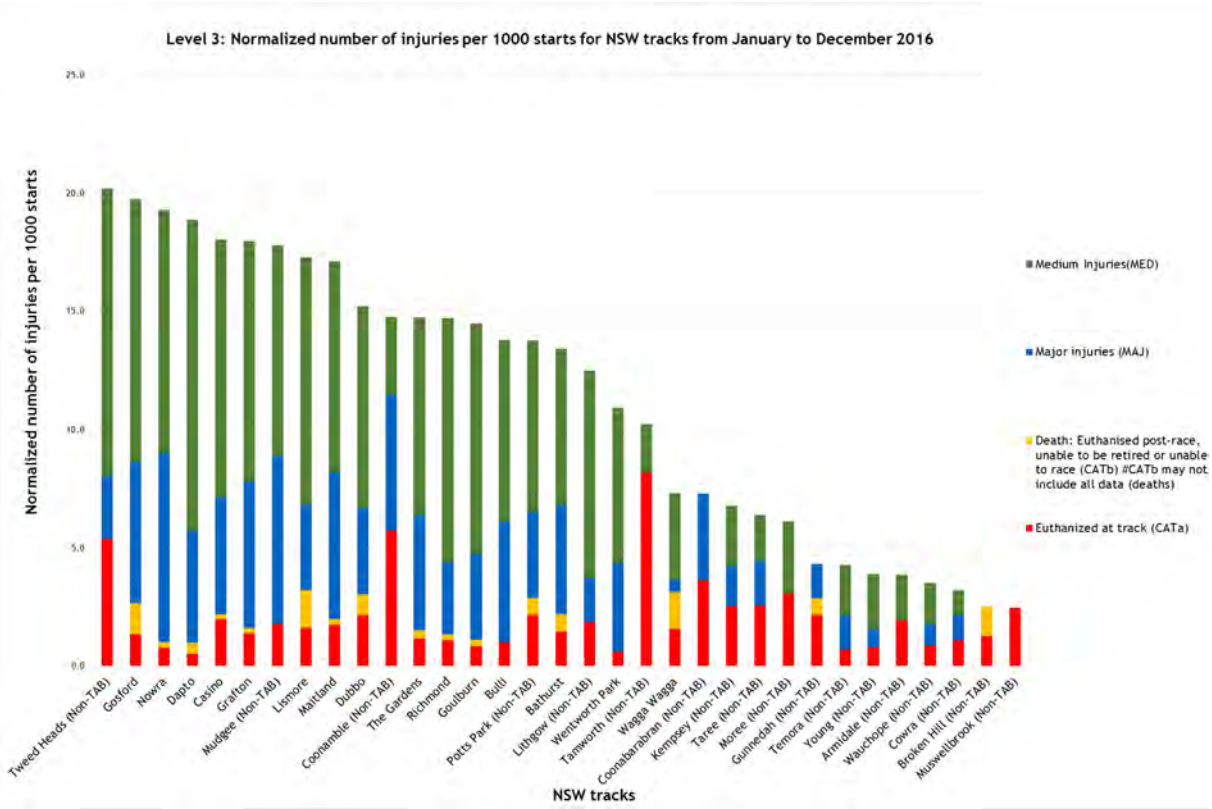

Figure 15: NSW Level 3 normalised injury rates – 1 Jan to 31 Dec 2016.

2.40 Figure 15 depicts the *normalised* Level 3 injury rates ranked from worst to best for 2016.

2.41 The worst five NSW tracks in **2016** were: Tweed Heads; Gosford; Nowra; Dapto; and Casino.

2.42 Figure 16 depicts the *normalised* Level 4 injury rates ranked from worst to best for 2017.

2.43 The worst five NSW tracks in **2017** were: Goulburn; Nowra; Gosford; Young; and The Gardens.

2.44 Figure 17 depicts the *normalised* Level 4 injury rates ranked from worst to best for 2016.

2.45 The worst five NSW tracks in **2016** were: Nowra; Mudgee; Dapto; Dubbo; and Gosford.

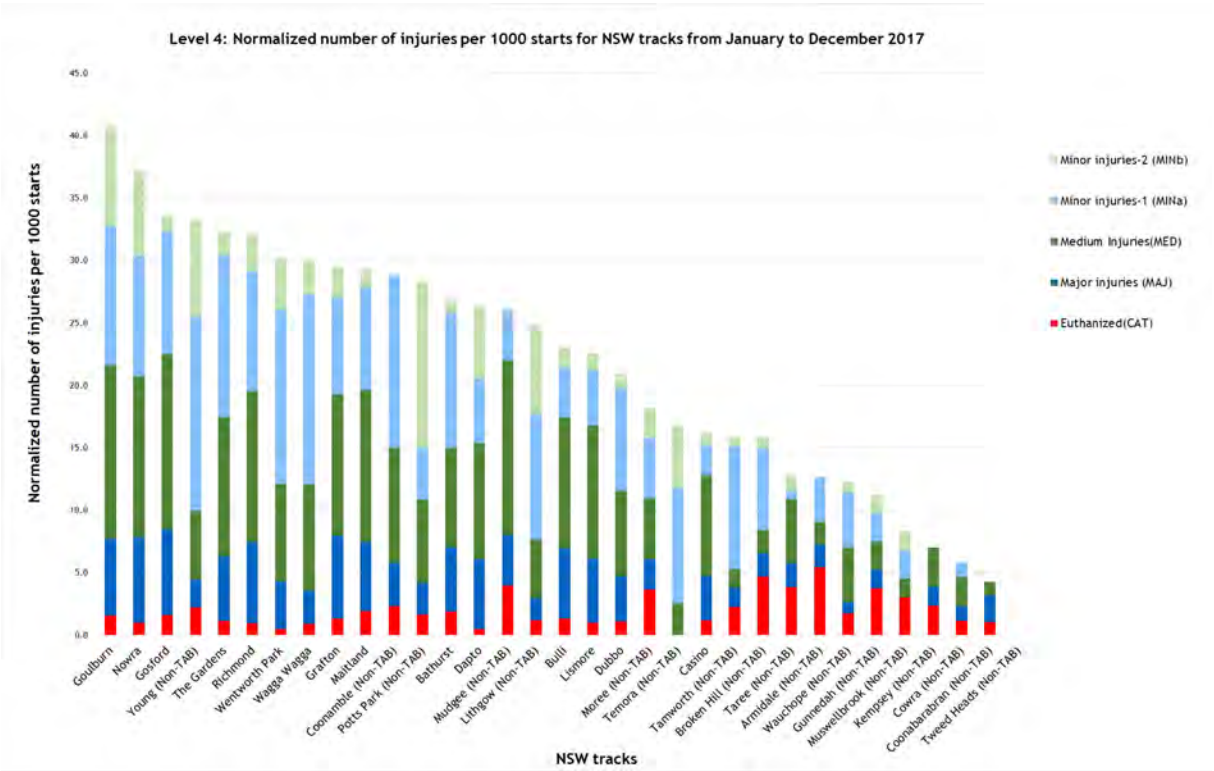

Figure 16: NSW Level 4 normalised injury rates – 1 Jan to 31 Dec 2017.

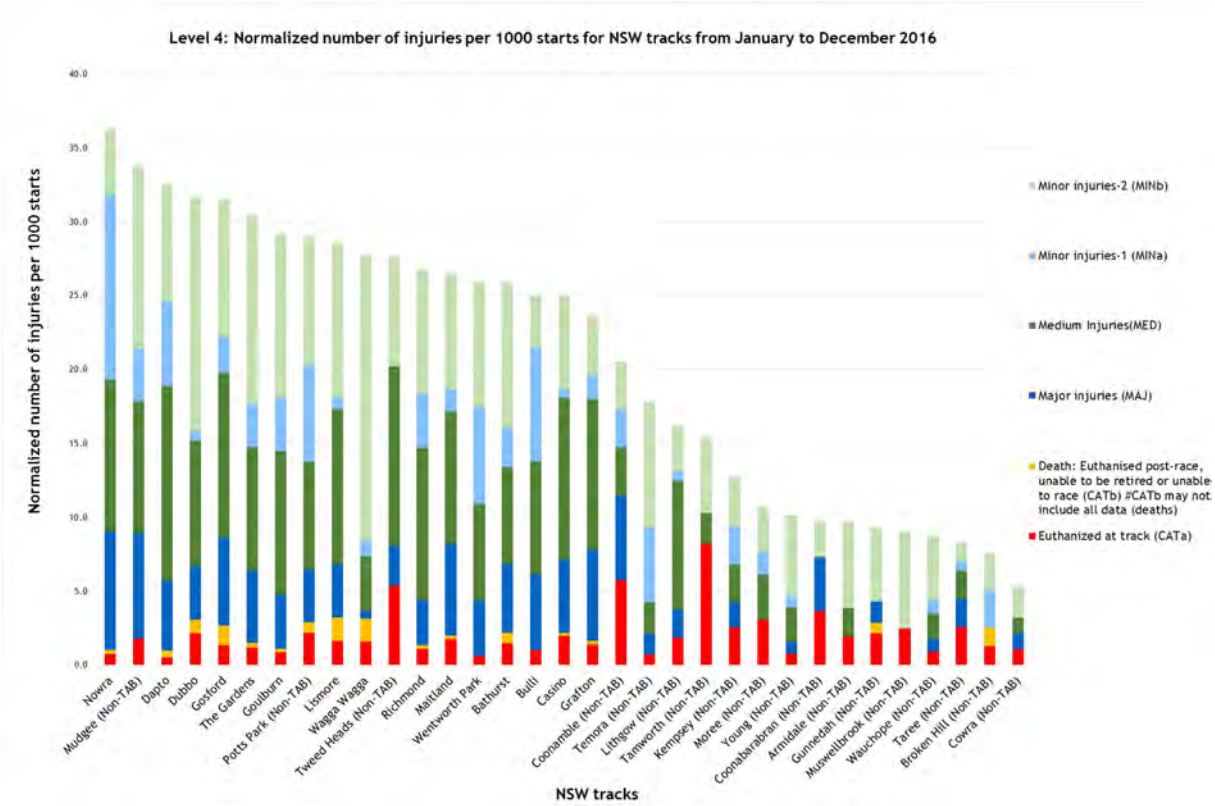

Figure 17: NSW Level 4 normalised injury rates – 1 Jan to 31 Dec 2016.

3 TRACK INVESTIGATIONS

INTRODUCTION

3.1 This chapter contains a review of each NSW track for the period 1 January 2016 to 31 December 2017.

3.2 It should be noted that the following injury location graphs may not include all the injuries as the location of some of the injuries was uncertain.

GOSFORD

GOSFORD: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.3 Figures 18 to 25 contain Grafton Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

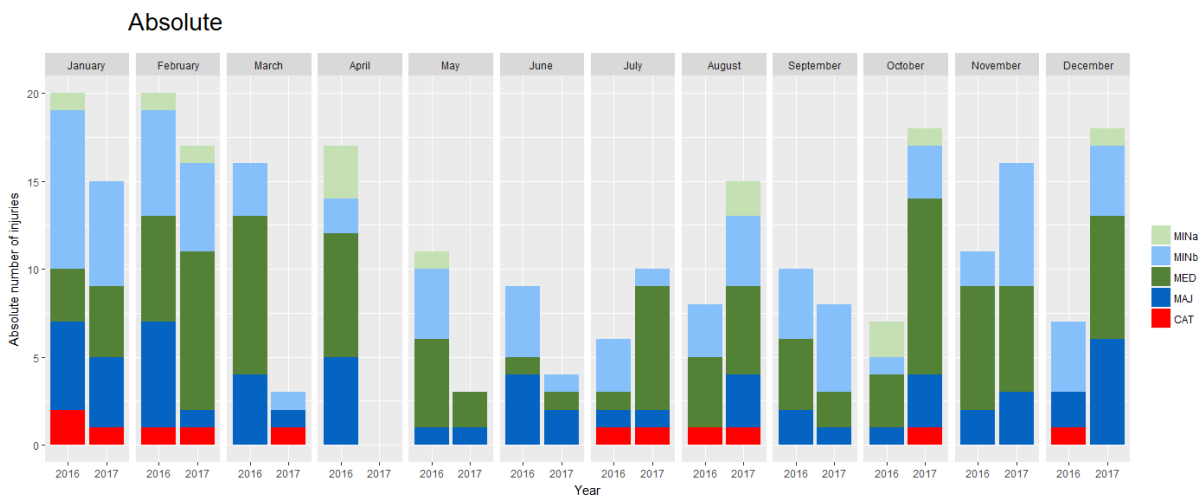

Figure 18: Gosford track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

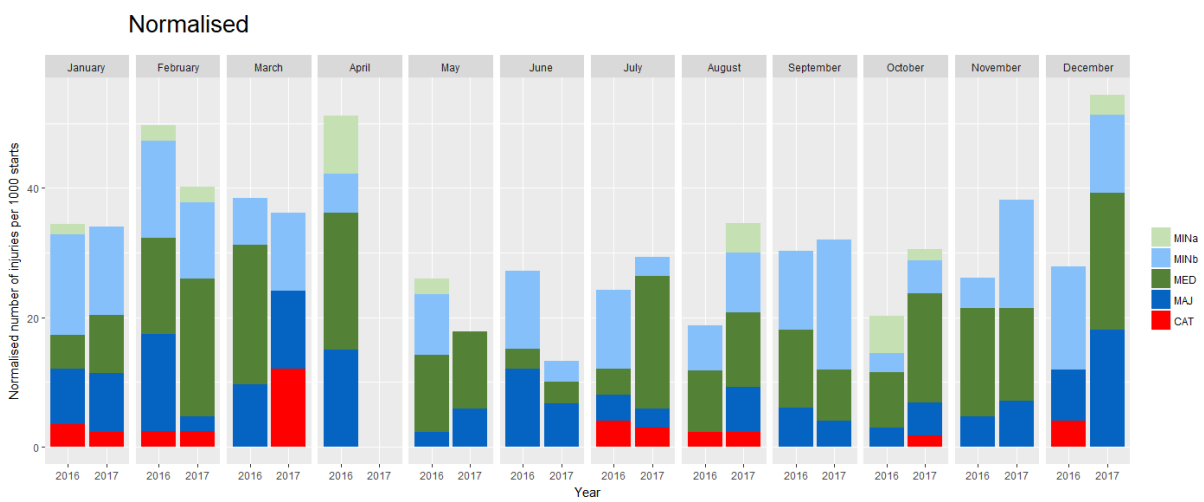

Figure 19: Gosford track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

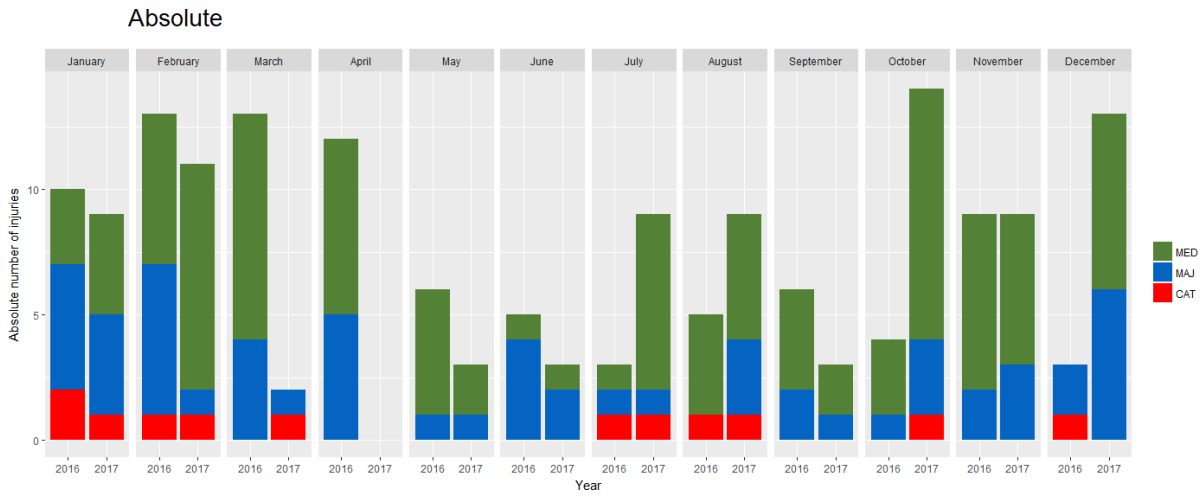

Figure 20: Gosford track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

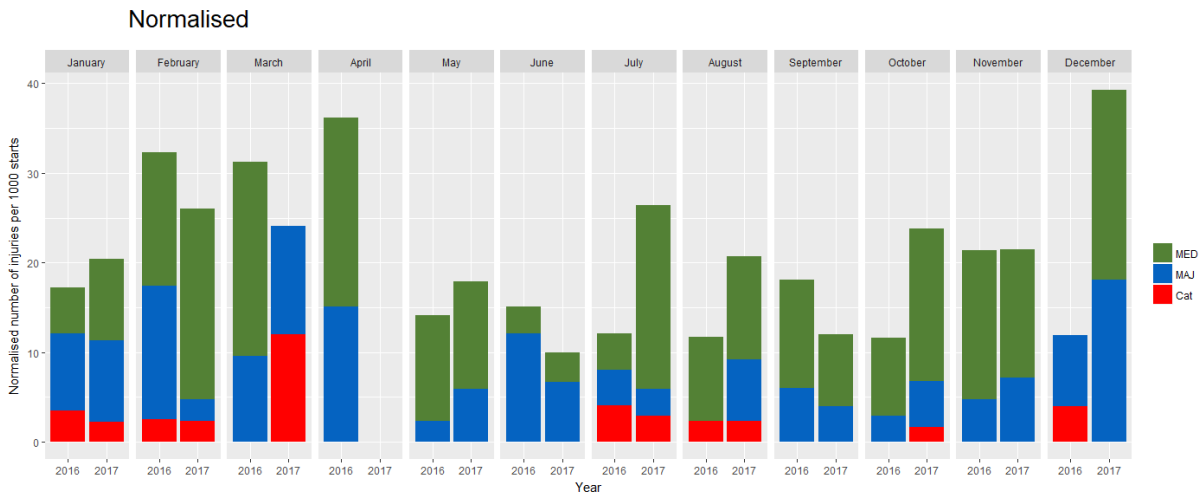

Figure 21: Gosford track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

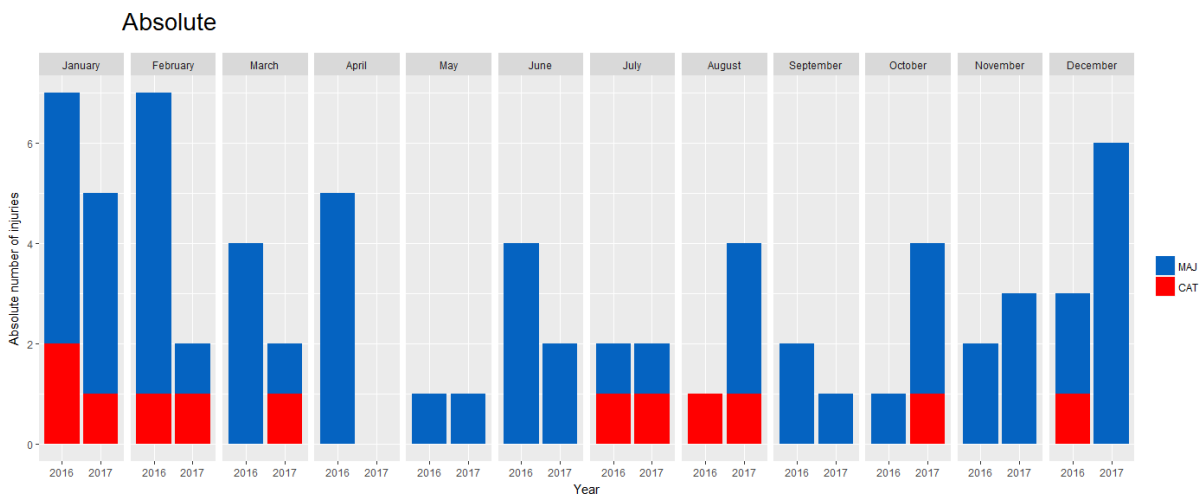

Figure 22: Gosford track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

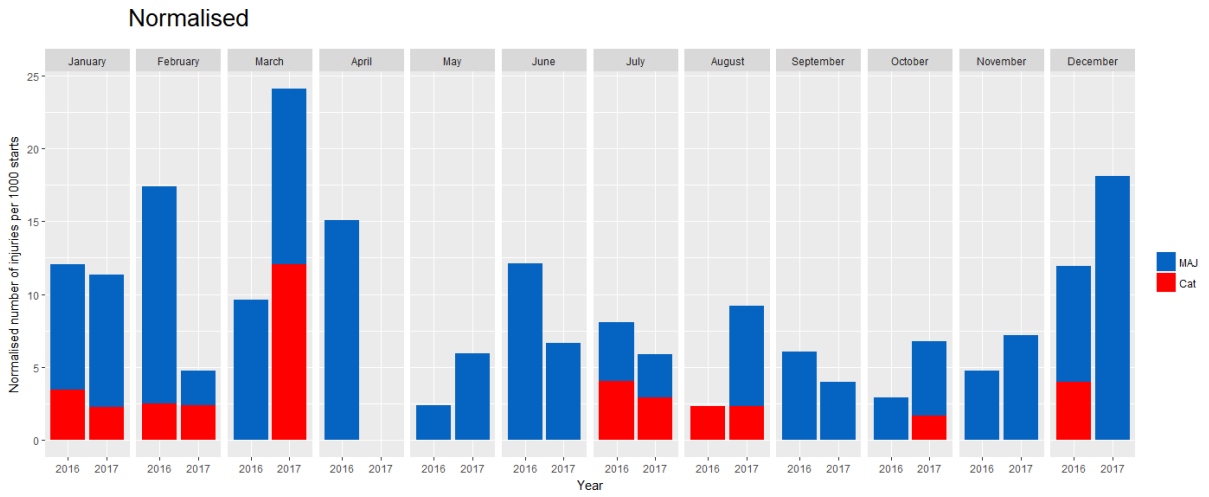

Figure 23: Gosford track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

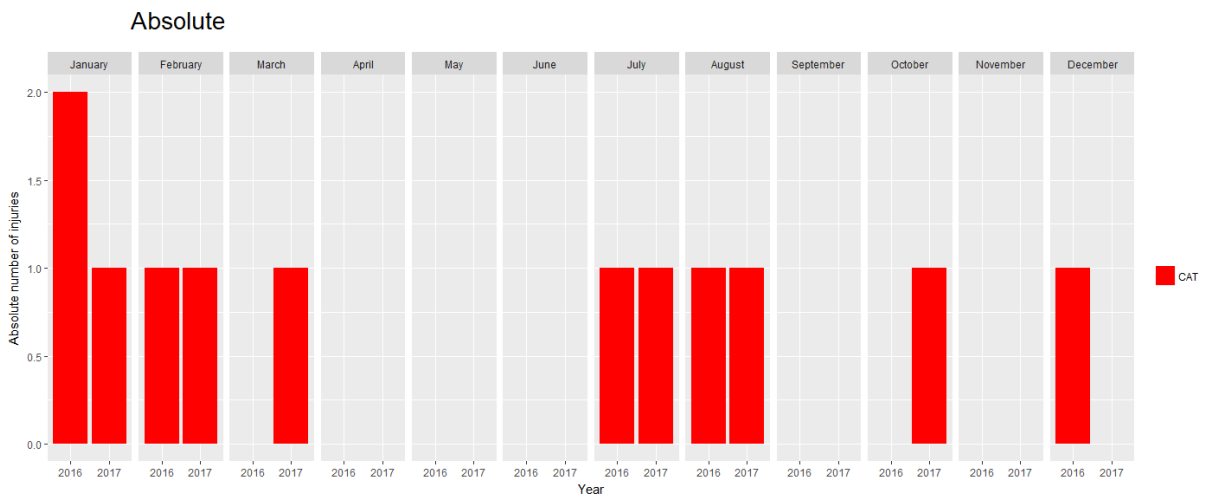

Figure 24: Gosford track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

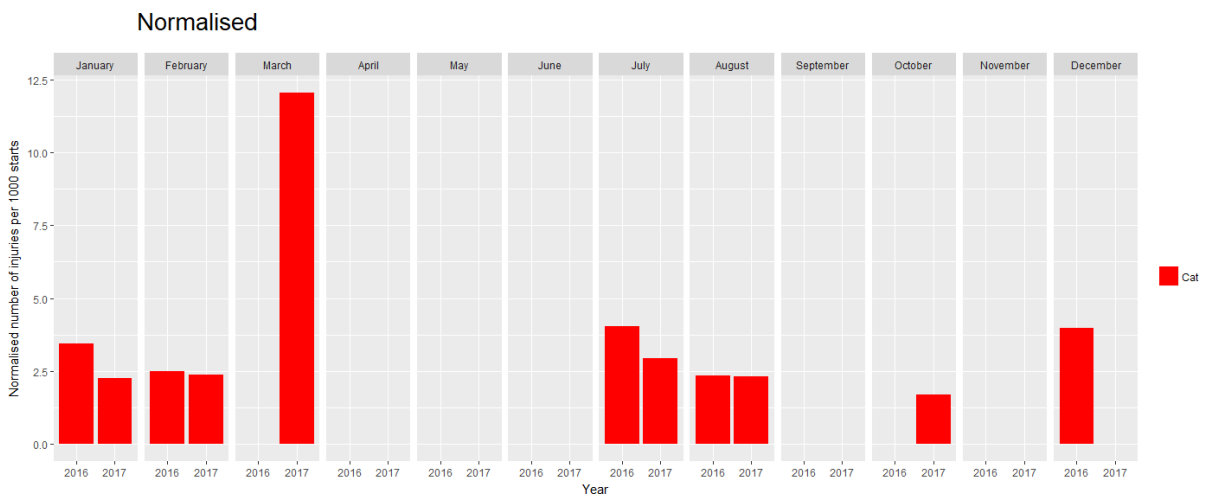

Figure 25: Gosford track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

GOSFORD: LOCATION OF INJURIES FOR 400 M - 1 JAN TO 31 DEC 2017

3.4 In this section, the injury locations of Gosford track for 400 m race distances are presented.

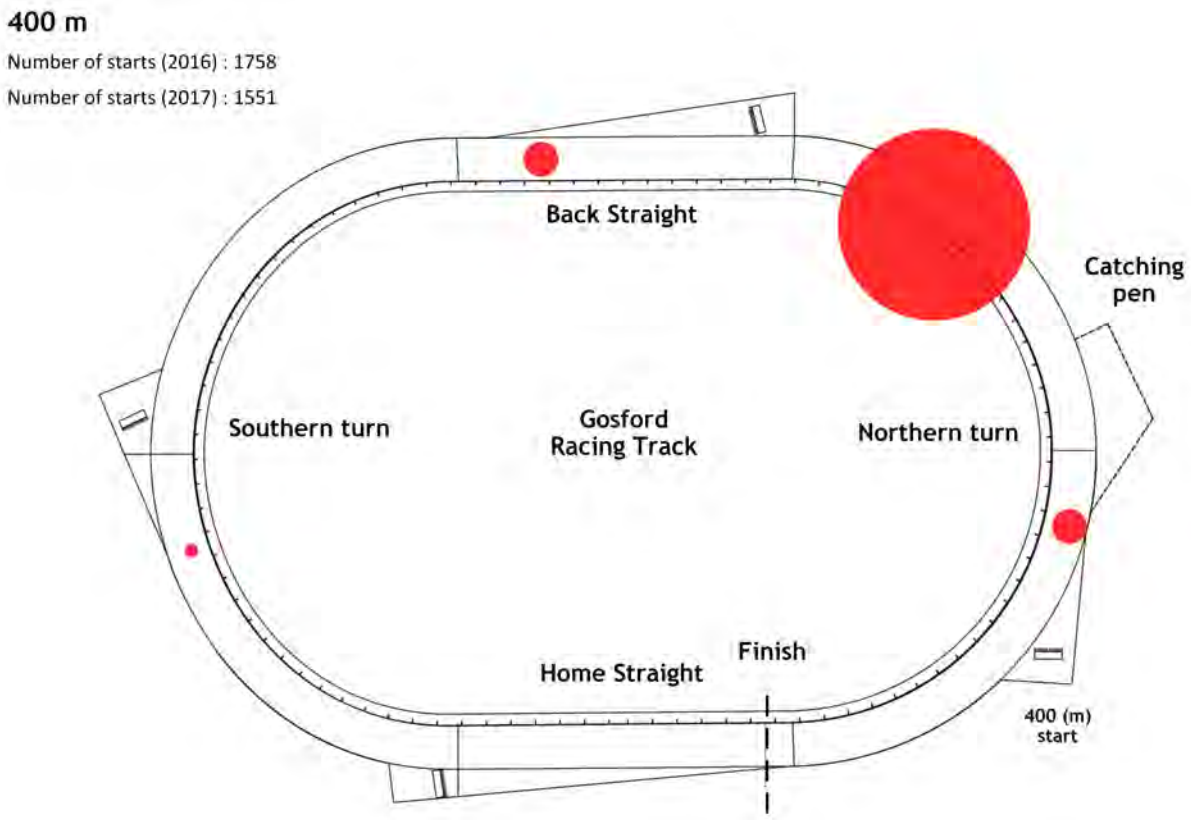

Figure 26: Gosford track location of injuries for the 400 m distance

3.5 The location of injuries is similar to that of 2016 i.e. the location of the majority of injuries continues to occur on the first bend after the start.

GOSFORD: LOCATION OF INJURIES FOR 515 M - 1 JAN TO 31 DEC 2017

3.6 In this section, the injury locations of Gosford track for 515 m race distances is presented.

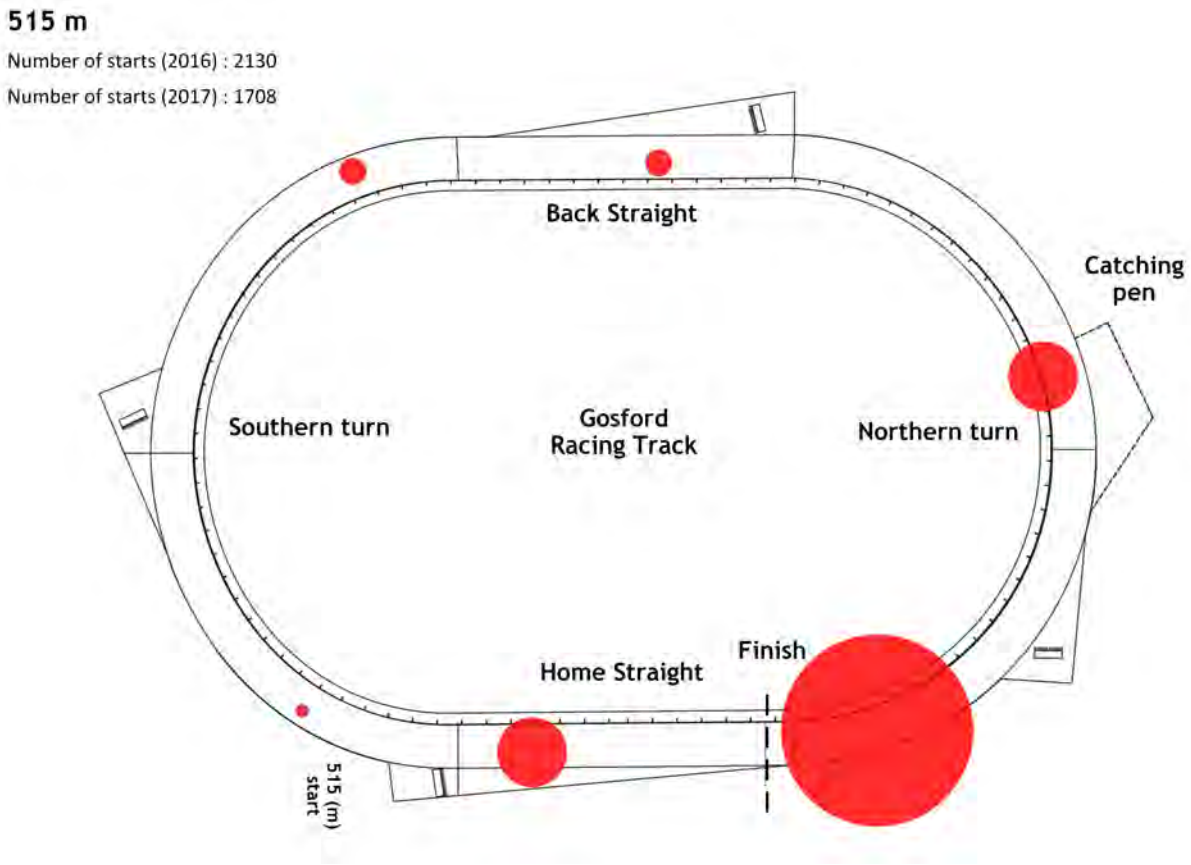

Figure 27: Gosford track location of injuries for the 515 m distance

3.7 The location of injuries is similar to that reported in the 2016 UTS Report i.e. the location of the majority of injuries continues to occur on the first bend after the start.

GOSFORD: LOCATION OF INJURIES FOR 600 M - 1 JAN TO 31 DEC 2017

3.8 The location of injuries is similar to that of 2016.

3.9 In this section, the injury locations of Gosford track for 600 m race distances is presented.

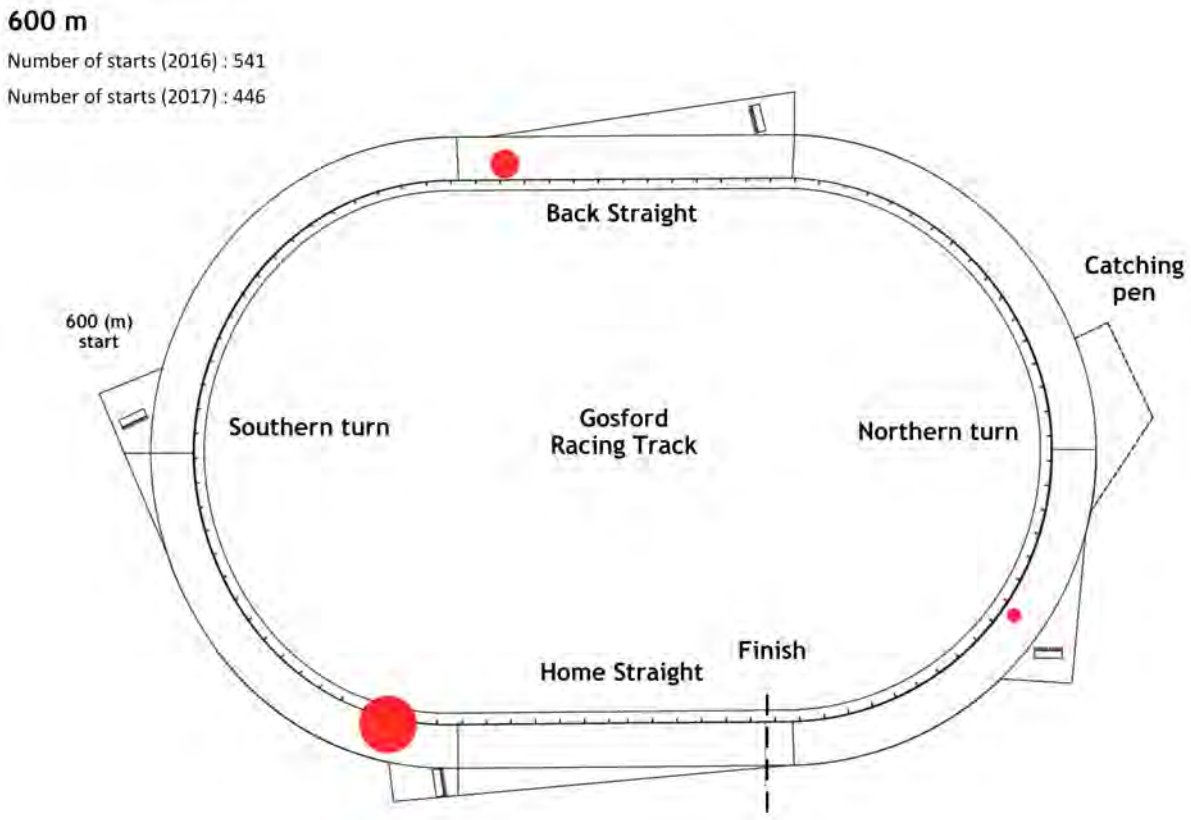

Figure 28: Gosford track location of injuries for the 600 m distance

3.10 The location of injuries is similar to 2016.

THE GARDENS

THE GARDENS: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.11 Figures 29 to 36 contain The Gardens Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

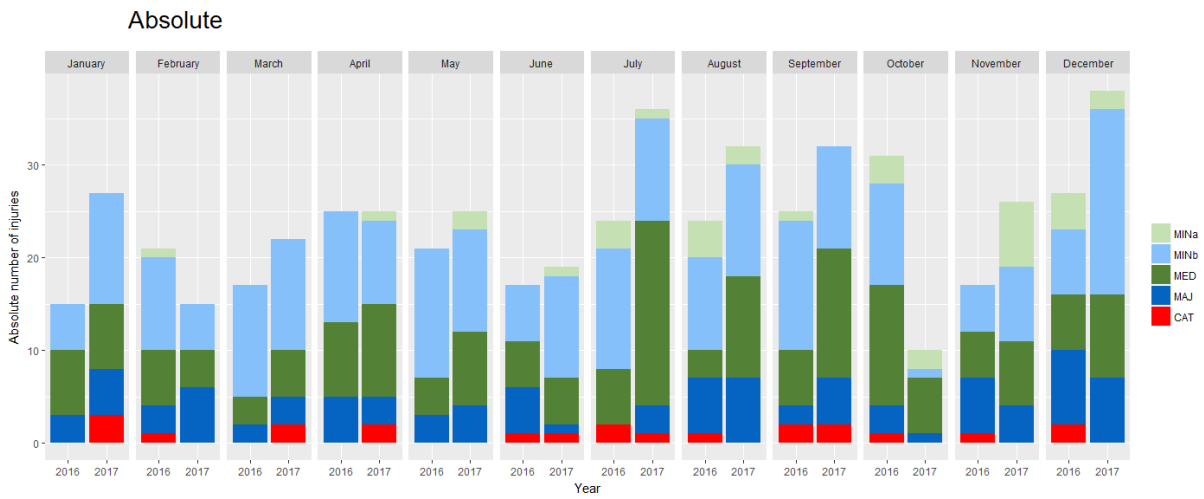

Figure 29: The Gardens track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

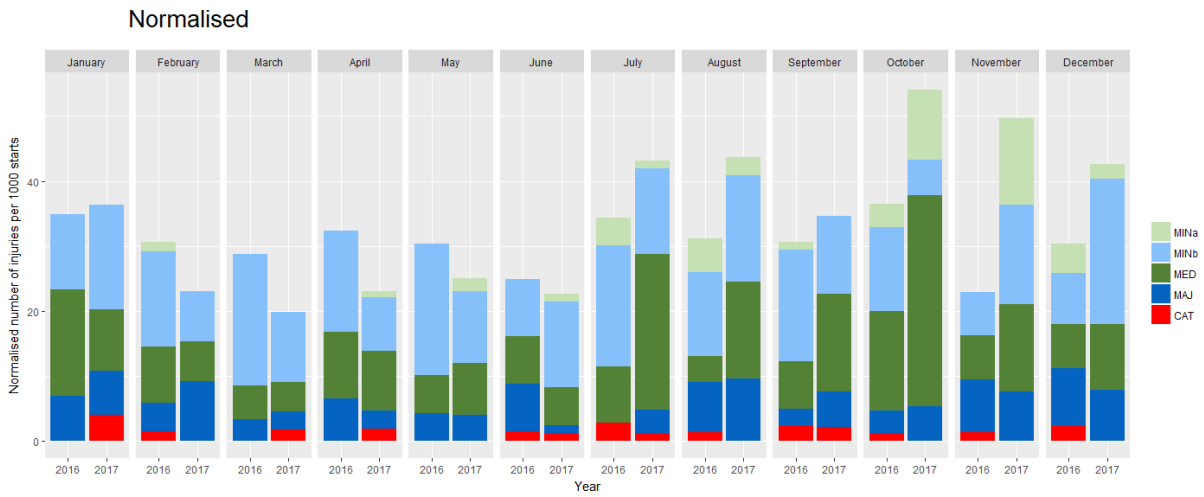

Figure 30: The Gardens track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

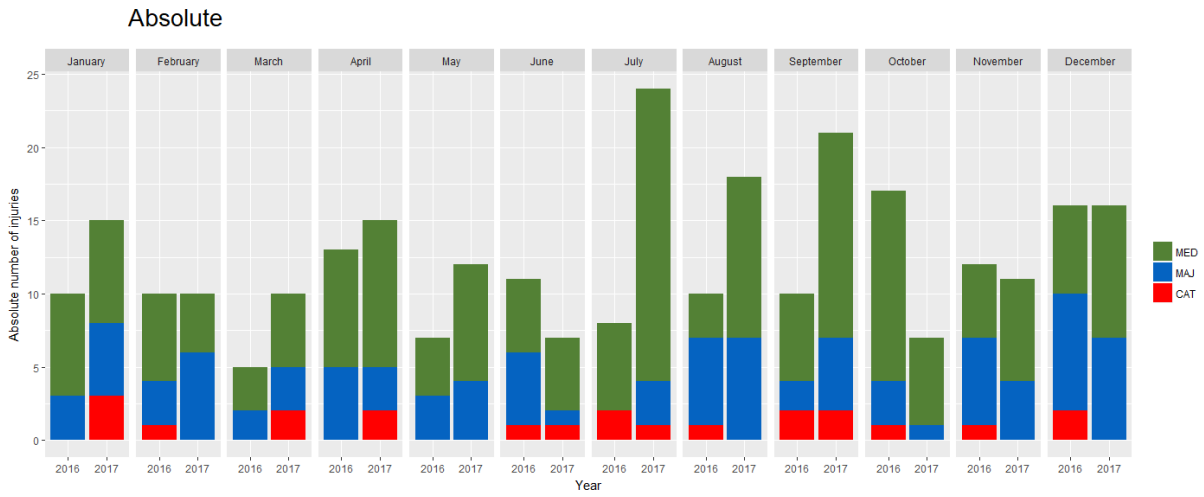

Figure 31: The Gardens track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

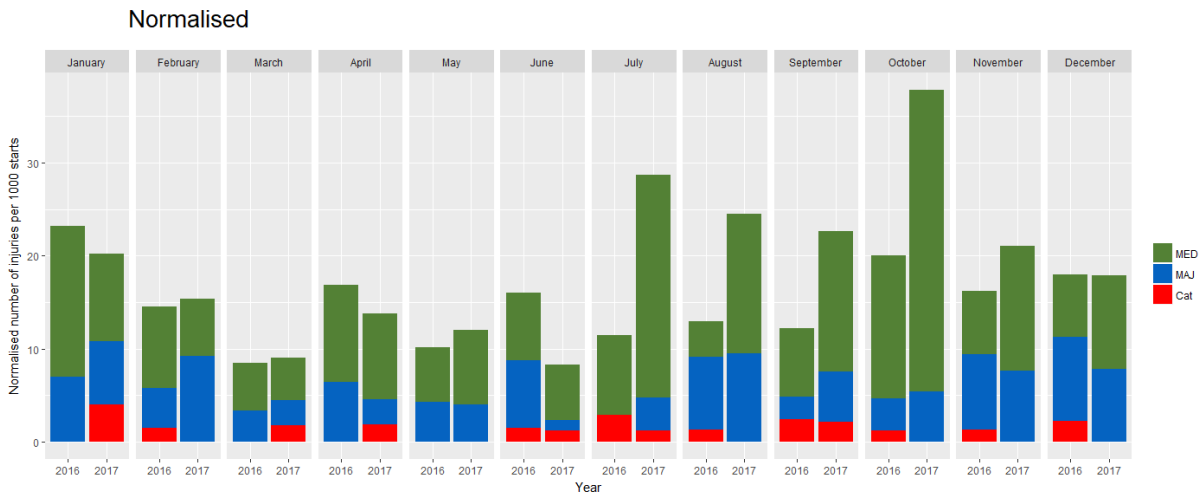

Figure 32: The Gardens track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

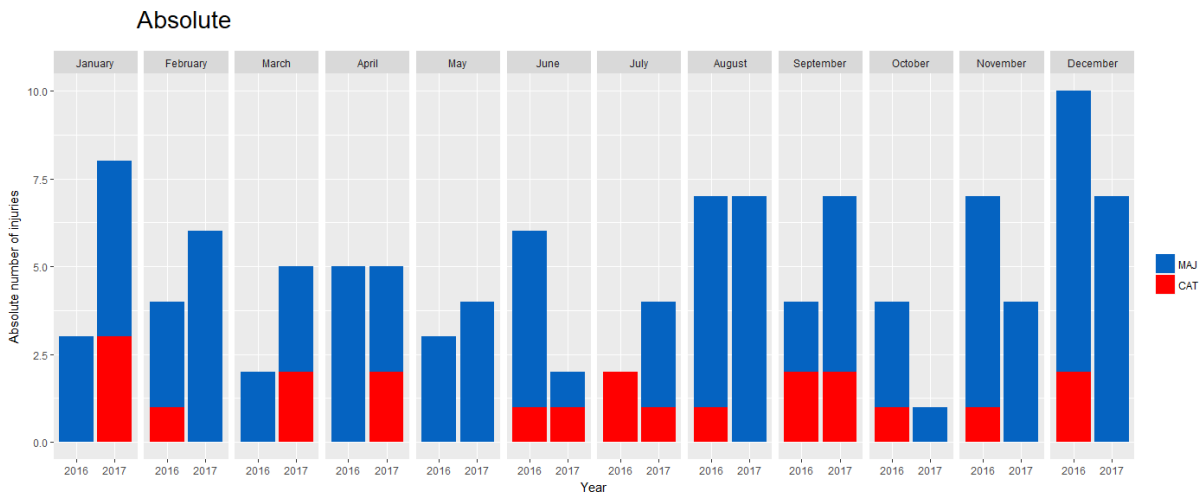

Figure 33: The Gardens track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

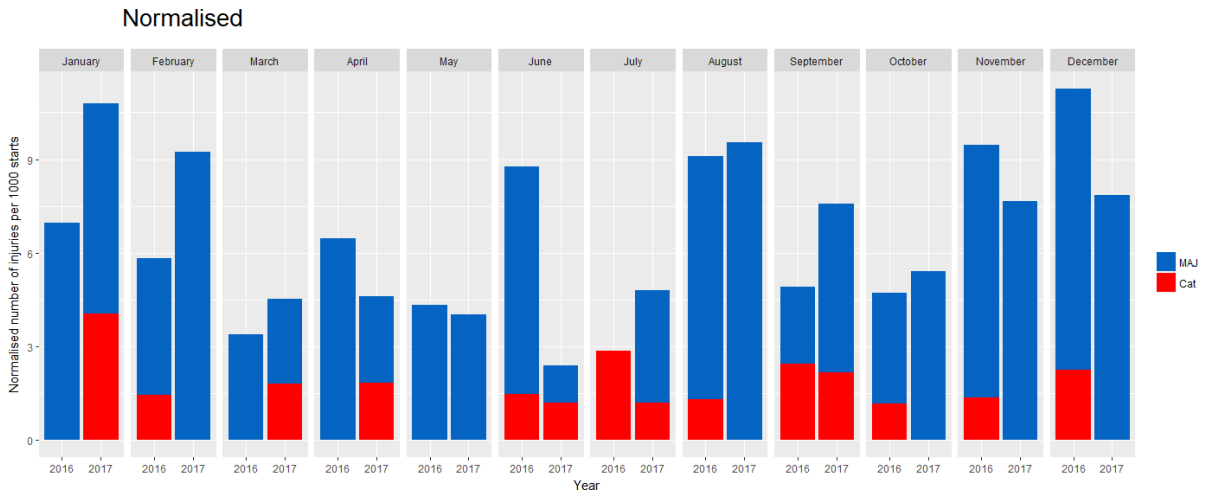

Figure 34: The Gardens track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

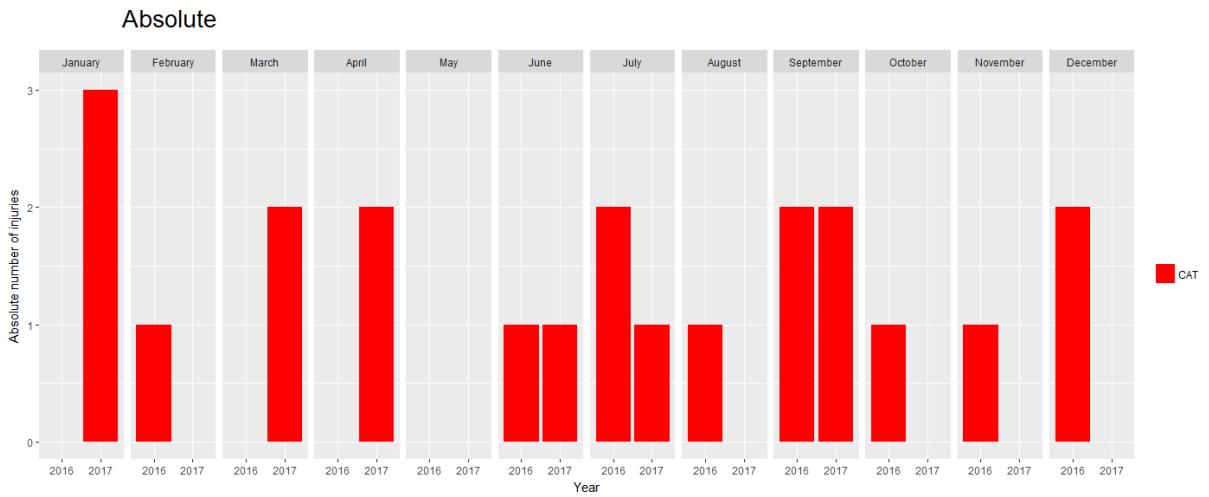

Figure 35: The Gardens track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

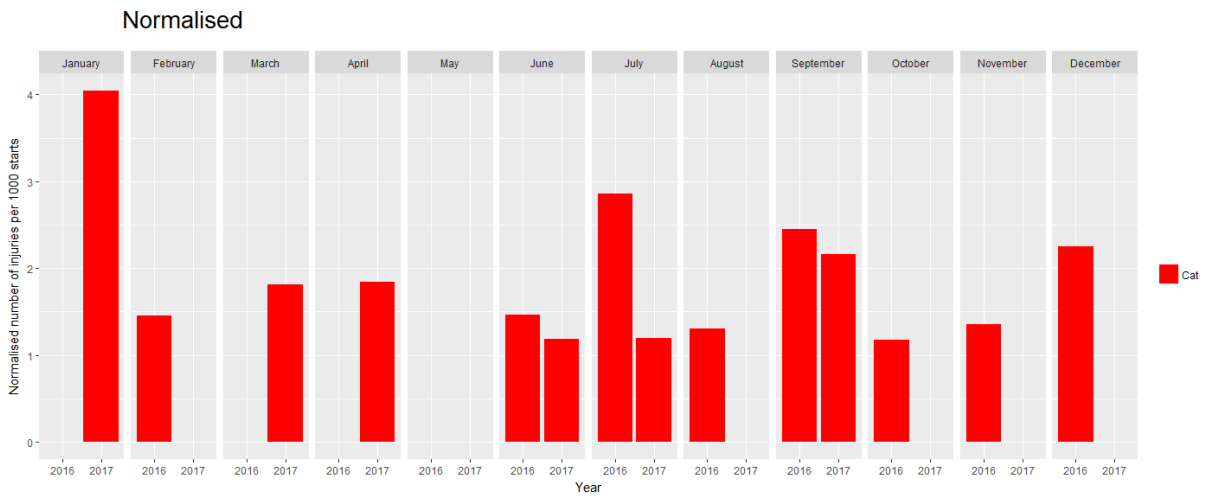

Figure 36: The Gardens track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

THE GARDENS: LOCATION OF INJURIES FOR 400 M - 1 JAN TO 31 DEC 2017

3.12 In this section, the injury locations of The Gardens track for 400 m race distances are presented.

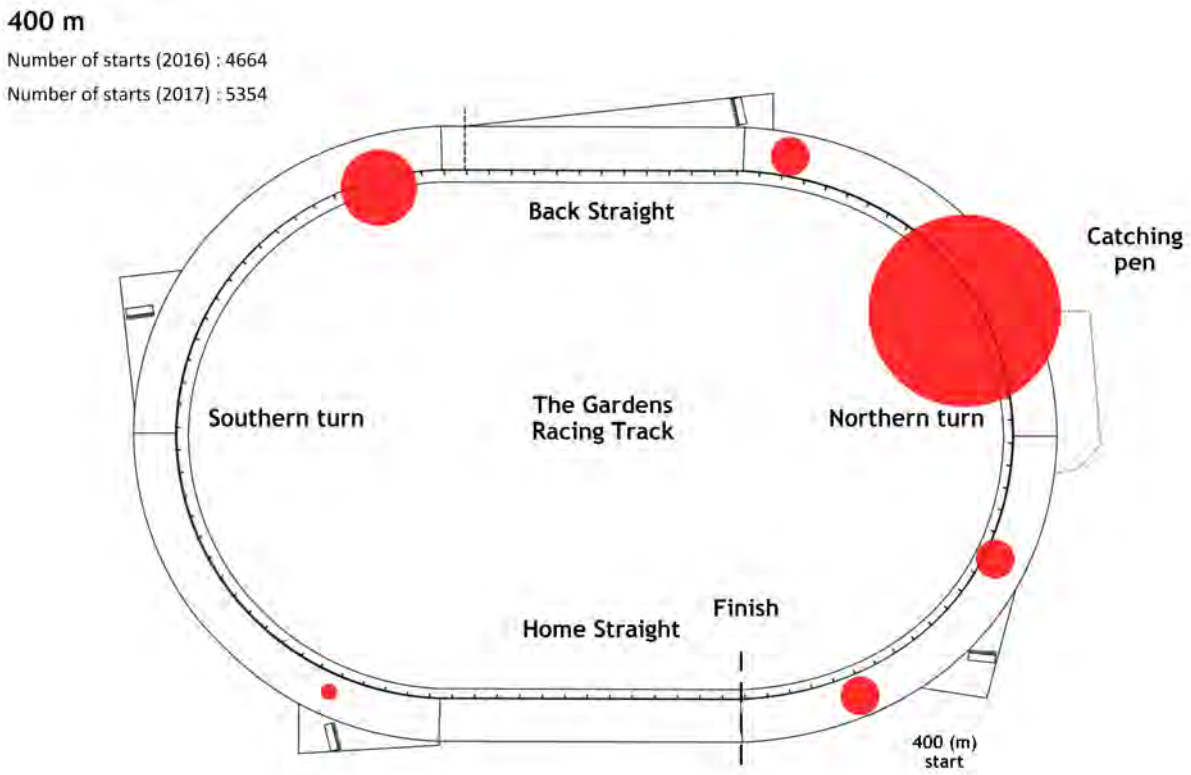

Figure 37: The Gardens track location of injuries for the 400 m distance

3.13 The location of injuries is similar to 2016.

THE GARDENS: LOCATION OF INJURIES FOR 515 M - 1 JAN TO 31 DEC 2017

3.14 In this section, the injury locations of The Gardens track for 515 m race distances is presented.

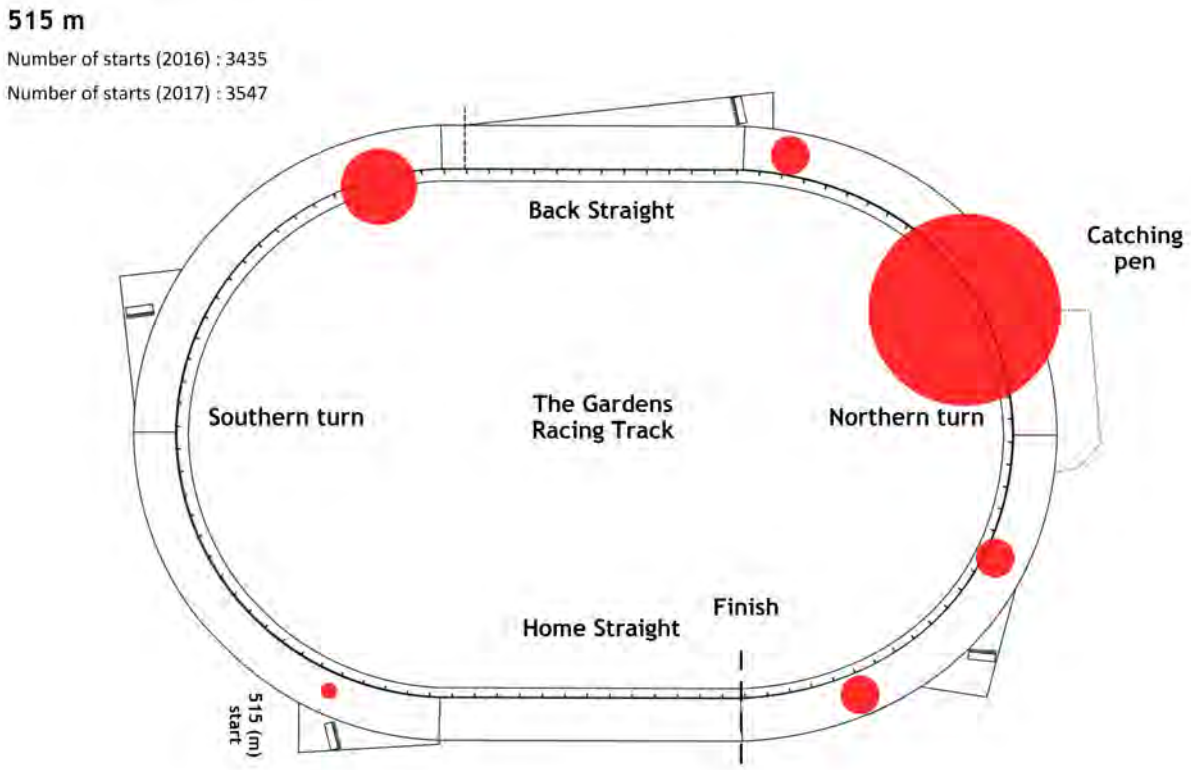

Figure 38: The Gardens track location of injuries for the 515 m distance

3.15 The location of injuries is similar to 2016.

THE GARDENS: LOCATION OF INJURIES FOR 600 M - 1 JAN TO 31 DEC 2017

3.16 In this section, the injury locations of The Gardens track for 600 m race distances are presented.

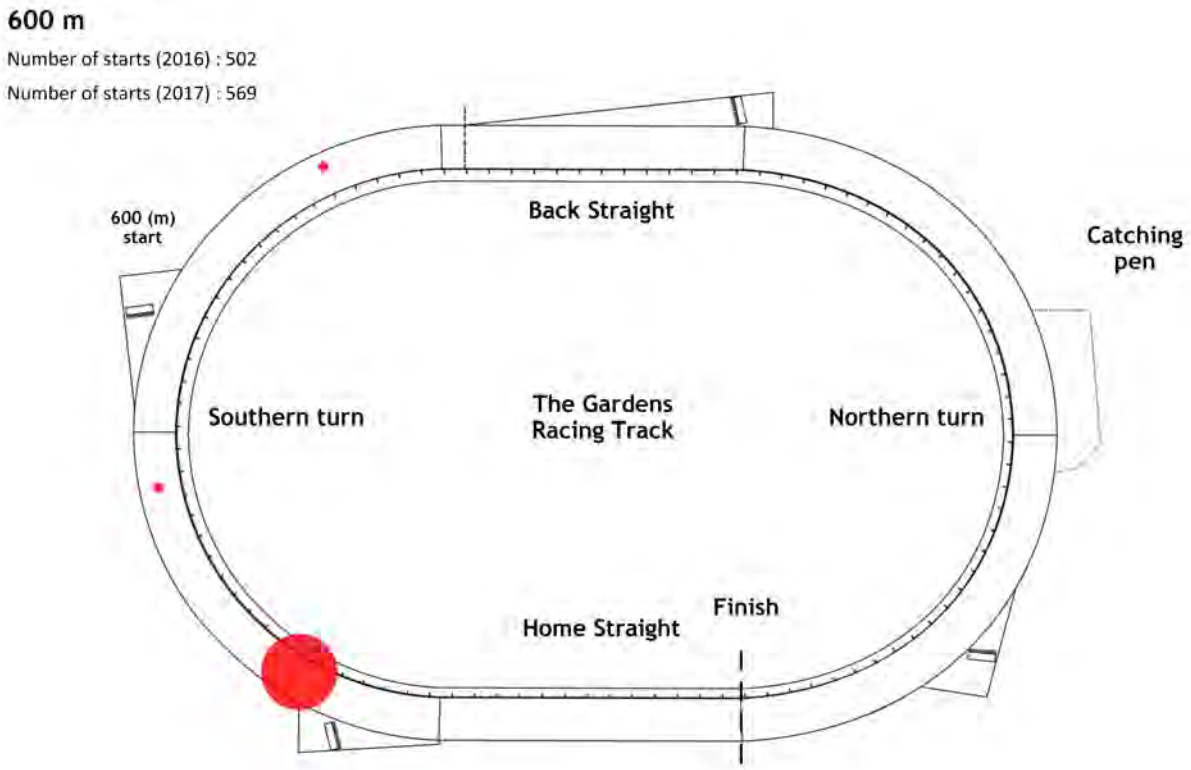

Figure 39: The Gardens track location of injuries for the 600 m distance

3.17 The location of injuries is similar to 2016.

NOWRA

NOWRA: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.18 Figures 40 to 47 contain Nowra Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

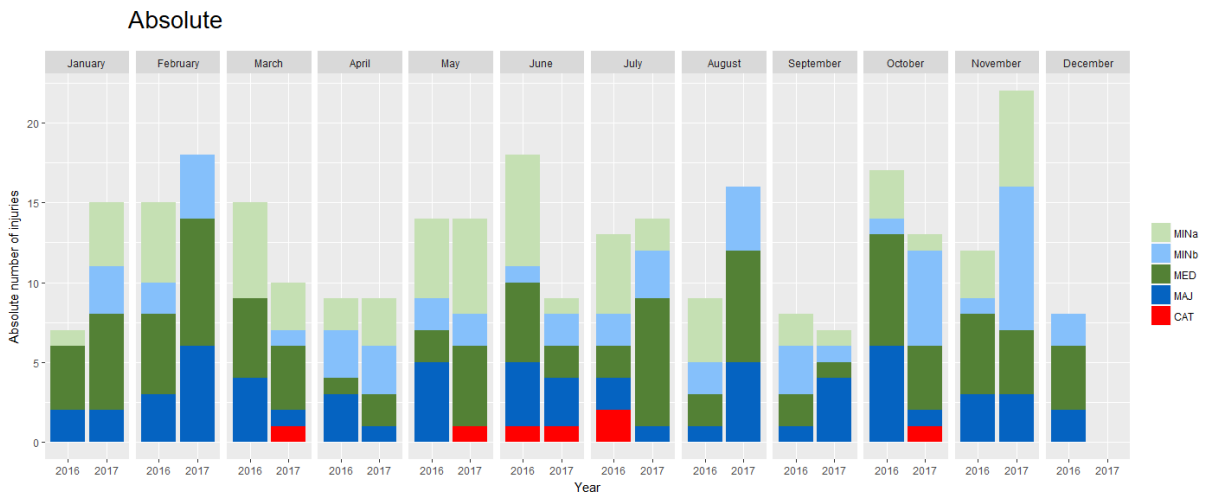

Figure 40: Nowra track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

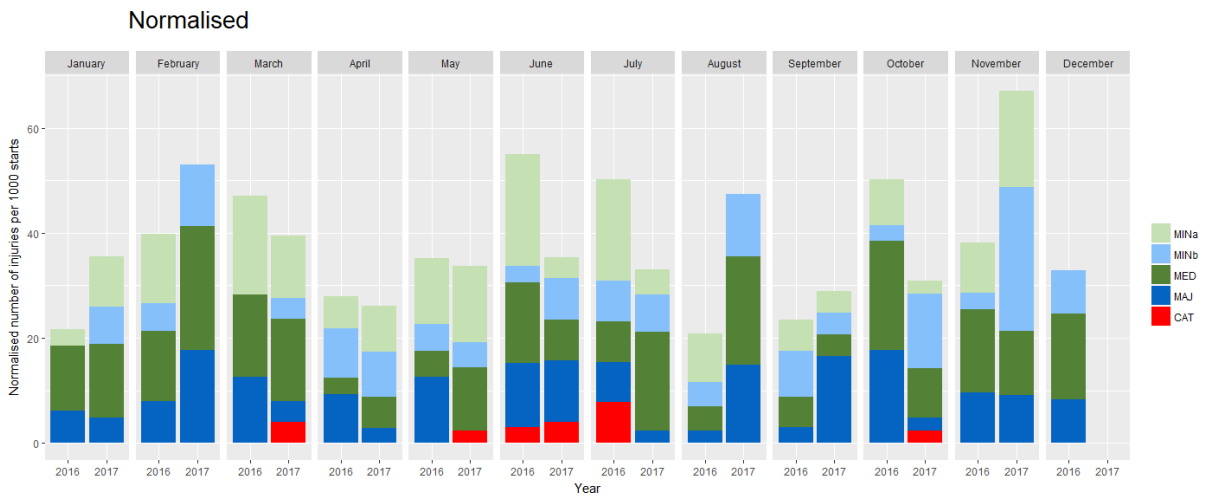

Figure 41: Nowra track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

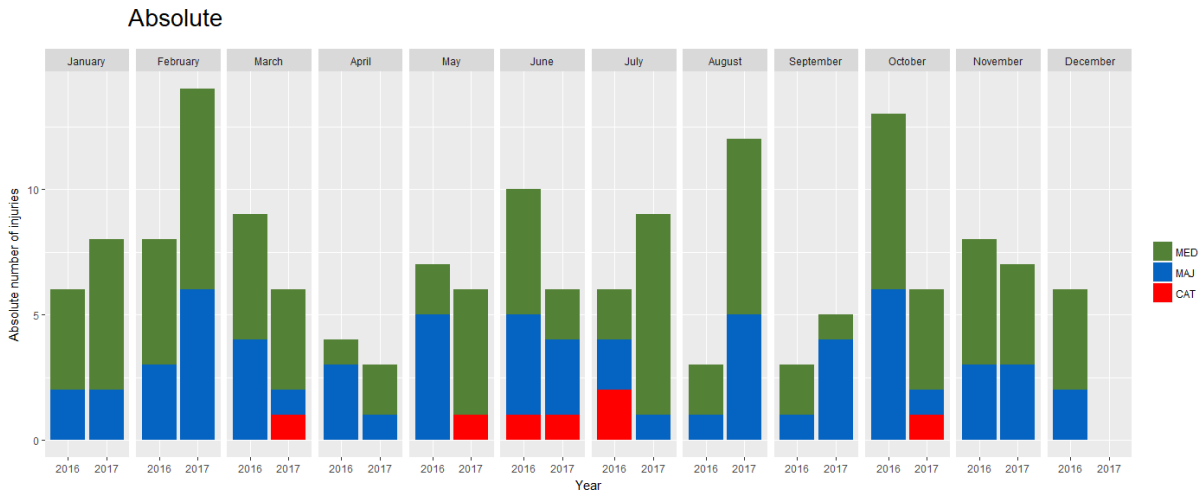

Figure 42: Nowra track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

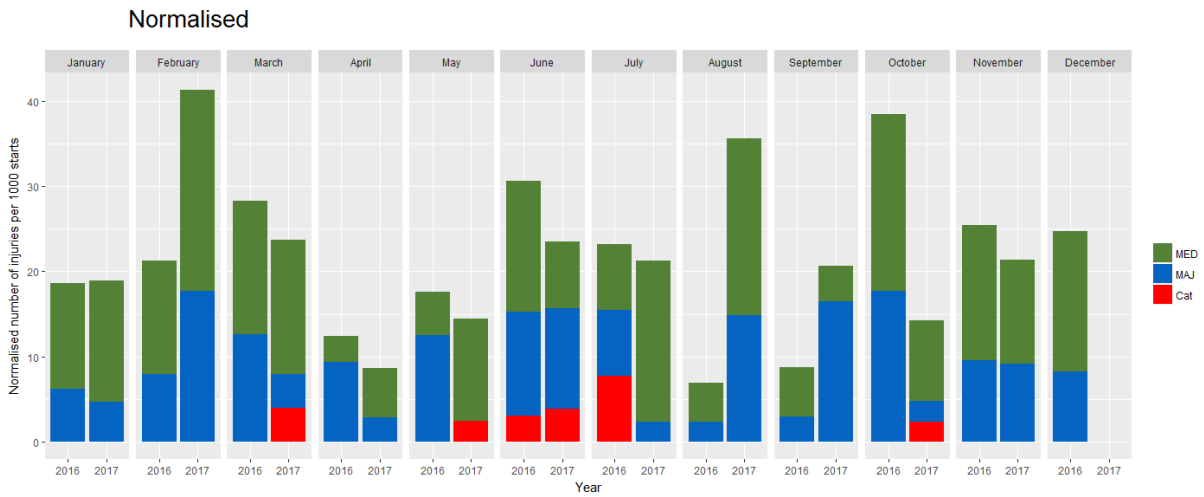

Figure 43: Nowra track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

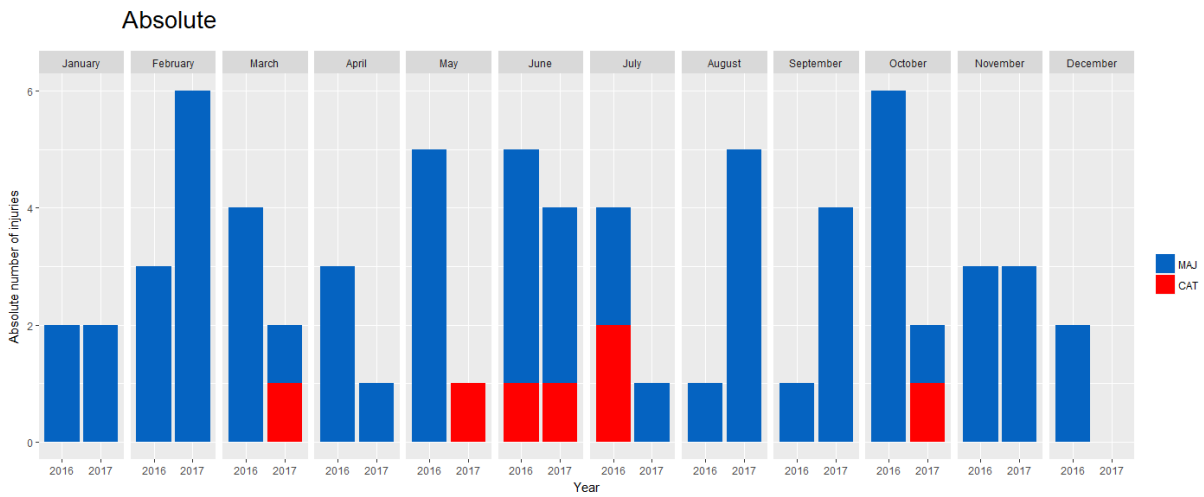

Figure 44: Nowra track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

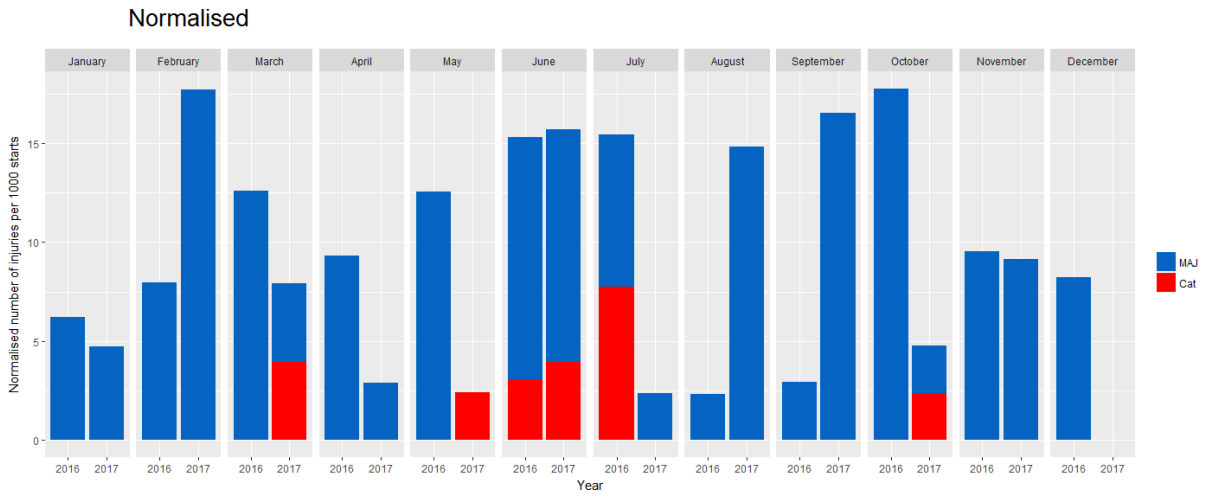

Figure 45: Nowra track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

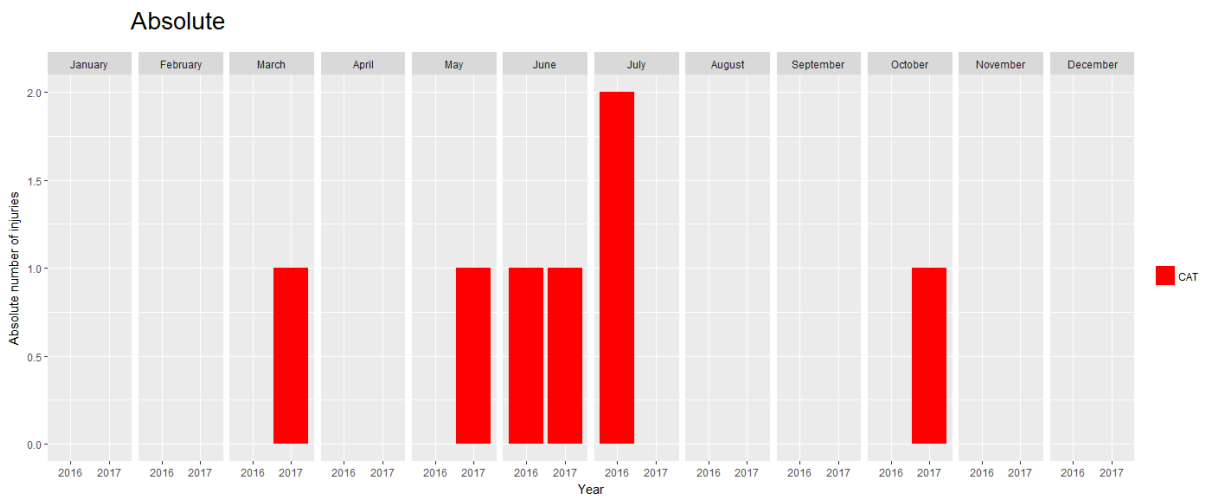

Figure 46: Nowra track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

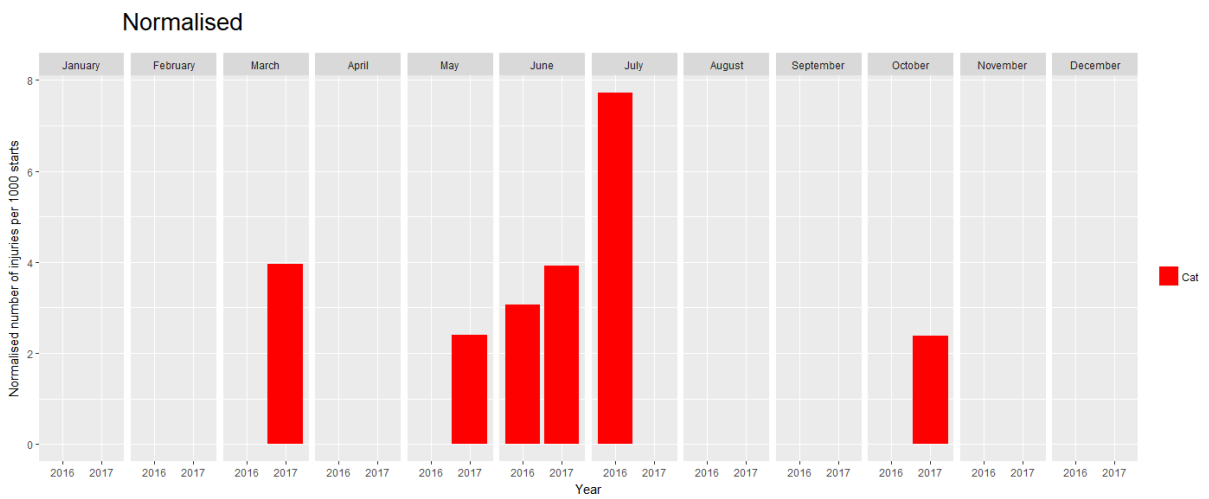

Figure 47: Nowra track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

NOWRA: LOCATION OF INJURIES FOR 365 M - 1 JAN TO 31 DEC 2017

3.19 In this section, the injury locations of Nowra track for 365 m race distances are presented.

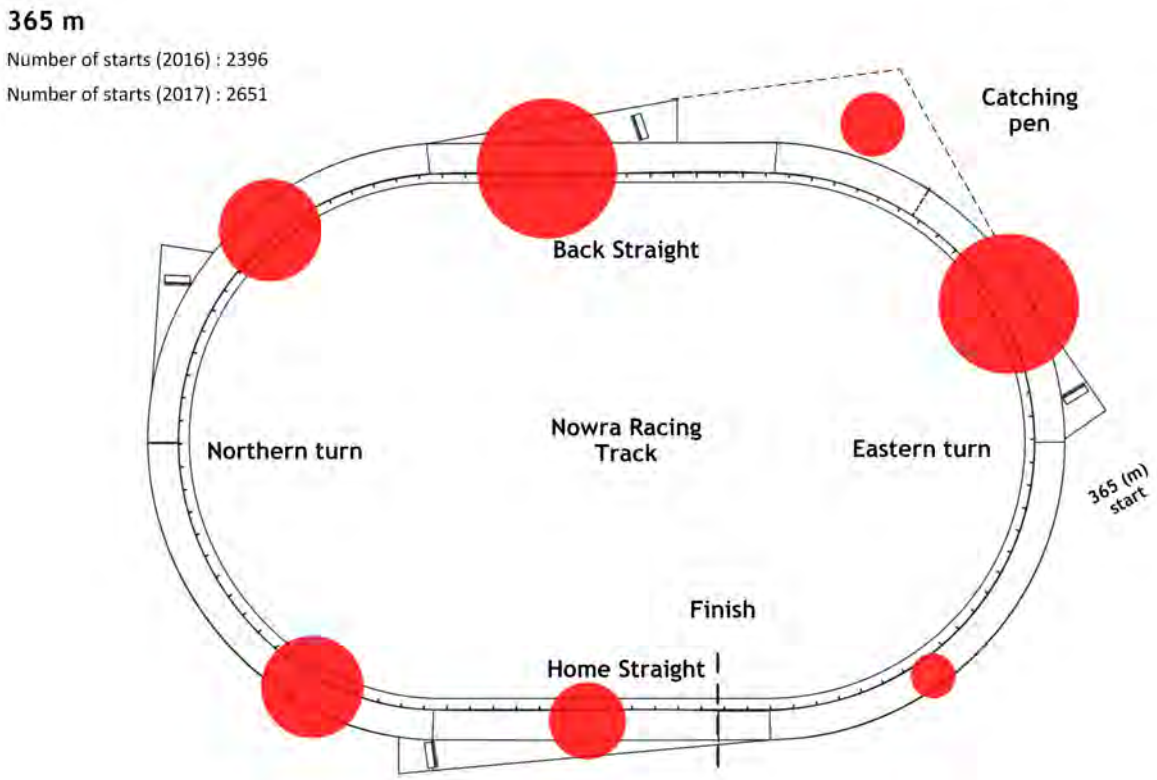

Figure 48: Nowra track location of injuries for the 365 m distance

3.20 The location of injuries is similar to 2016.

NOWRA: LOCATION OF INJURIES FOR 520 M - 1 JAN TO 31 DEC 2017

3.21 In this section, the injury locations of Nowra track for 520 m race distances are presented.

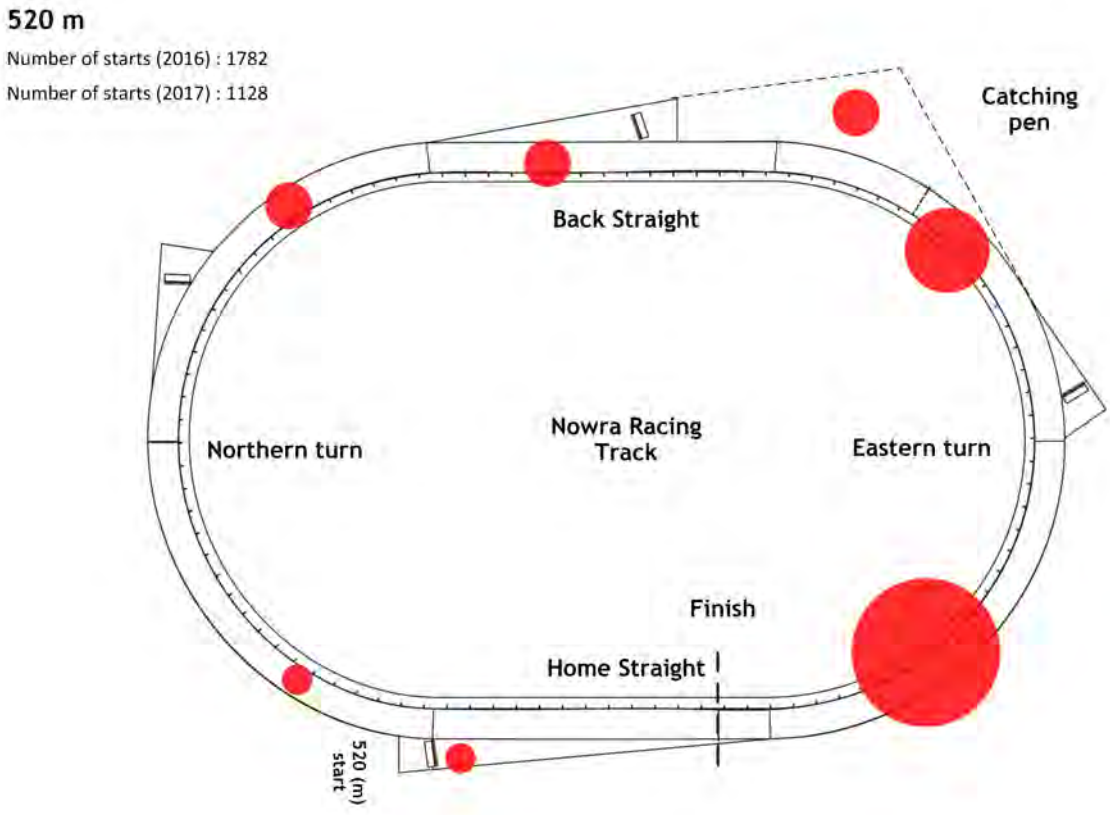

Figure 49: Nowra track location of injuries for the 520 m distance

3.22 The location of injuries is similar to 2016.

RICHMOND

RICHMOND: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.23 Figures 50 to 57 contain Richmond Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

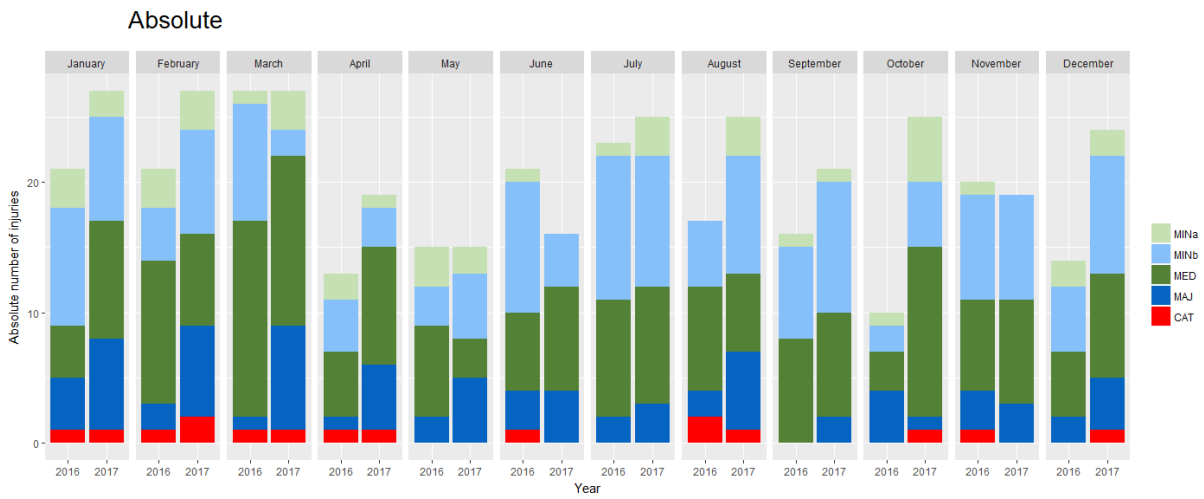

Figure 50: Richmond track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

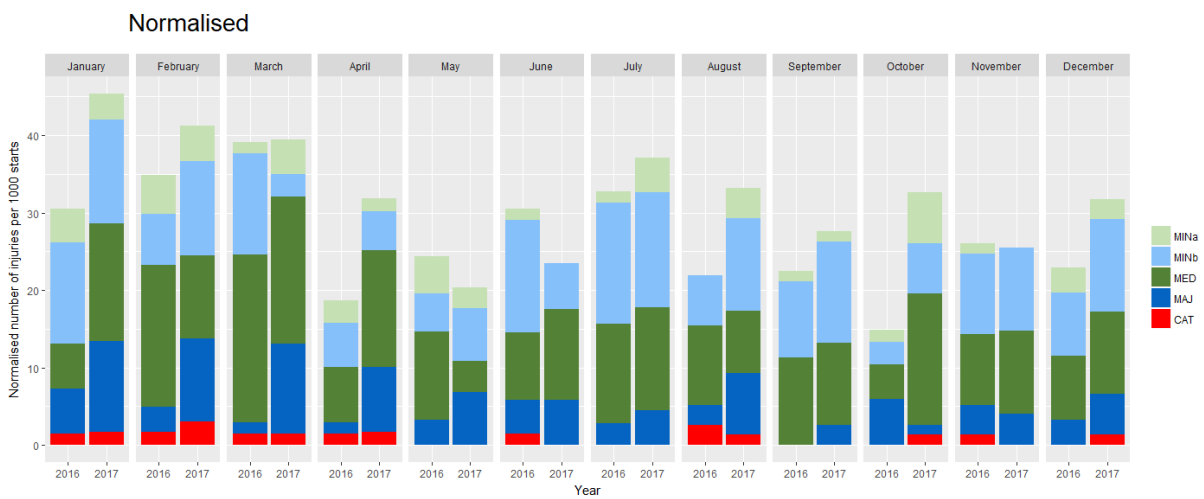

Figure 51: Richmond track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

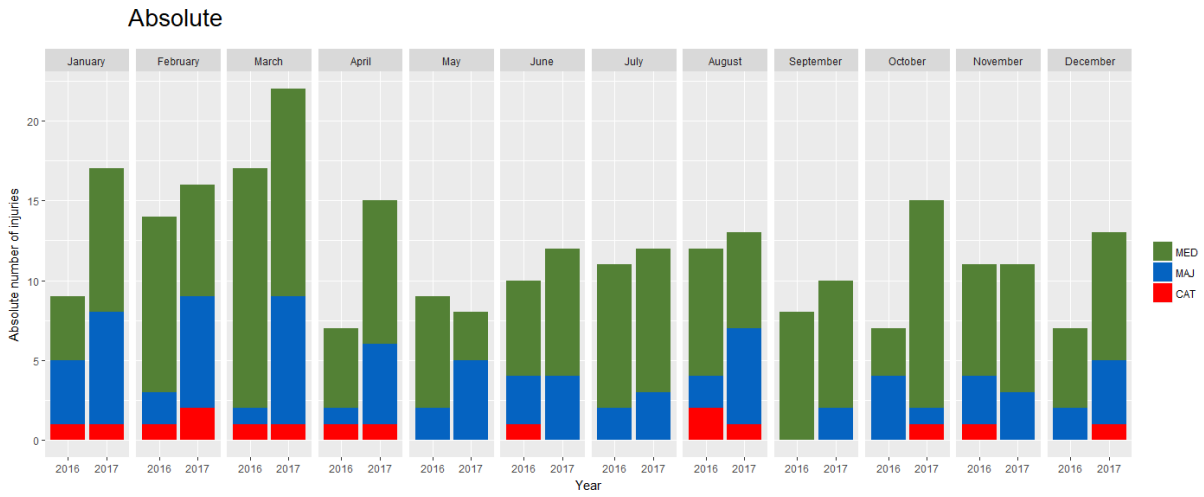

Figure 52: Richmond track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

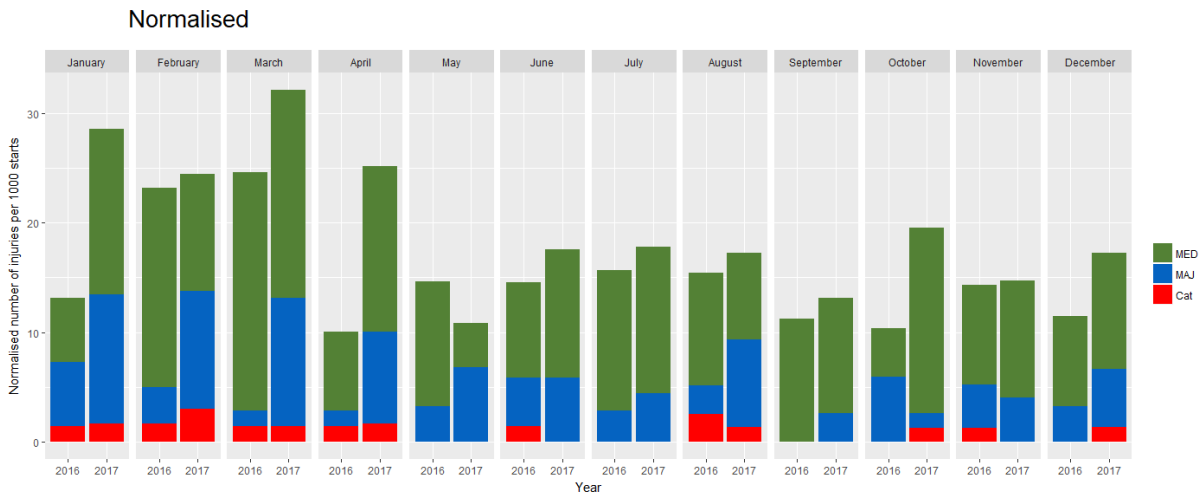

Figure 53: Richmond track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

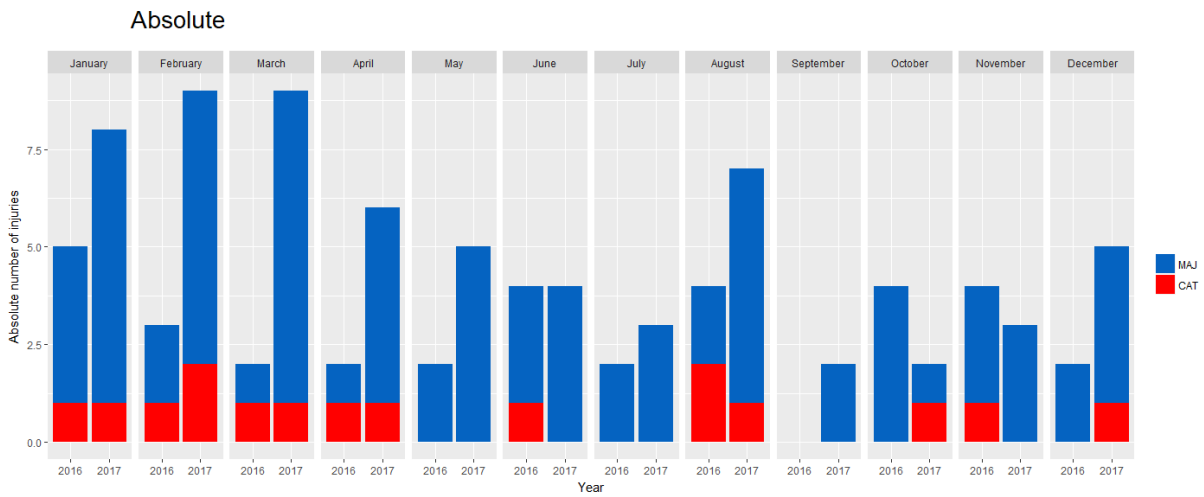

Figure 54: Richmond track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

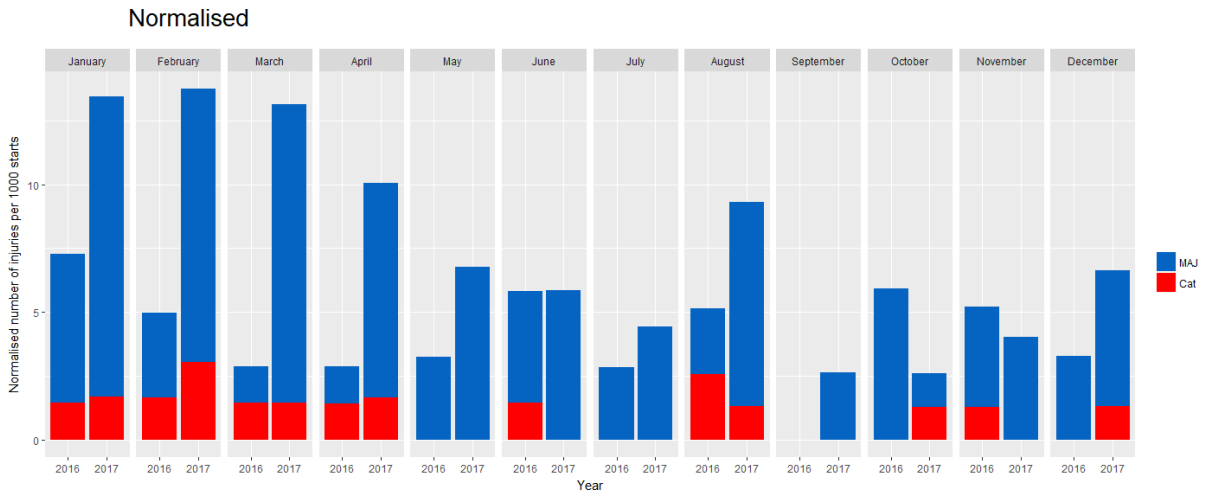

Figure 55: Richmond track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

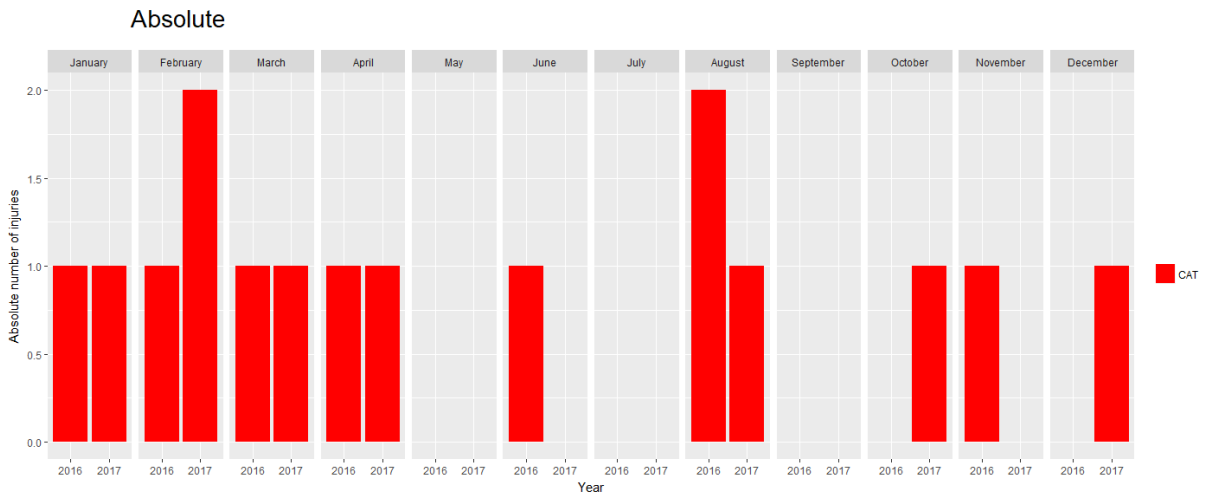

Figure 56: Richmond track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

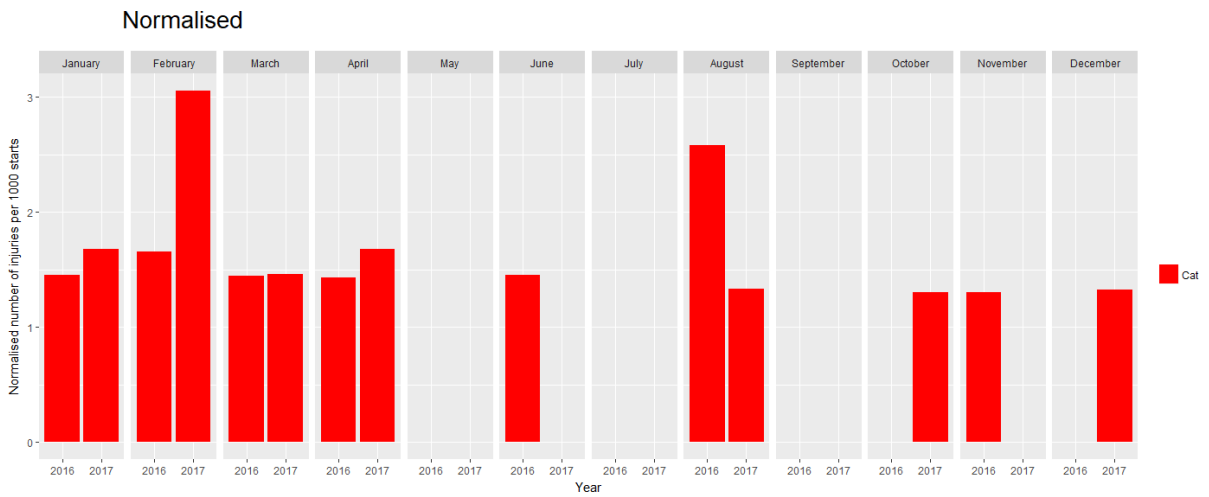

Figure 57: Richmond track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

RICHMOND: LOCATION OF INJURIES FOR 330 M - 1 JAN TO 31 DEC 2017

3.24 In this section, the injury locations of Richmond track for 330 m race distances are presented.

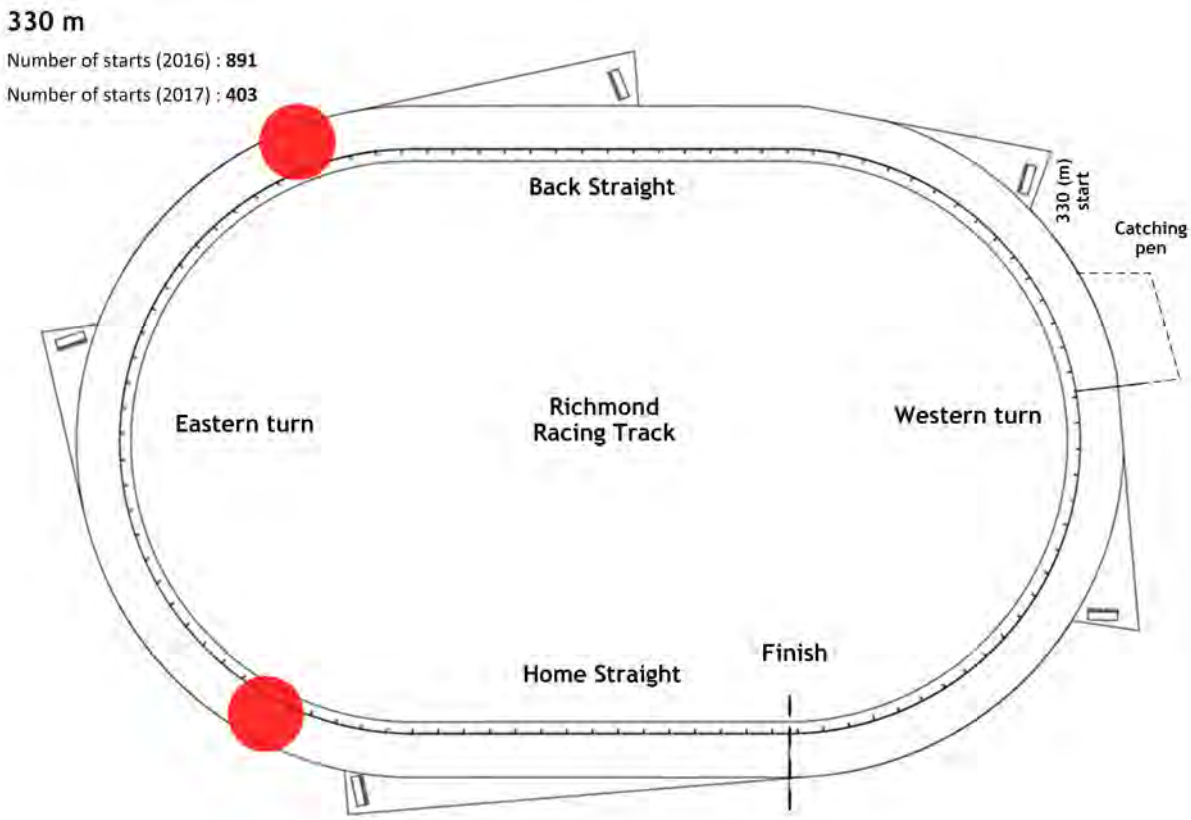

Figure 58: Richmond track location of injuries for the 330 m distance

3.25 The location of injuries is similar to 2016.

RICHMOND: LOCATION OF INJURIES FOR 400 M - 1 JAN TO 31 DEC 2017

3.26 In this section, the injury locations of Richmond track for 400 m race distances are presented.

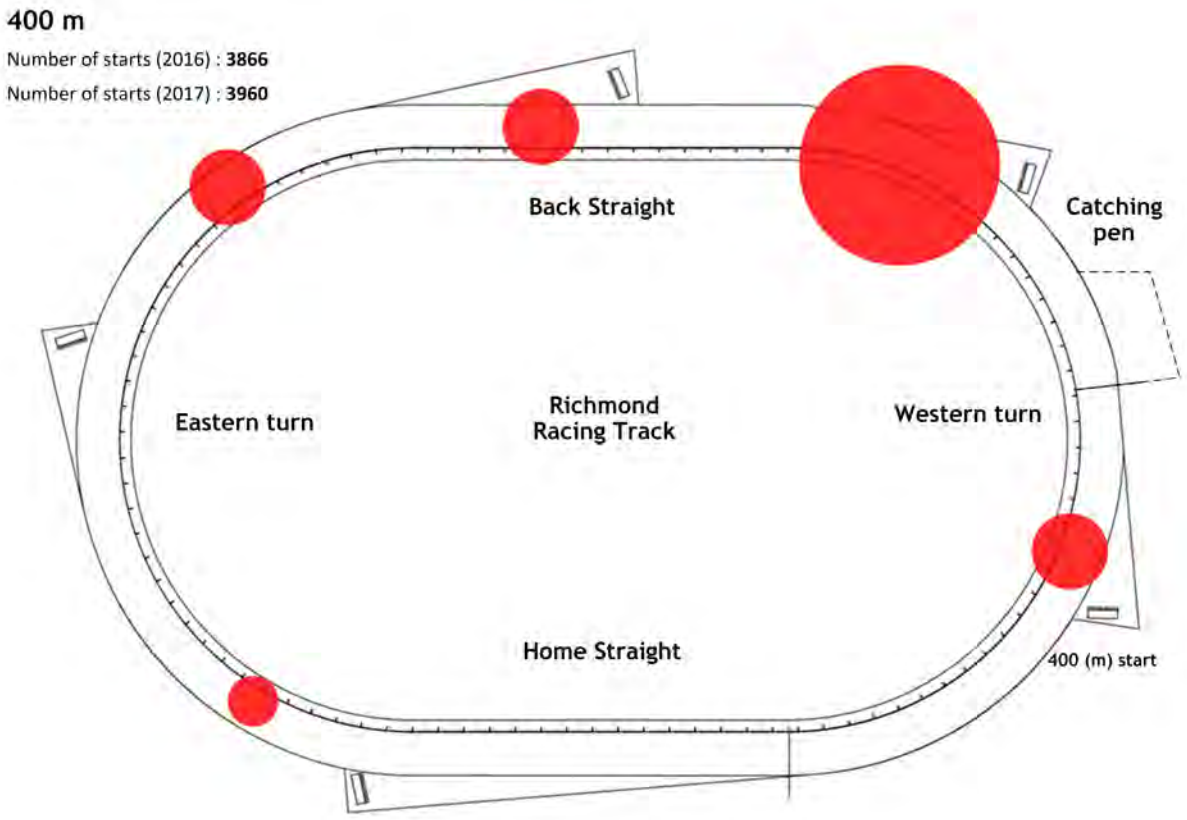

Figure 59: Richmond track location of injuries for the 400 m distance

3.27 The location of injuries is similar to 2016.

RICHMOND: LOCATION OF INJURIES FOR 535 M - 1 JAN TO 31 DEC 2017

3.28 In this section, the injury locations of Richmond track for 535 m race distances are presented.

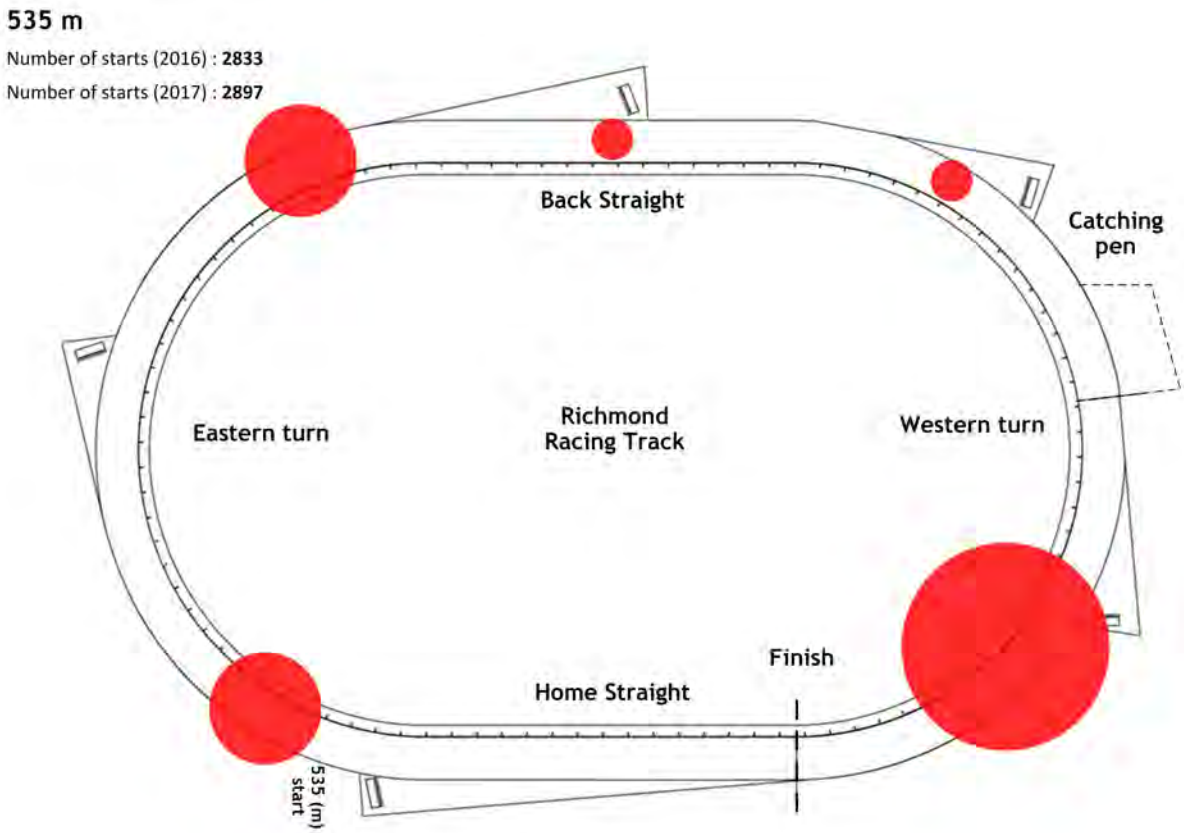

Figure 60: Richmond track location of injuries for the 535 m distance

3.29 The location of injuries is similar 2016.

RICHMOND: LOCATION OF INJURIES FOR 618 M - 1 JAN TO 31 DEC 2017

3.30 In this section, the injury locations of Richmond track for 618 m race distances are presented.

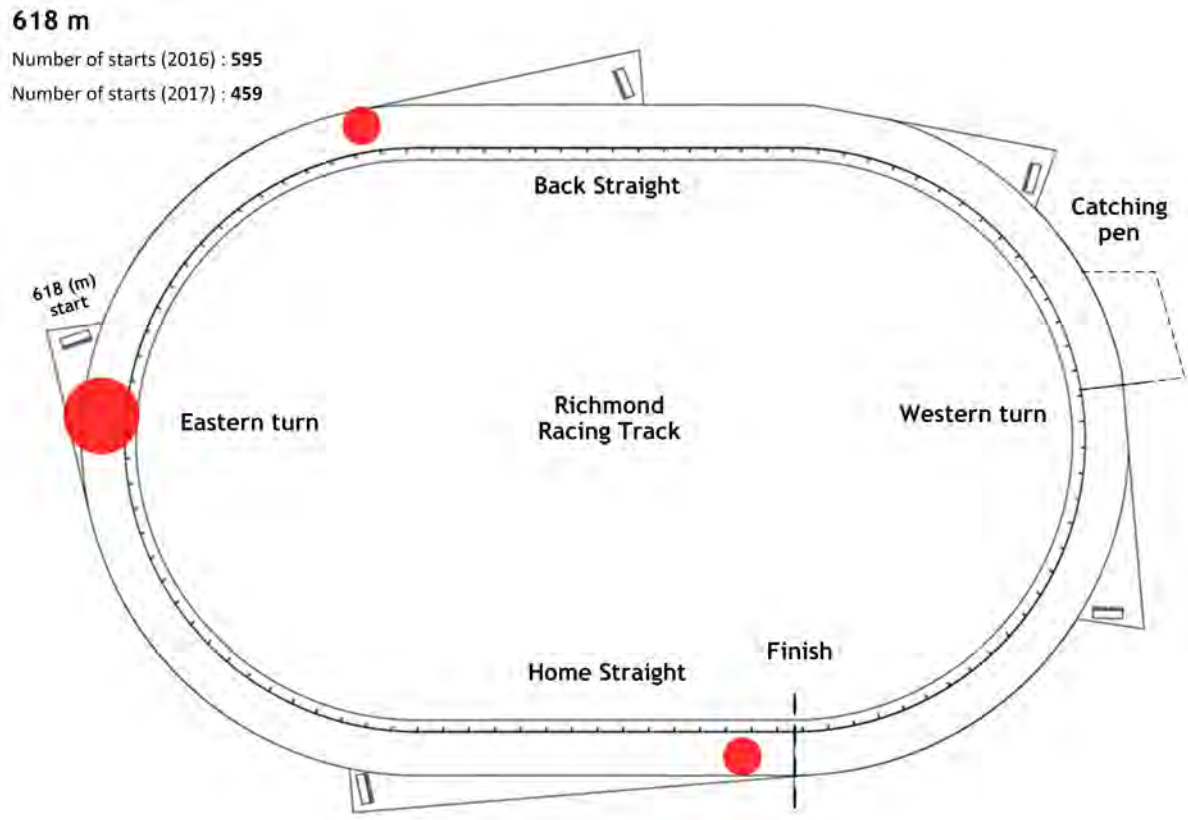

Figure 61: Richmond track location of injuries for the 618 m distance

3.31 The location of injuries is similar 2016.

WENTWORTH PARK

WENTWORTH PARK: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.32 Figures 62 to 69 contain Wentworth Park Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

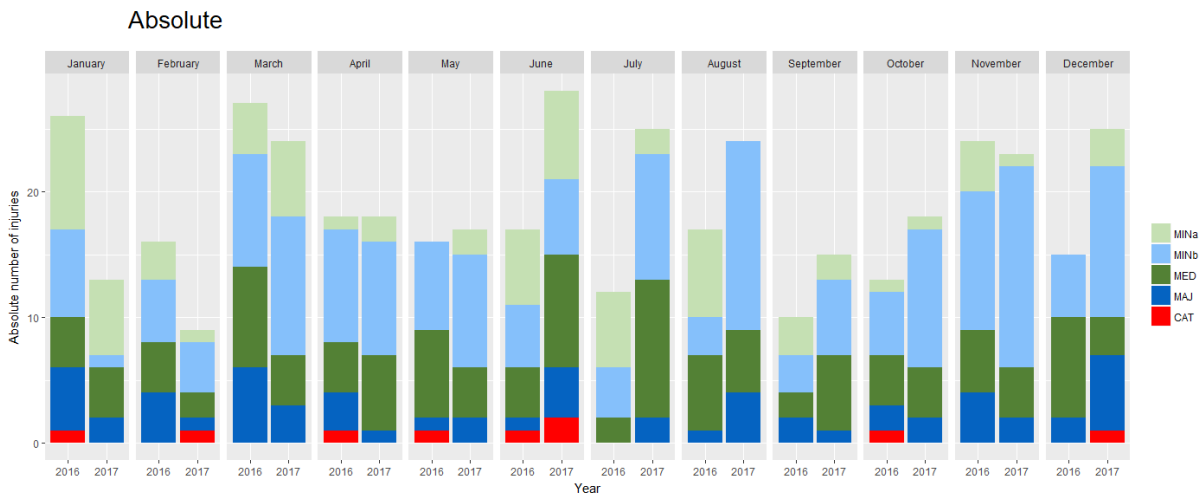

Figure 62: Wentworth Park track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

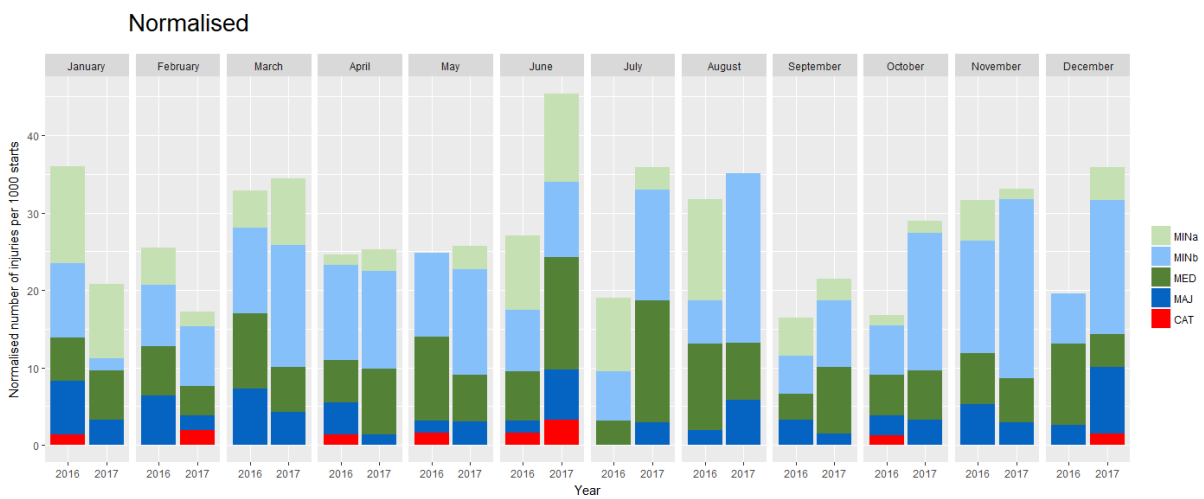

Figure 63: Richmond track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

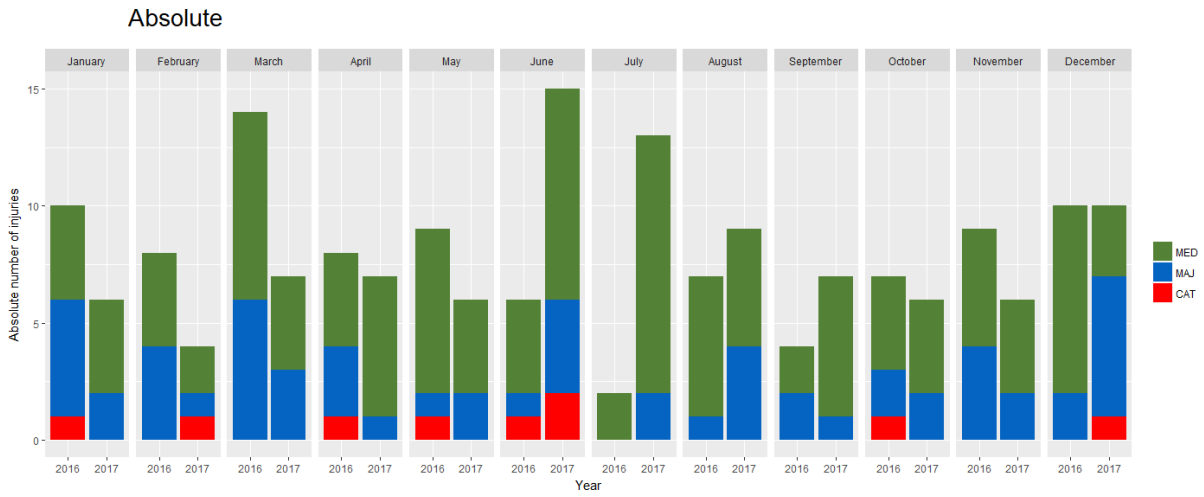

Figure 64: Wentworth Park track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

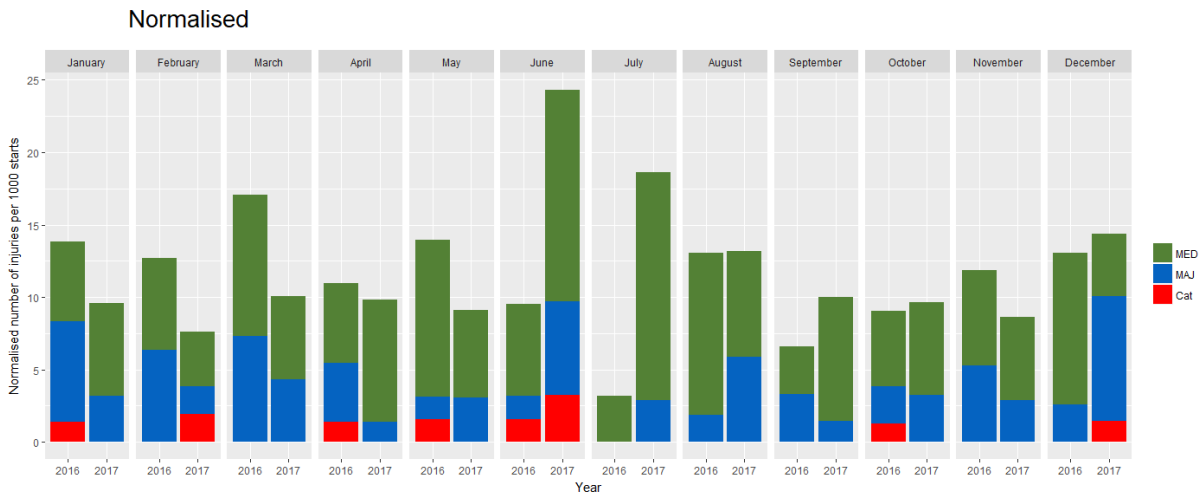

Figure 65: Richmond track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017.

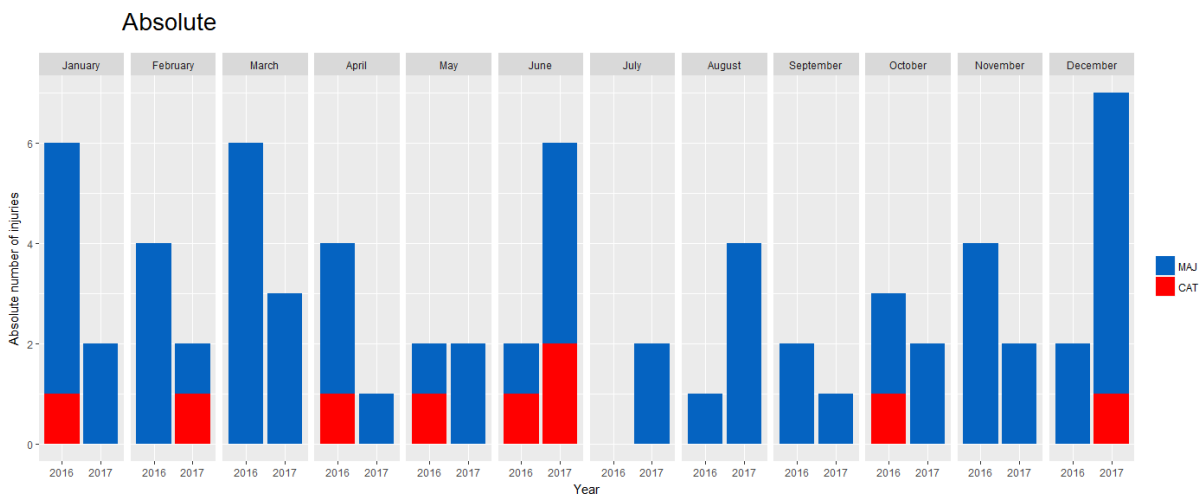

Figure 66: Wentworth Park track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

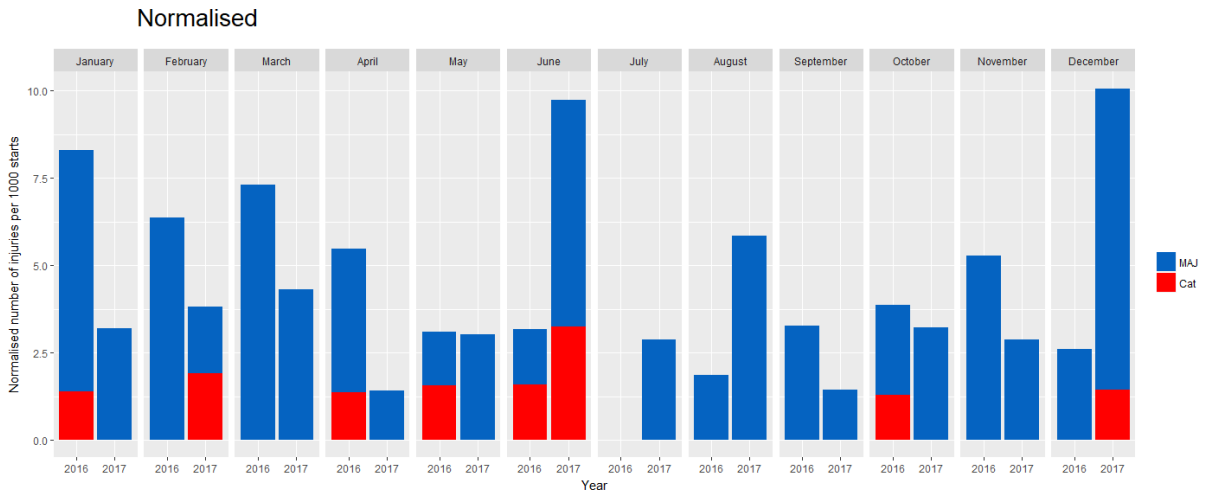

Figure 67: Richmond track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

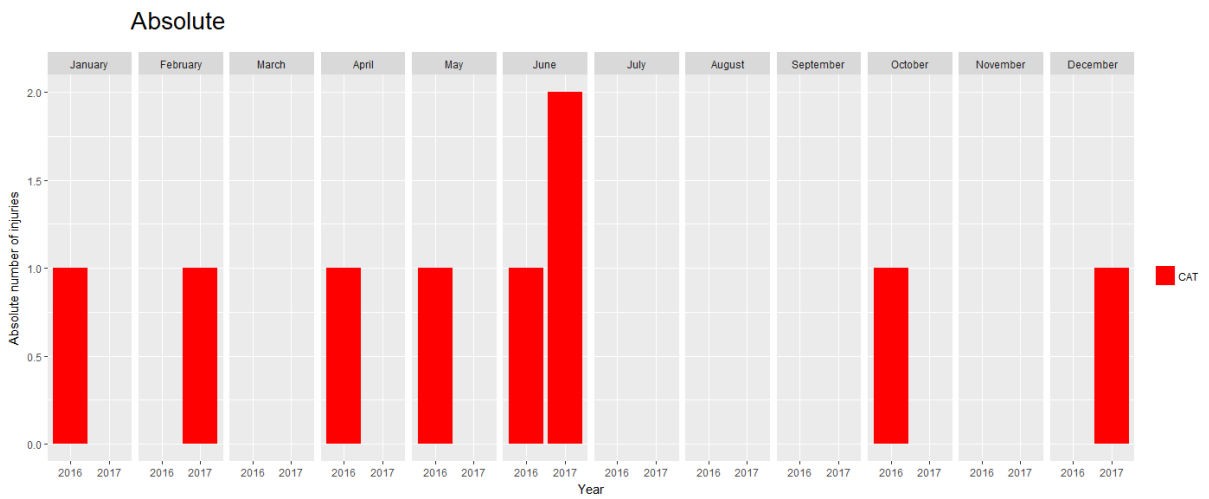

Figure 68: Wentworth Park track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

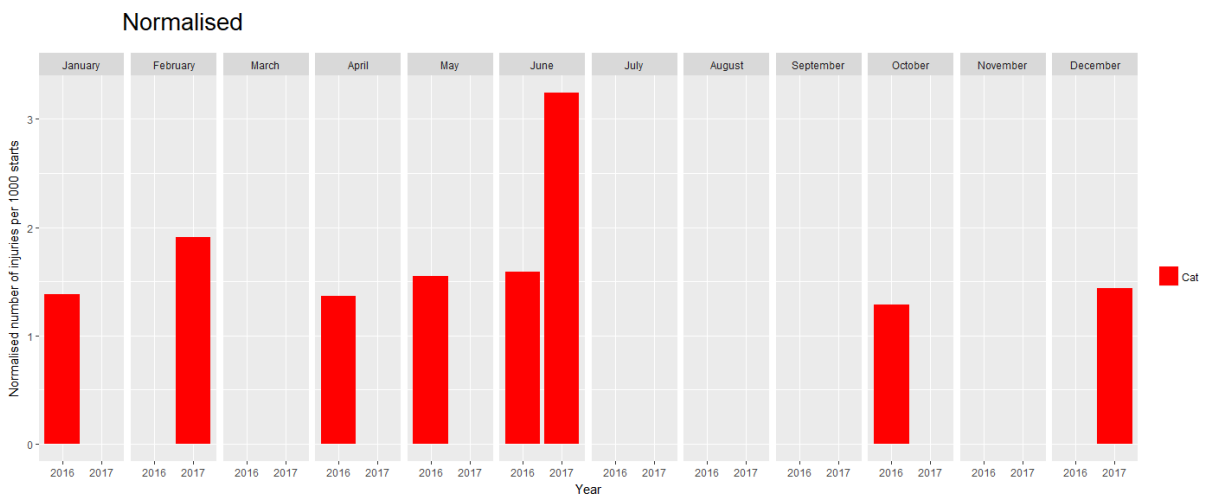

Figure 69: Richmond track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

WENTWORTH PARK: LOCATION OF INJURIES FOR 520 M - 1 JAN TO 31 DEC 2017

3.33 In this section, the injury locations of Wentworth Park track for 520 m race distances are presented.

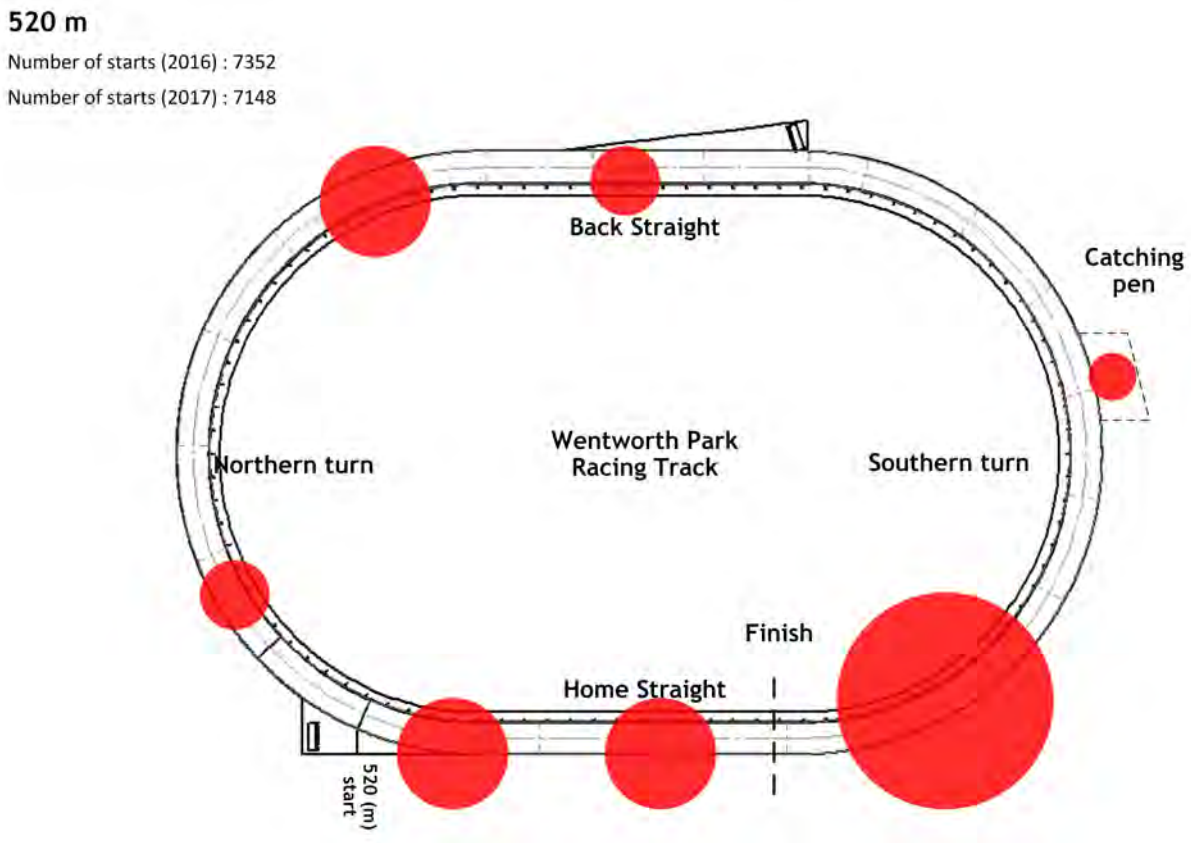

Figure 70: Wentworth Park track location of injuries for the 520 m distance

3.34 The location of injuries is similar to 2016.

WENTWORTH PARK: LOCATION OF INJURIES FOR 720 M - 1 JAN TO 31 DEC 2017

3.35 In this section, the injury locations of Wentworth Park track for 720 m race distances are presented.

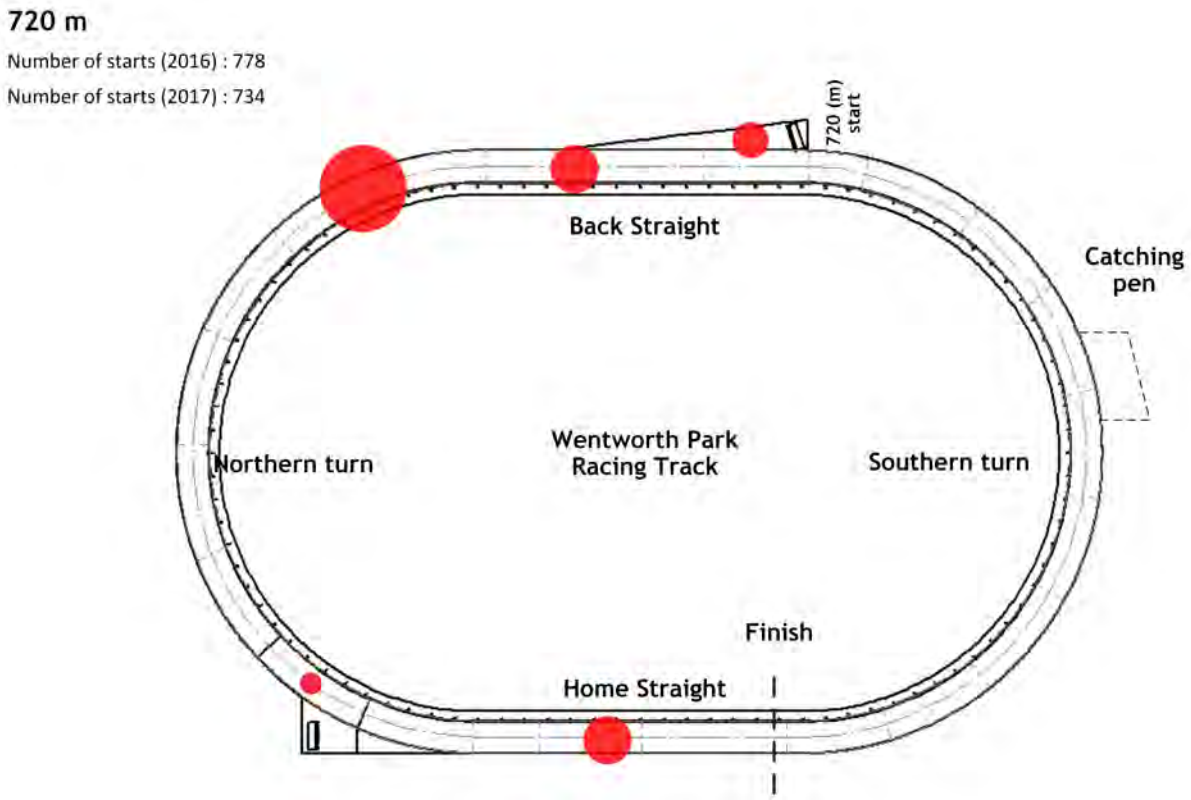

Figure 71: Wentworth Park track location of injuries for the 720 m distance

3.36 The location of injuries is similar 2016.

GRAFTON

GRAFTON: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.37 Figures 72 to 79 contain Grafton Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

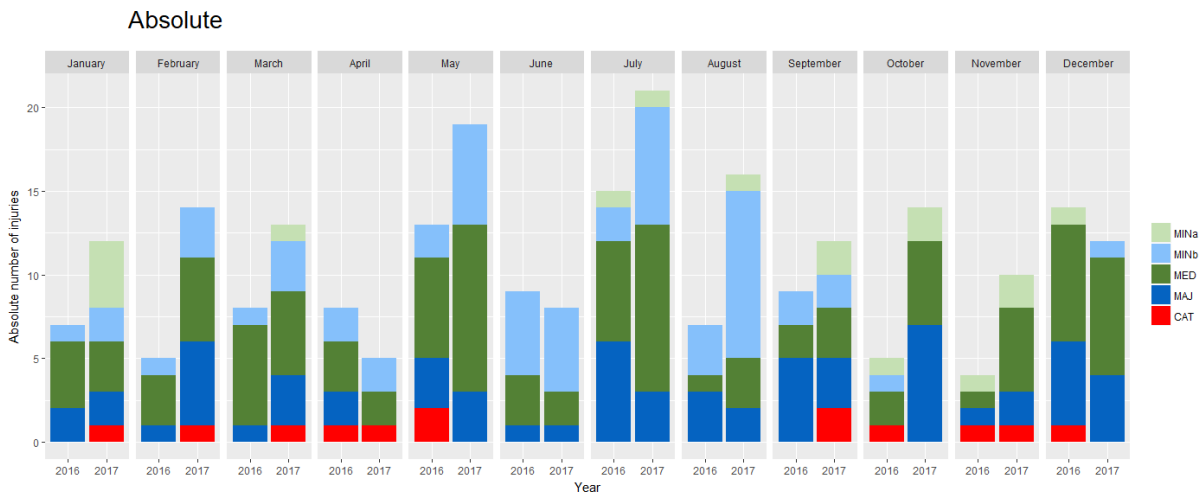

Figure 72: Grafton track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

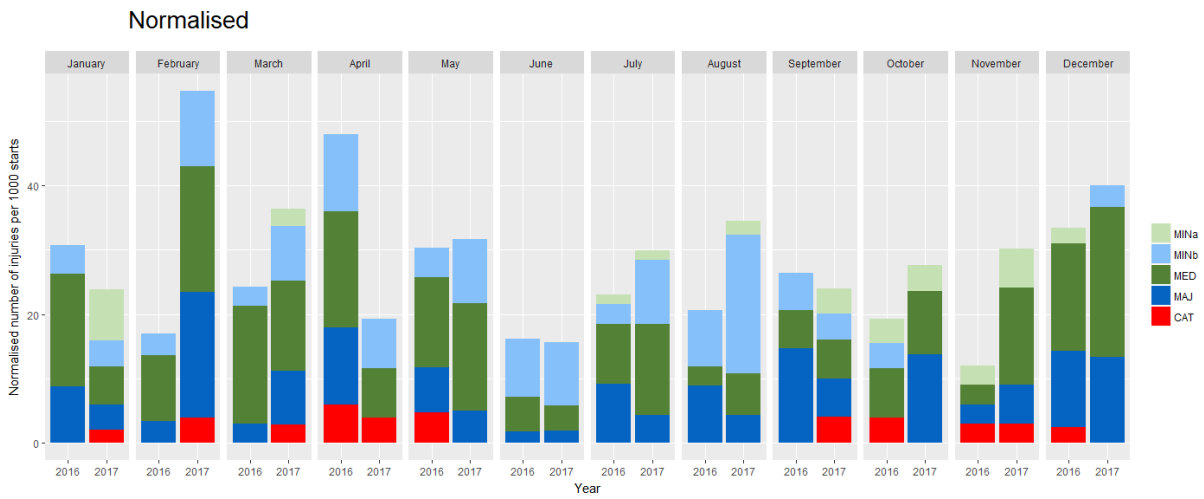

Figure 73: Grafton track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

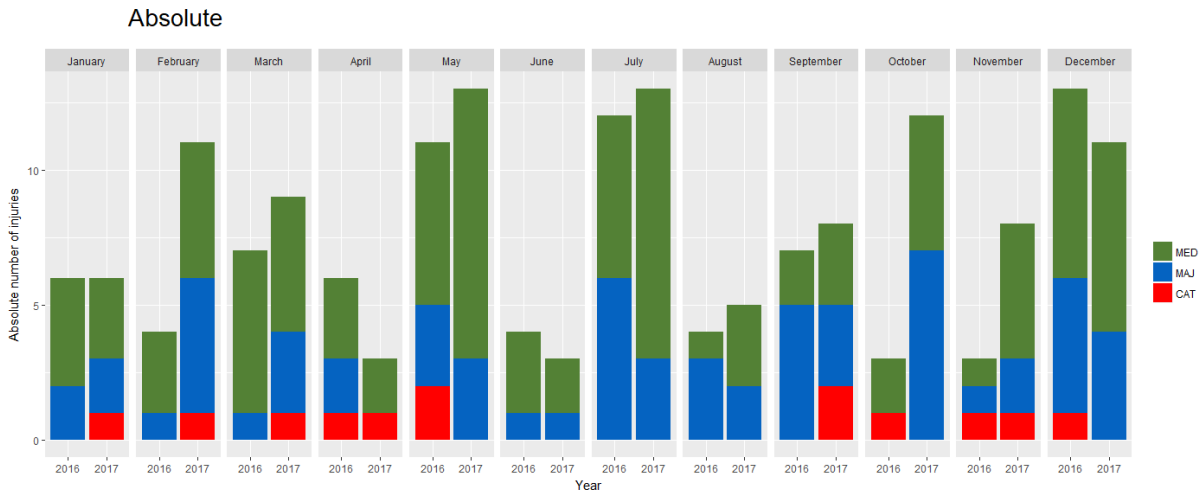

Figure 74: Grafton track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

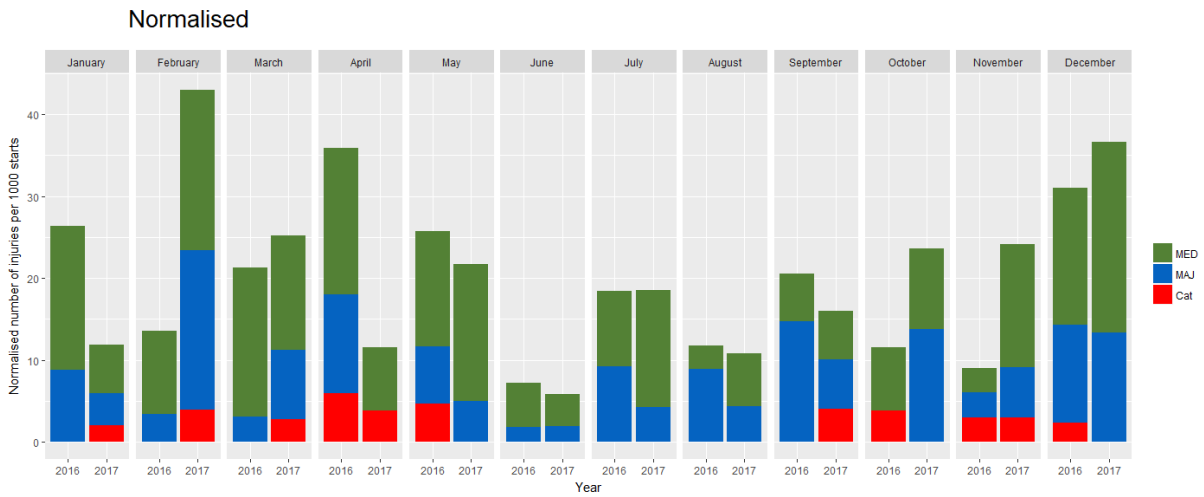

Figure 75: Grafton track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

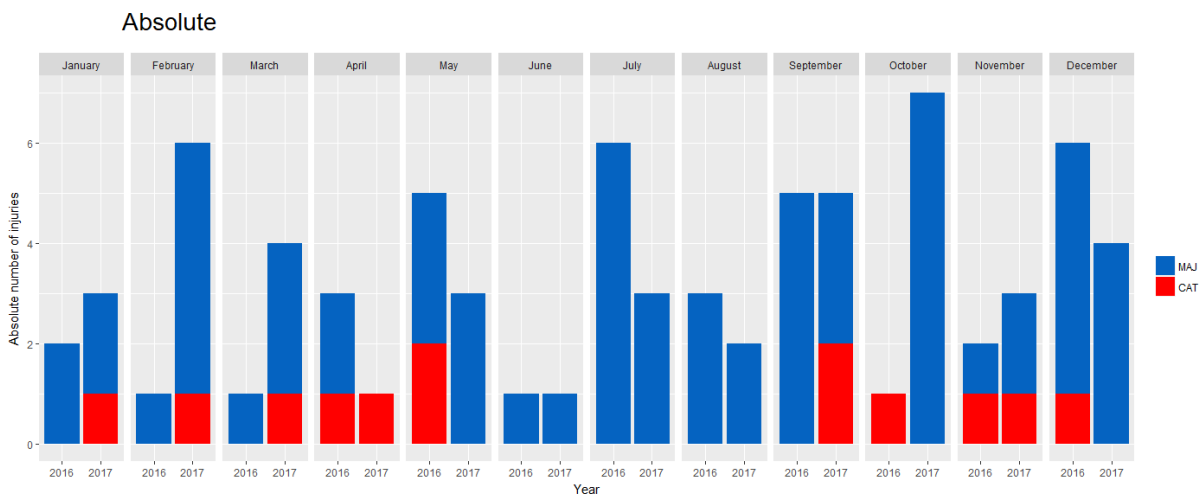

Figure 76: Grafton track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

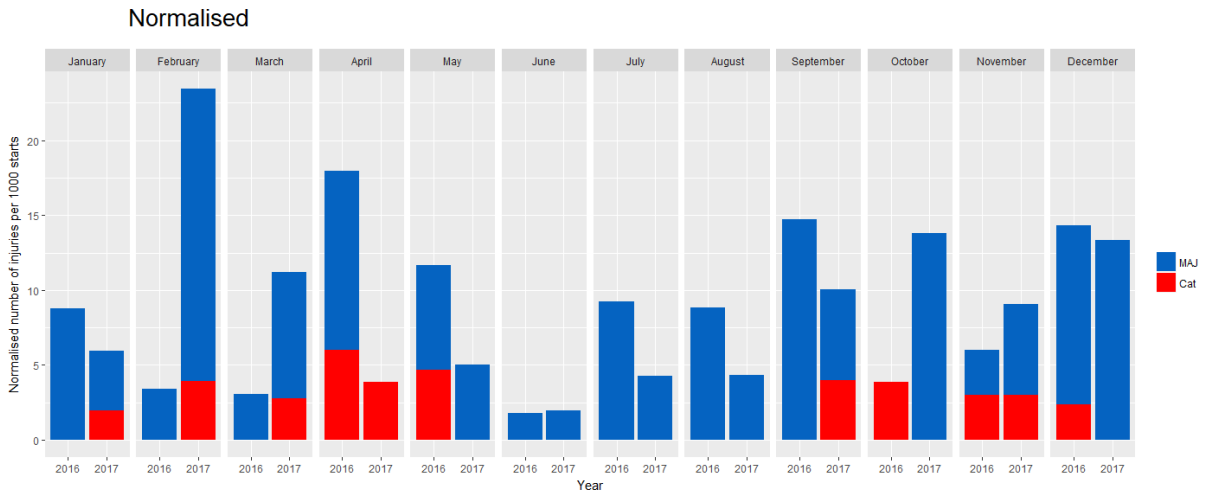

Figure 77: Grafton track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

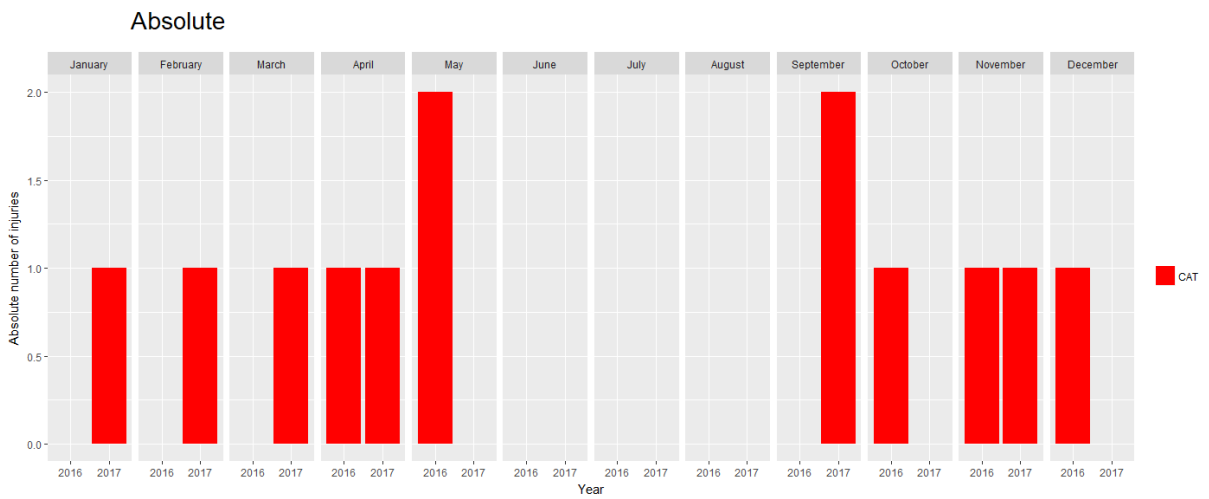

Figure 78: Grafton track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

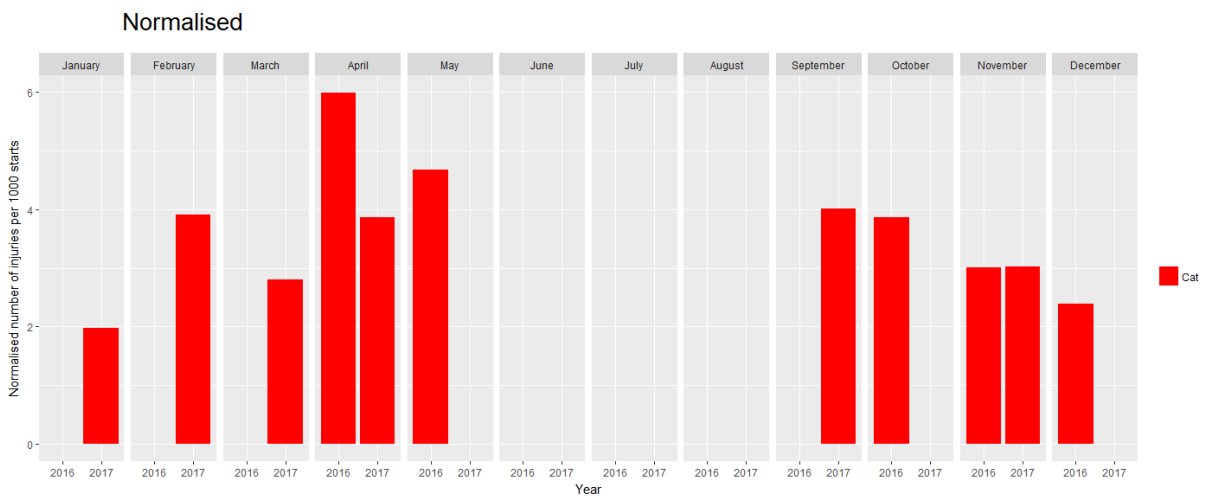

Figure 79: Grafton track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

GRAFTON: LOCATION OF INJURIES FOR 305 M - 1 JAN TO 31 DEC 2017

3.38 In this section, the injury locations of Grafton track for 305 m race distances are presented.

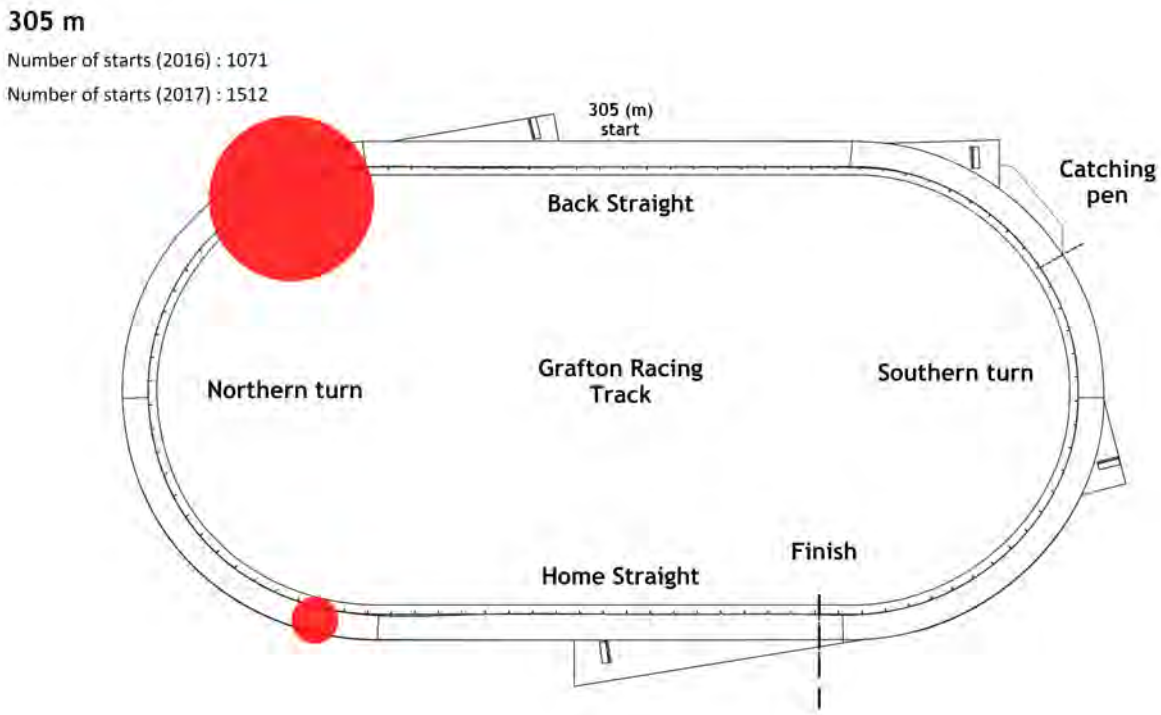

Figure 80: Grafton track location of injuries for the 305 m distance

3.39 The location of injuries is similar to 2016.

GRAFTON: LOCATION OF INJURIES FOR 407 M - 1 JAN TO 31 DEC 2017

3.40 In this section, the injury locations of Grafton track for 407 m race distances are presented.

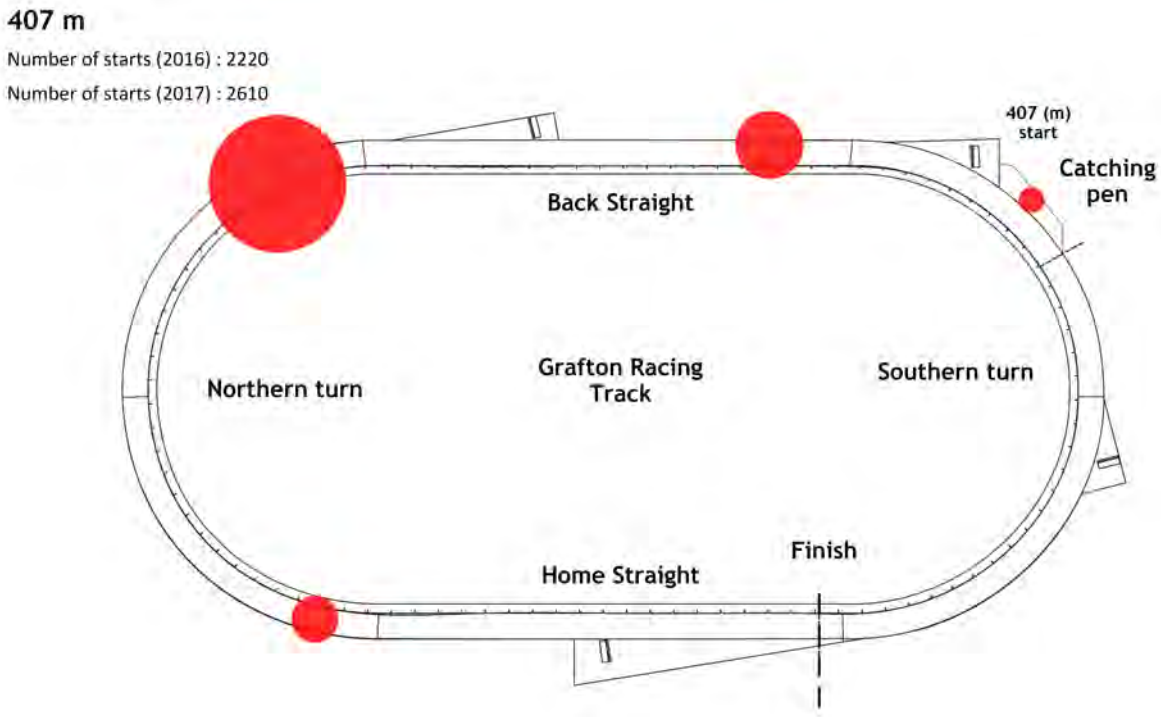

Figure 81: Grafton track location of injuries for the 407 m distance

3.41 The location of injuries is similar to 2016.

GRAFTON: LOCATION OF INJURIES FOR 480 M - 1 JAN TO 31 DEC 2017

3.42 In this section, the injury locations of Grafton track for 480 m race distances are presented.

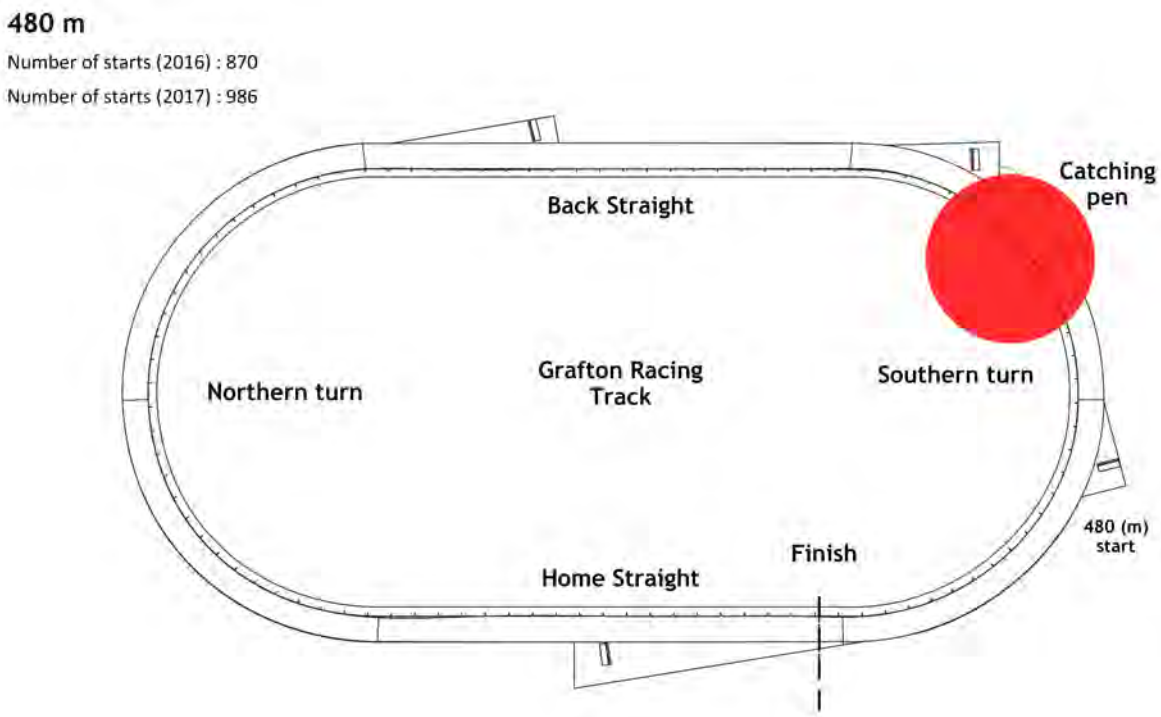

Figure 82: Grafton track location of injuries for the 480 m distance

3.43 The location of injuries is similar to 2016.

CASINO

CASINO: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.44 Figures 83 to 90 contain Casino Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

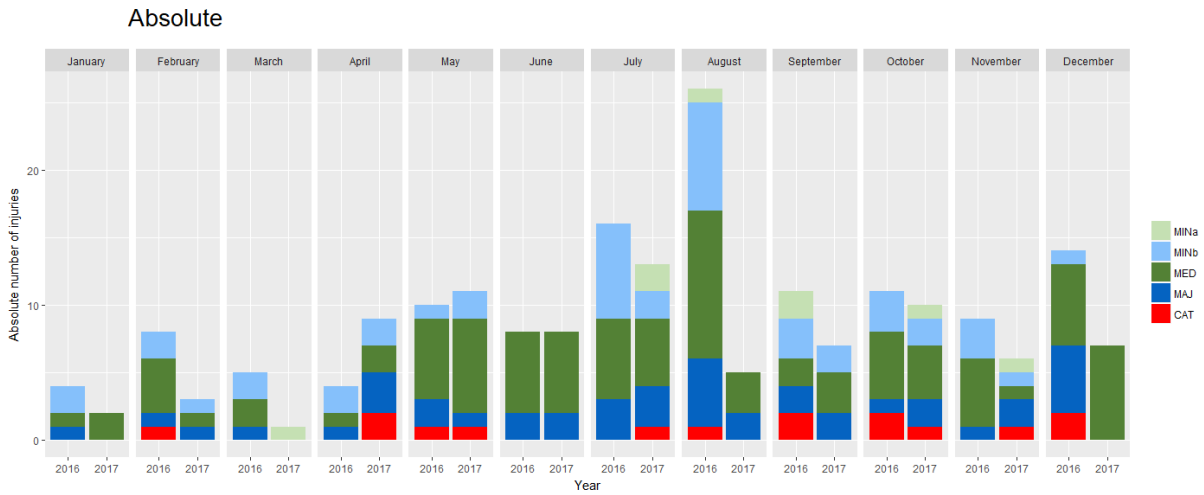

Figure 83: Casino track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

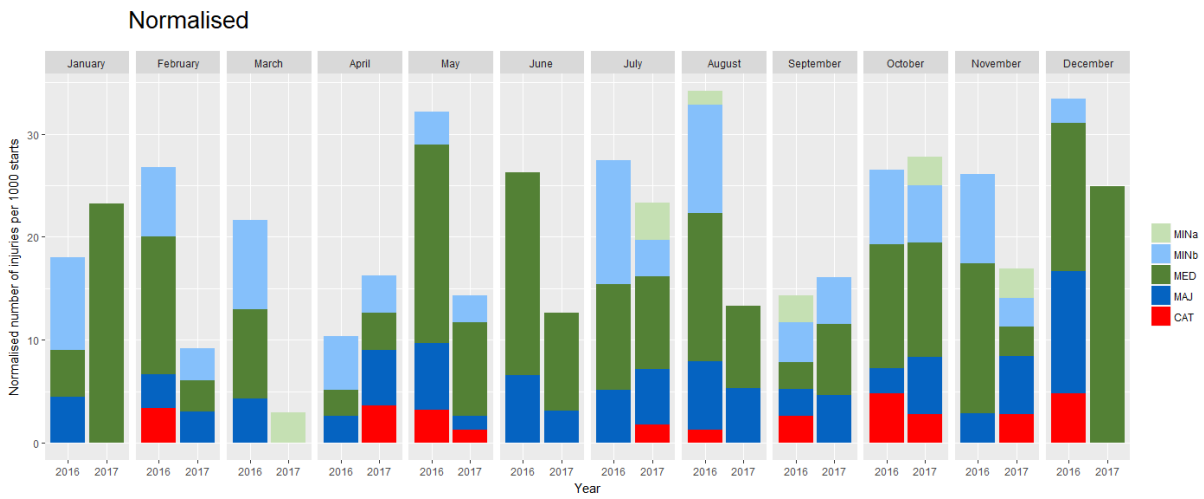

Figure 84: Casino track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

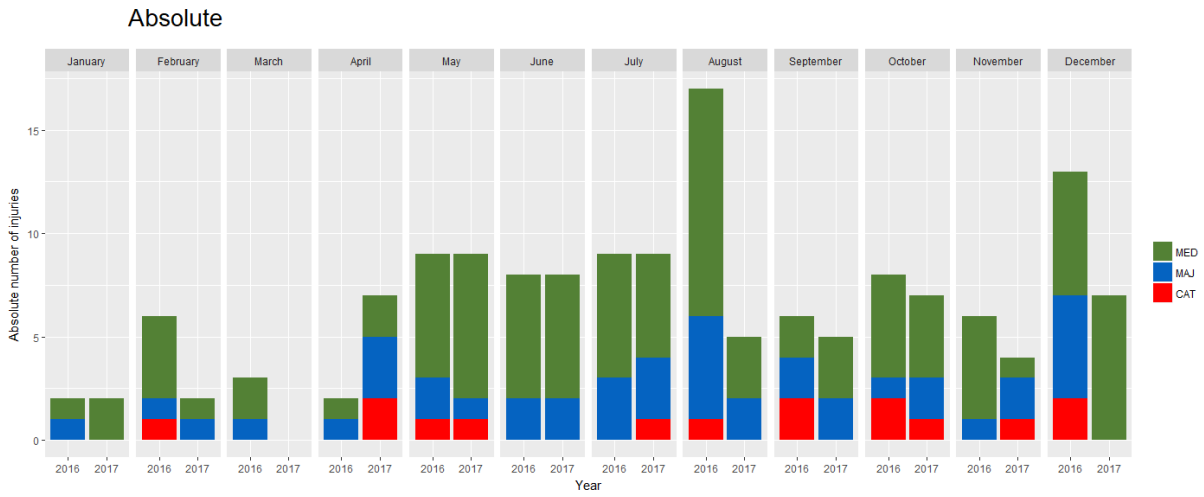

Figure 85: Casino track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

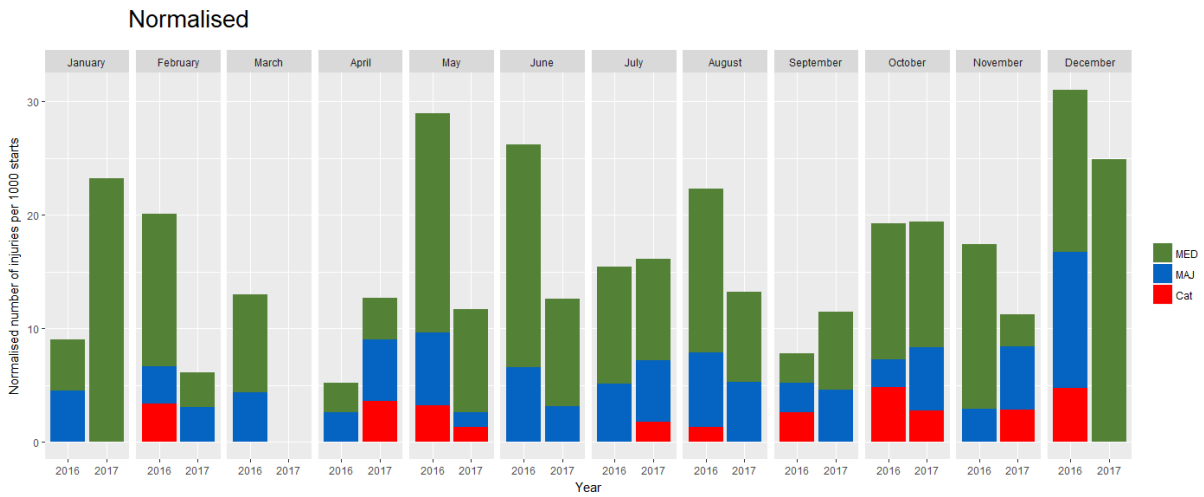

Figure 86: Casino track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

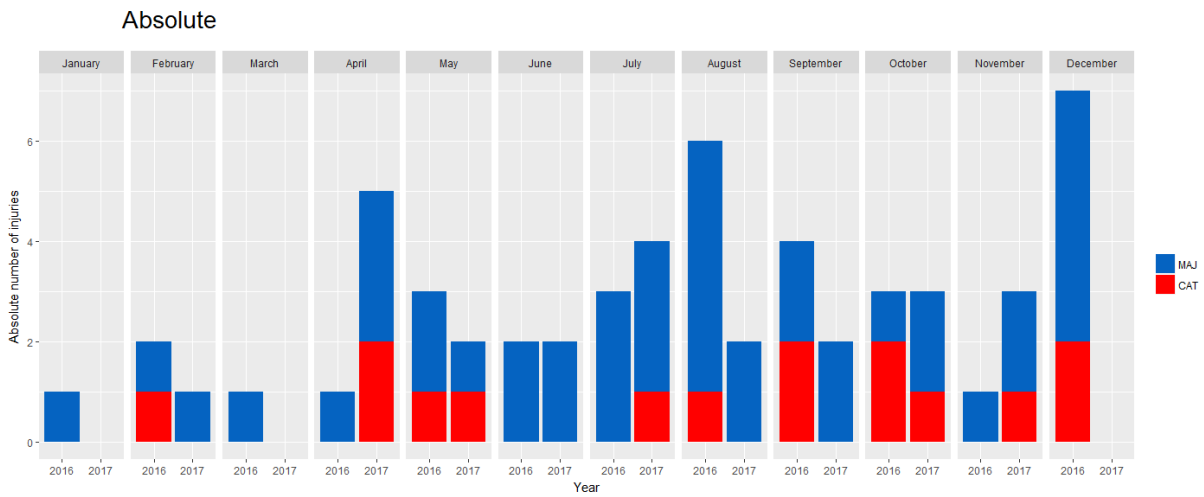

Figure 87: Casino track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

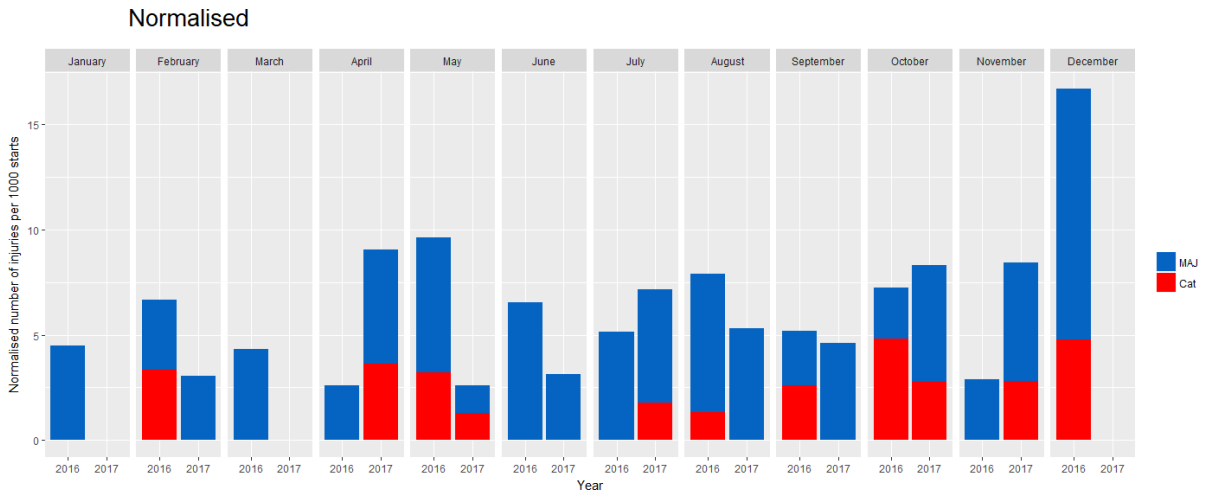

Figure 88: Casino track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

Figure 89: Casino track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

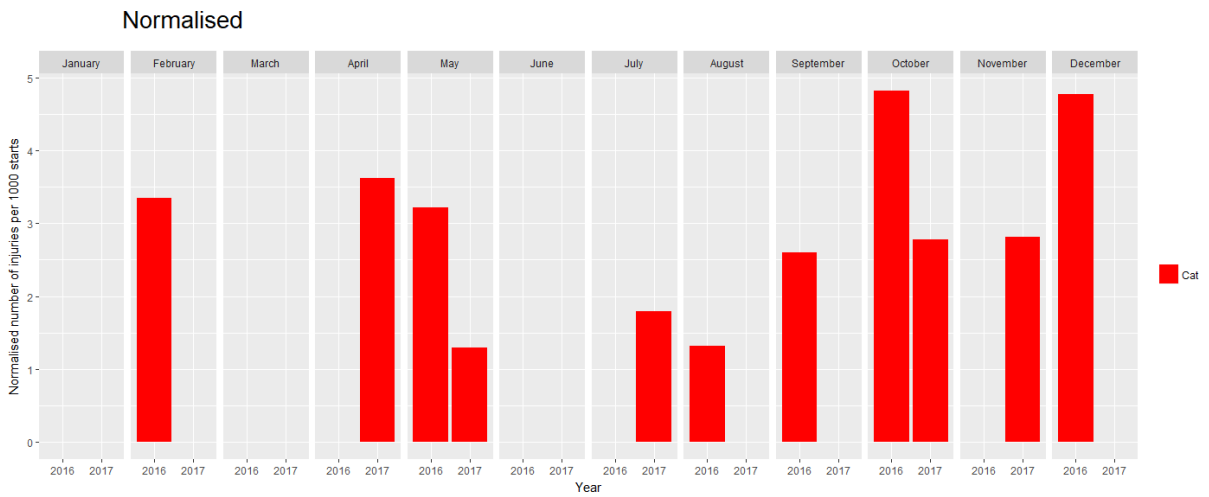

Figure 90: Casino track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

CASINO: LOCATION OF INJURIES FOR 411 M - 1 JAN TO 31 DEC 2017

3.45 In this section, the injury locations of Casino track for 411 m race distances are presented.

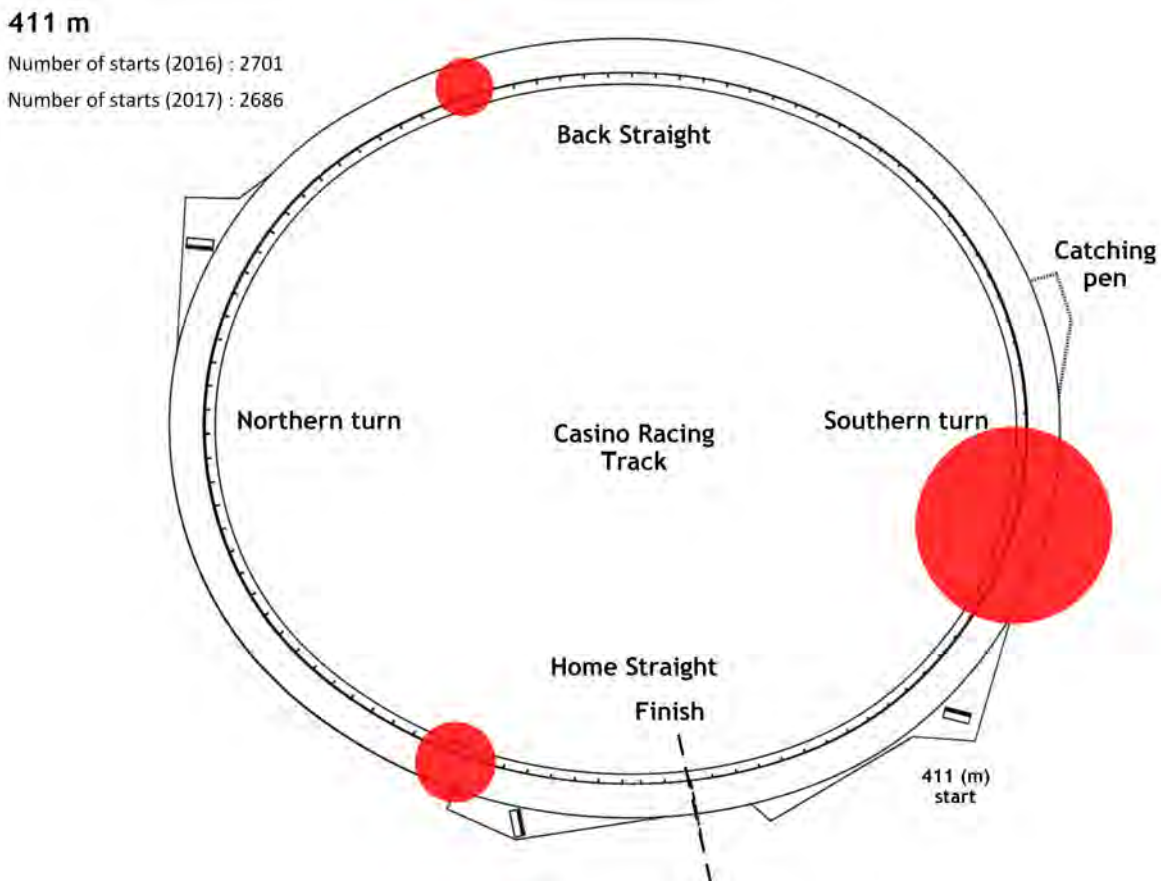

Figure 91: Casino track location of injuries for the 411 m distance

3.46 The location of injuries is similar to 2016.

CASINO: LOCATION OF INJURIES FOR 484 M - 1 JAN TO 31 DEC 2017

3.47 In this section, the injury locations of Casino track for 484 m race distances are presented.

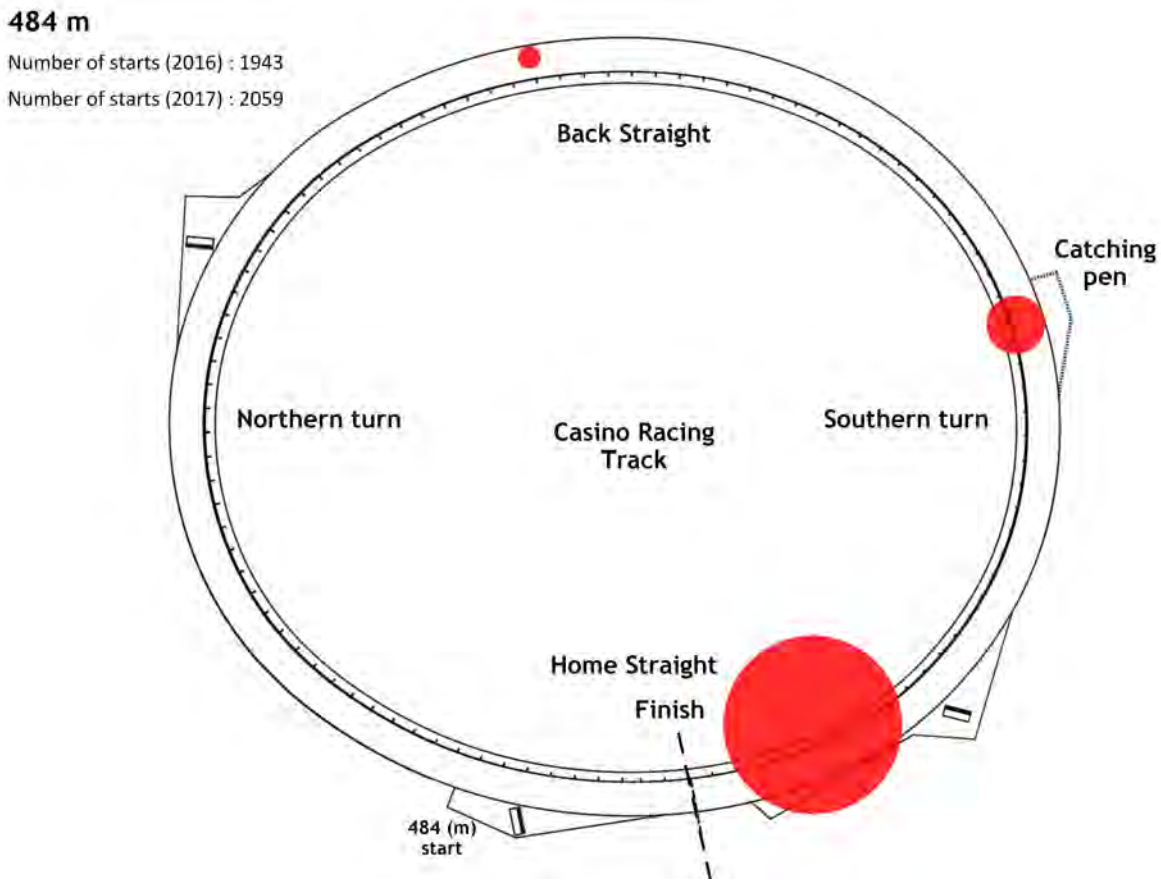

Figure 92: Casino track location of injuries for the 484 m distance

3.48 The location of injuries is similar to 2016.

CASINO: LOCATION OF INJURIES FOR 600 M - 1 JAN TO 31 DEC 2017

3.49 In this section, the injury locations of Casino track for 600 m race distances are presented.

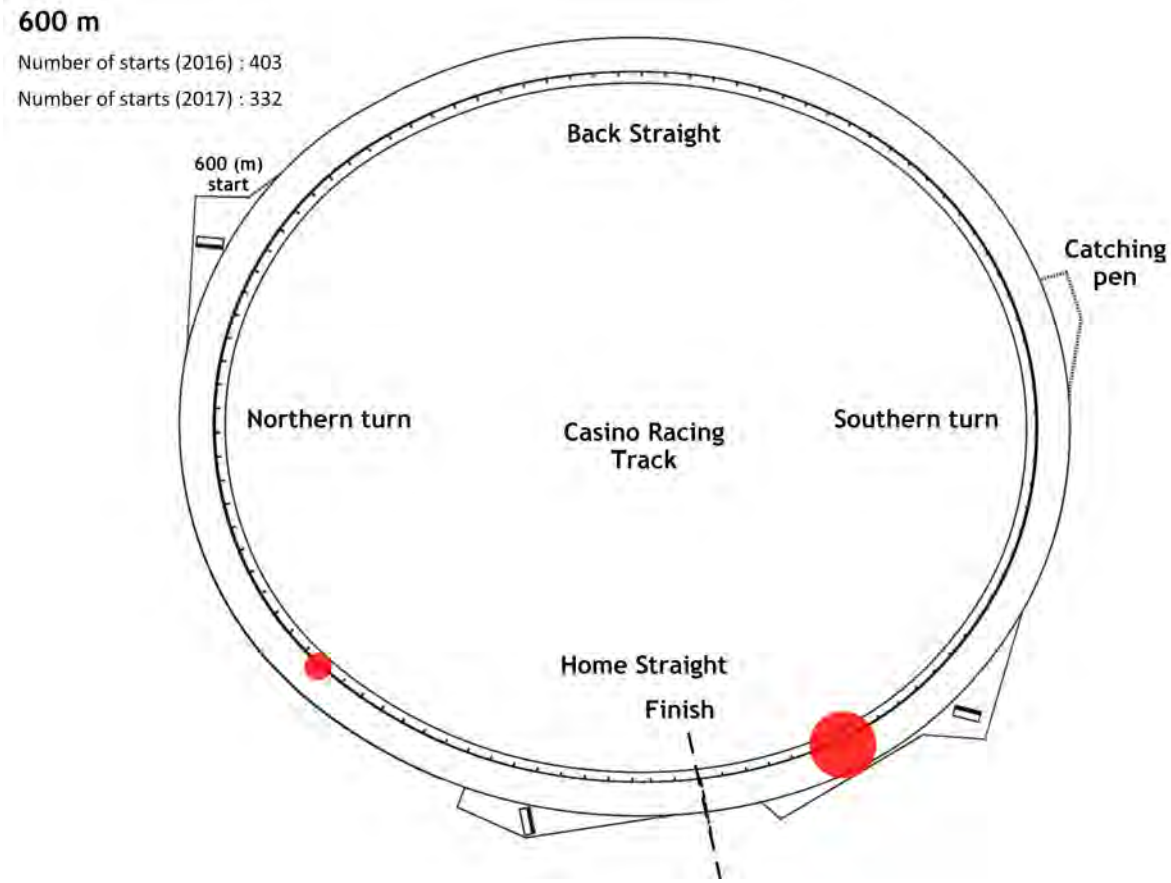

Figure 93: Casino track location of injuries for the 600 m distance

3.50 The location of injuries is similar to 2016.

MAITLAND

MAITLAND: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.51 Figures 94 to 101 contain Maitland Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

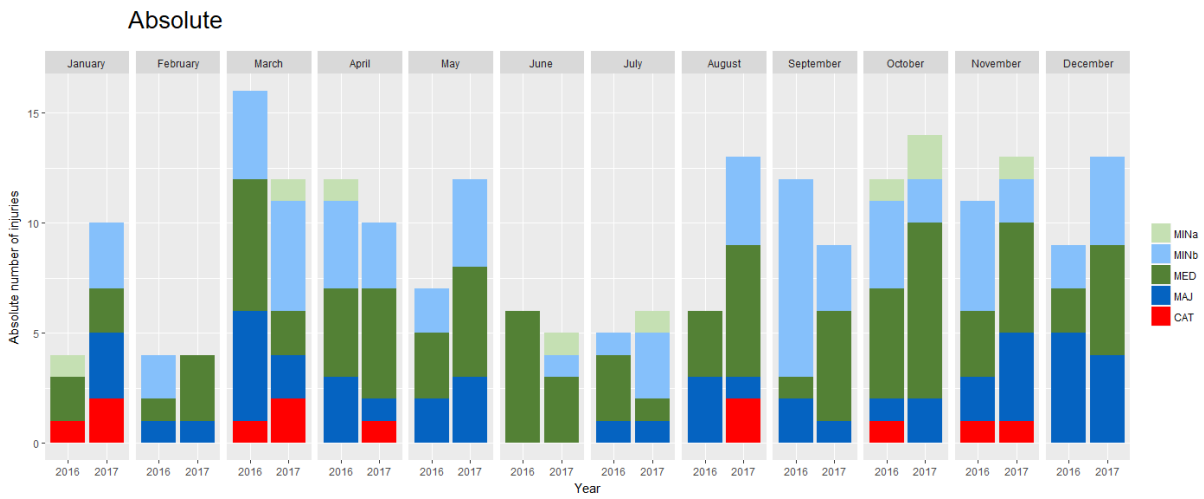

Figure 94: Maitland track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

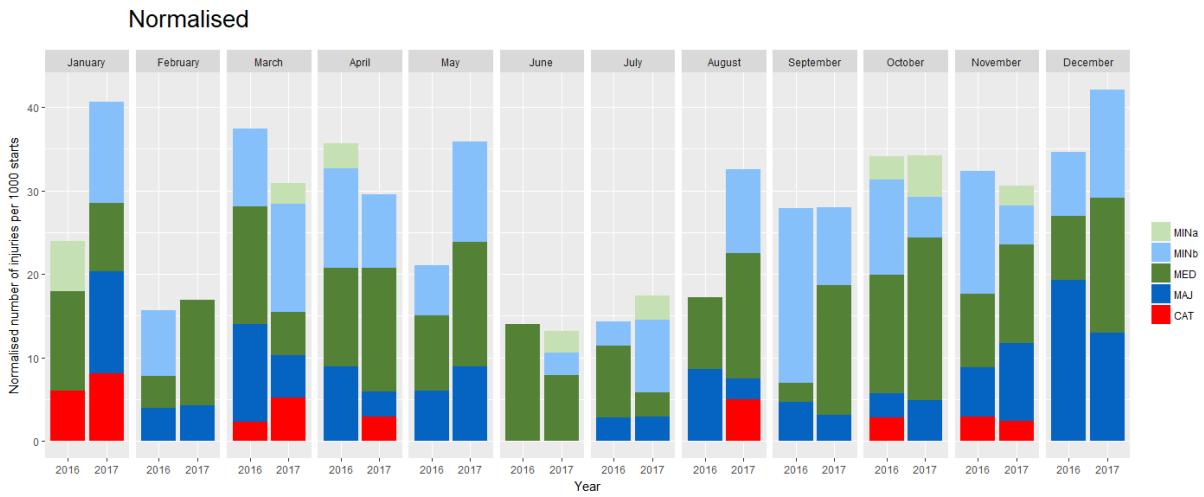

Figure 95: Maitland track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

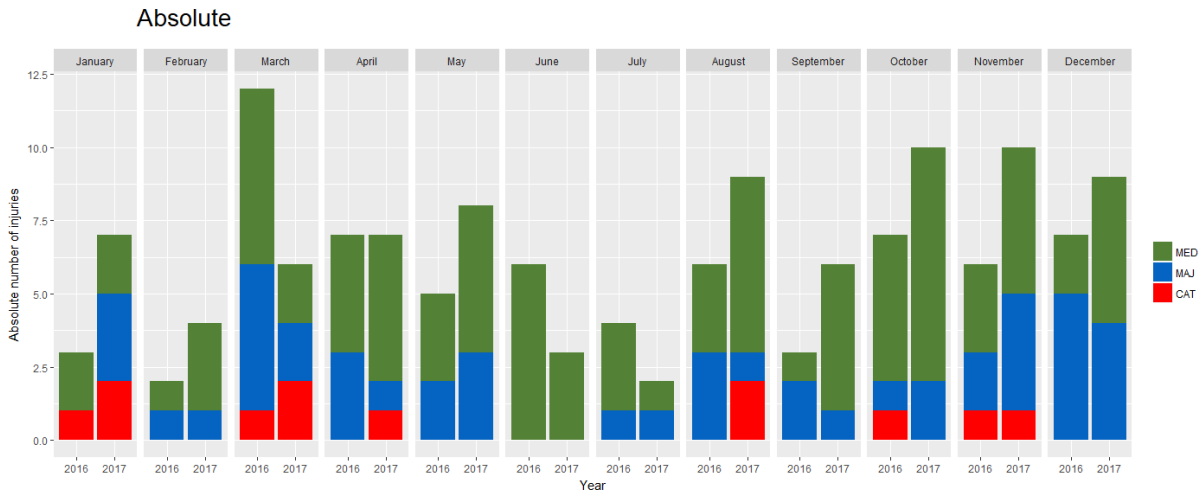

Figure 96: Maitland track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

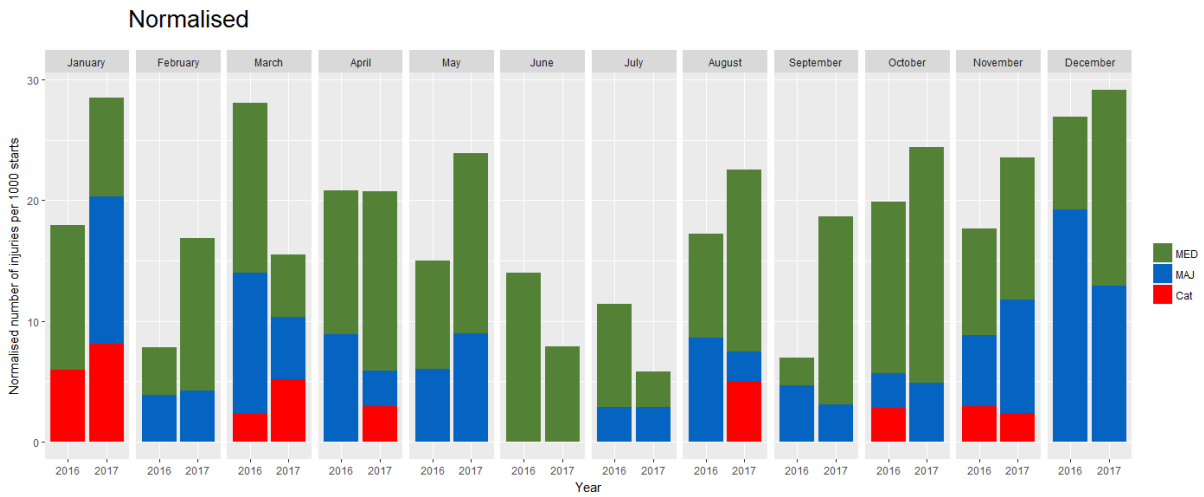

Figure 97: Maitland track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

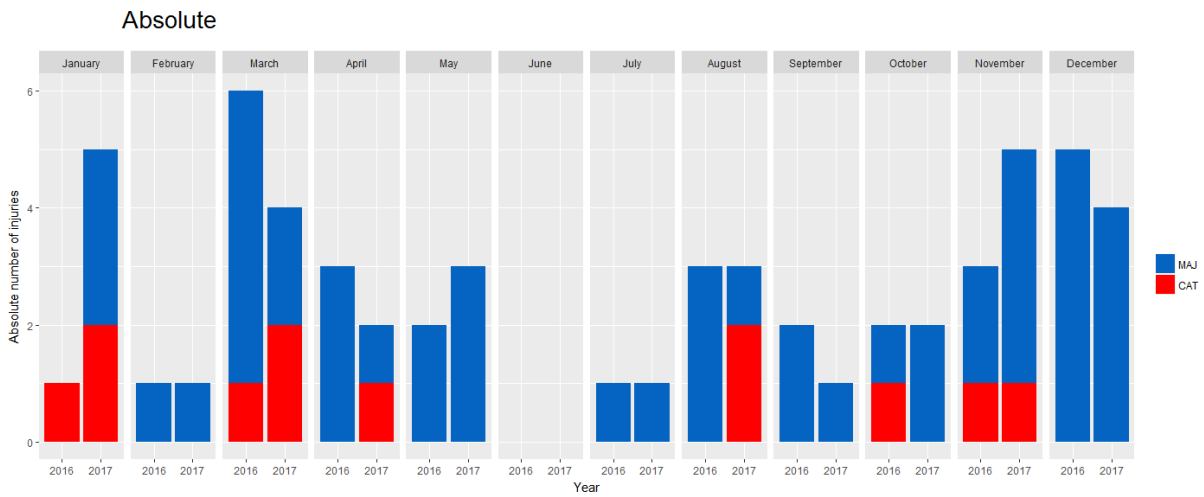

Figure 98: Maitland track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

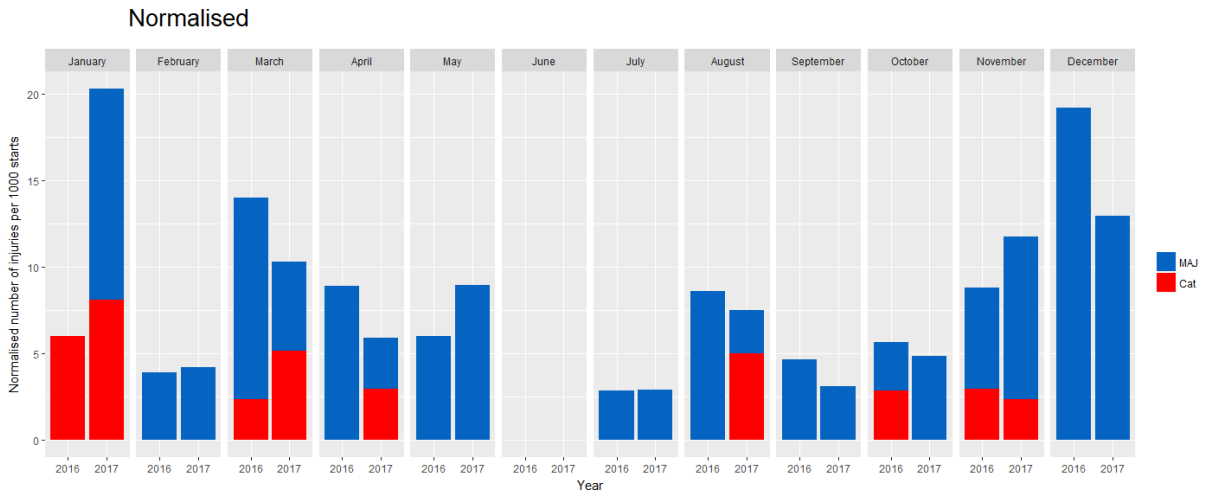

Figure 99: Maitland track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

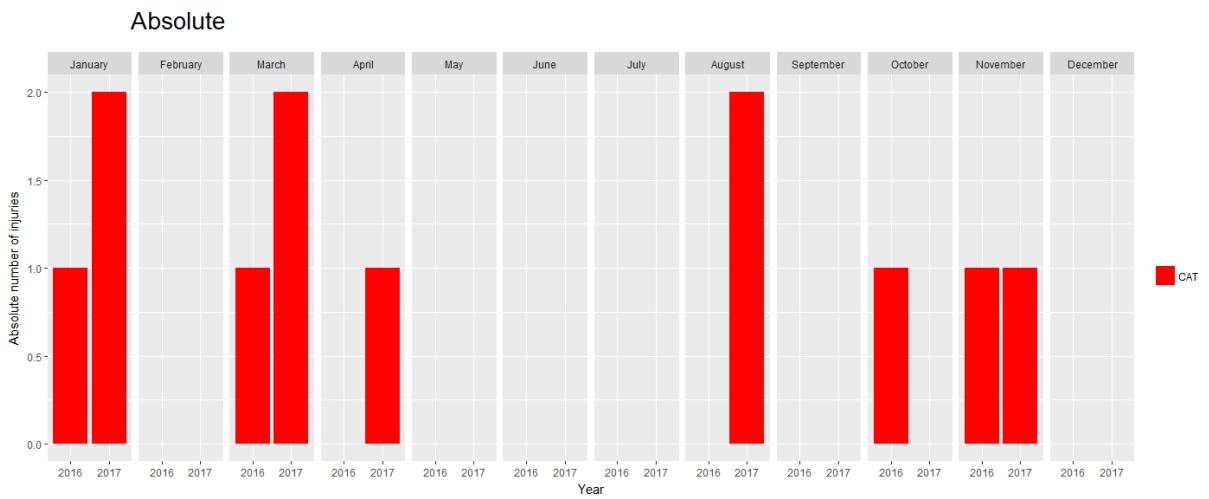

Figure 100: Maitland track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

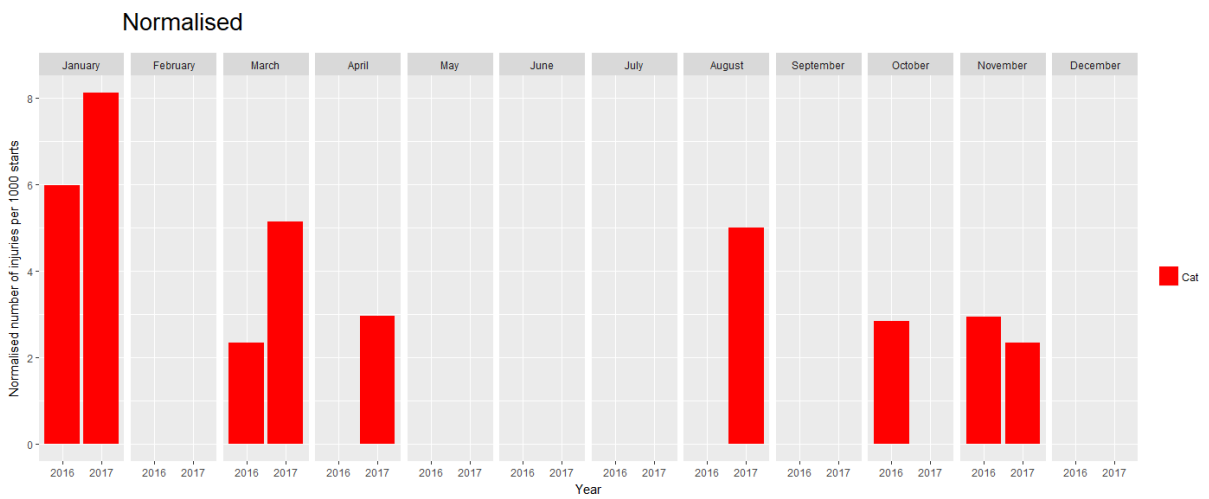

Figure 101: Maitland track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

MAITLAND: LOCATION OF INJURIES FOR 400 M - 1 JAN TO 31 DEC 2017

3.52 In this section, the injury locations of Maitland track for 400 m race distances are presented.

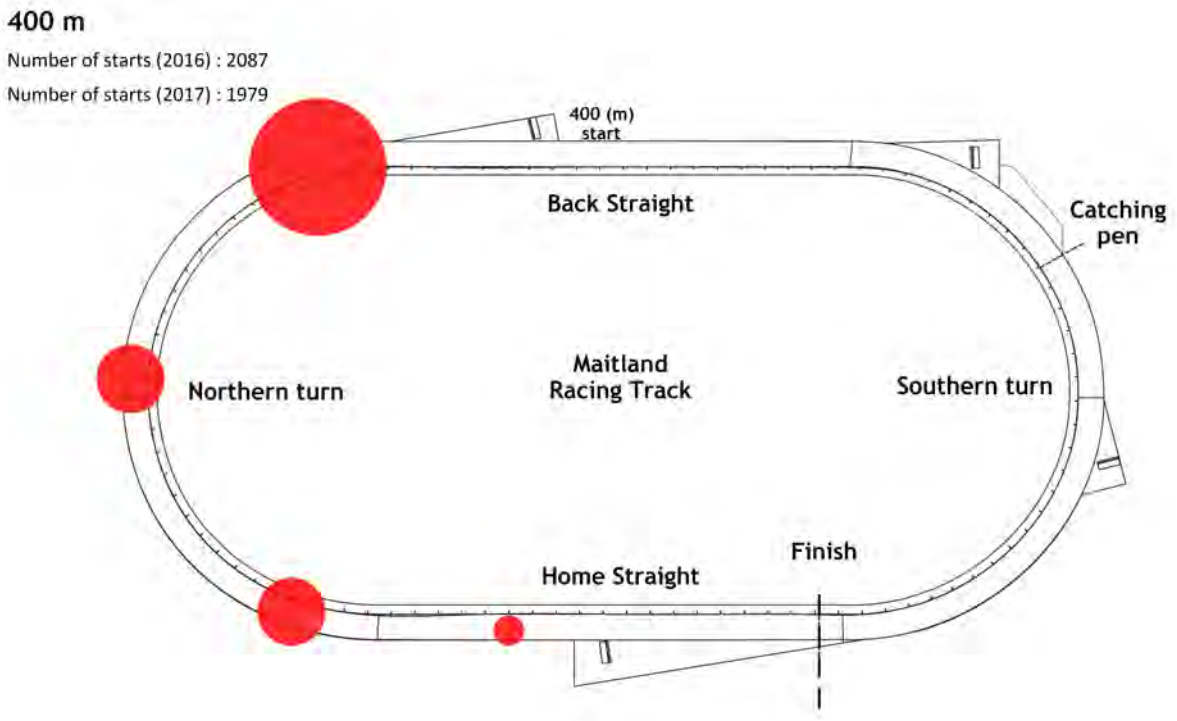

Figure 102: Maitland track location of injuries for the 400 m distance

3.53 The location of injuries is similar to 2016.

MAITLAND: LOCATION OF INJURIES FOR 450 M - 1 JAN TO 31 DEC 2017

3.54 In this section, the injury locations of Maitland track for 450 m race distances are presented.

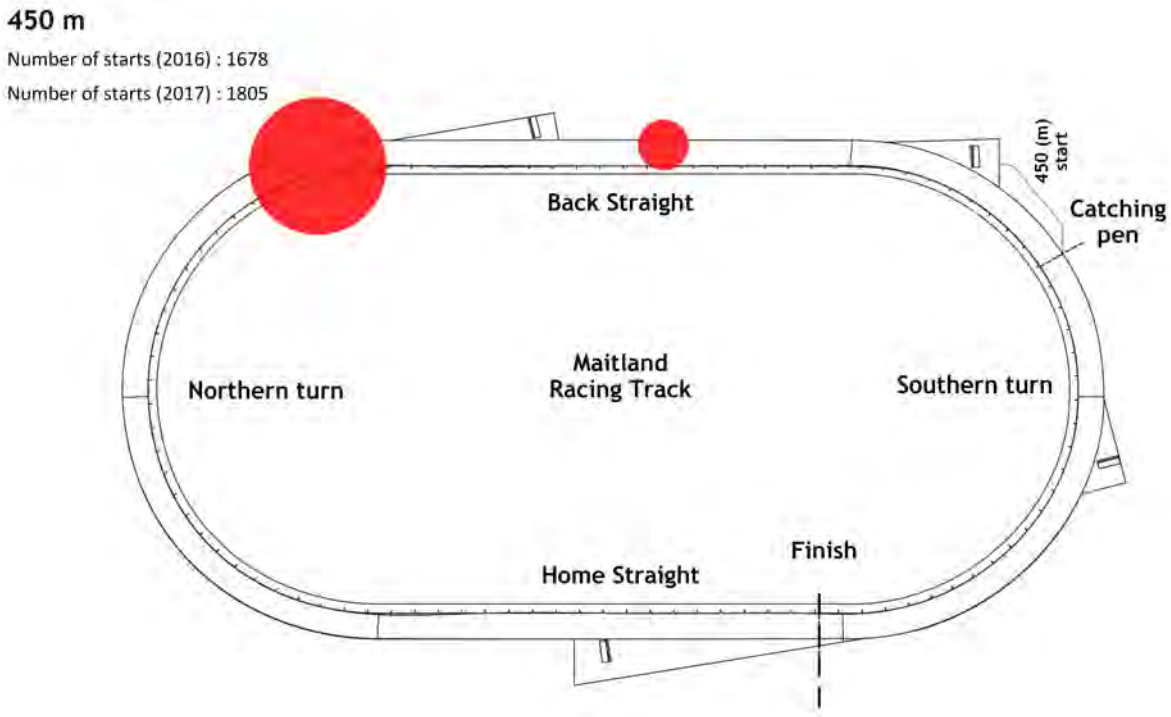

Figure 103: Maitland track location of injuries for the 450 m distance

3.55 The location of injuries is similar to 2016.

BATHURST

BATHURST: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.56 Figures 104 to 111 contain Bathurst Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

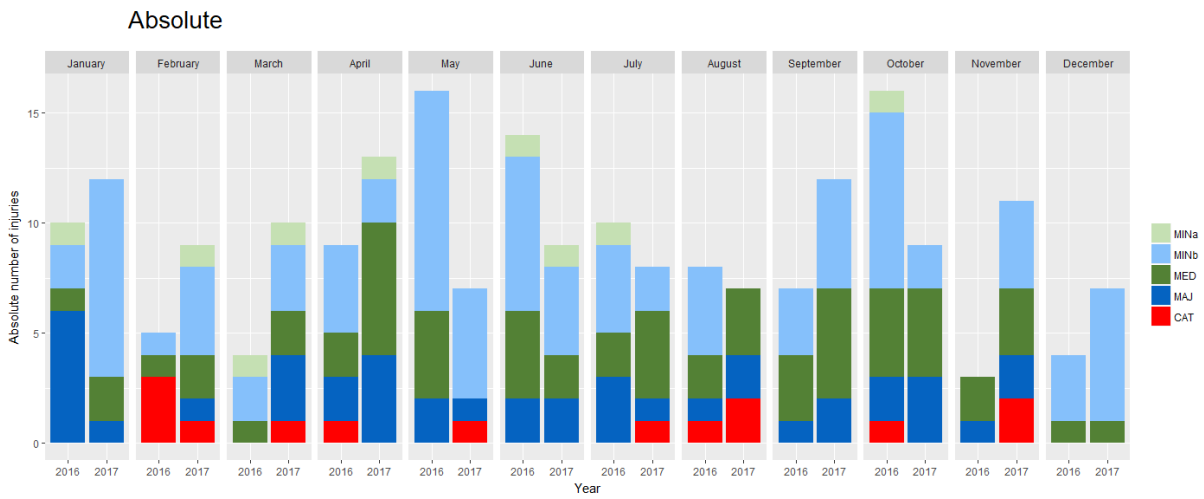

Figure 104: Bathurst track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

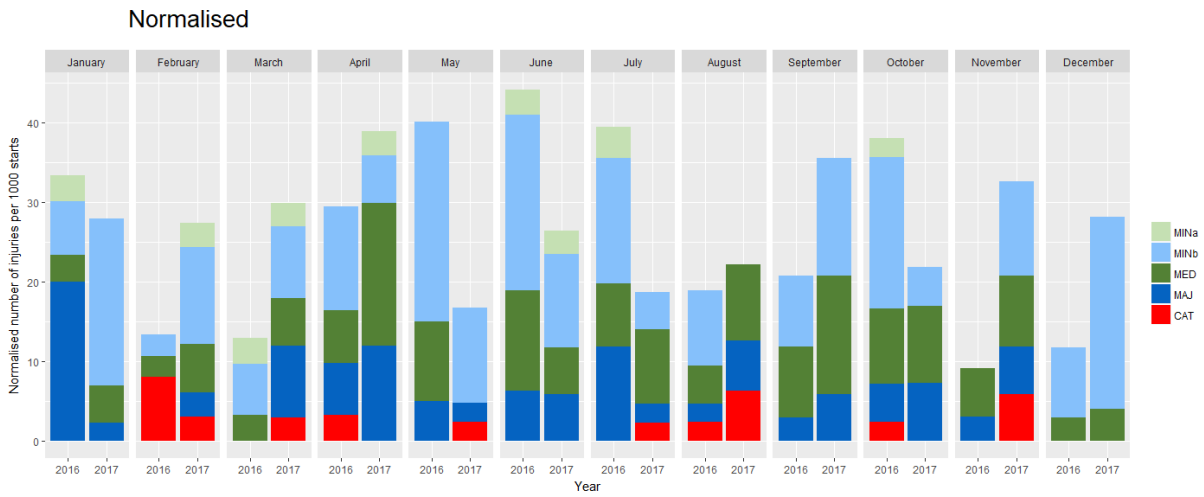

Figure 105: Bathurst track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

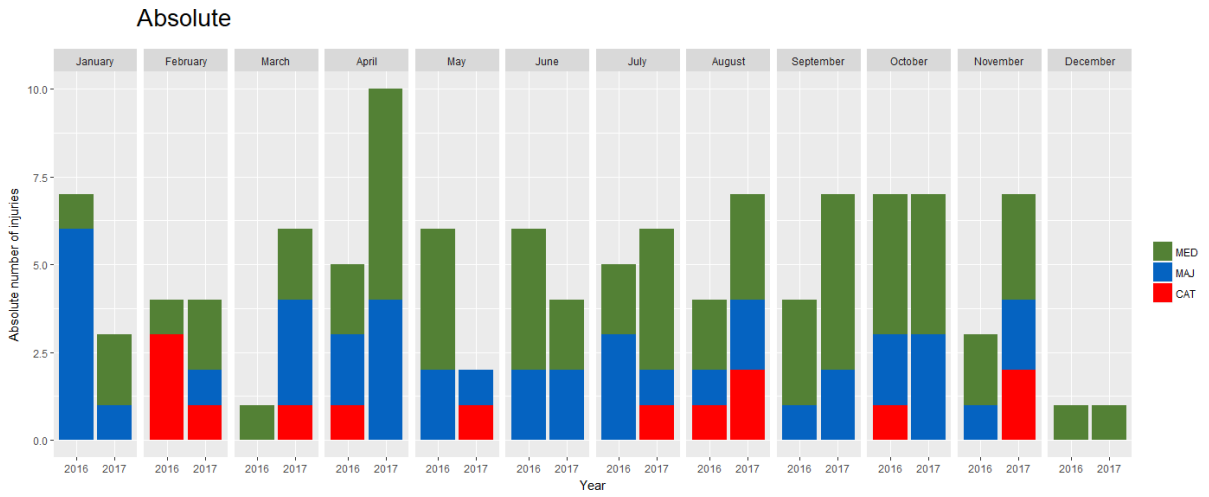

Figure 106: Bathurst track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

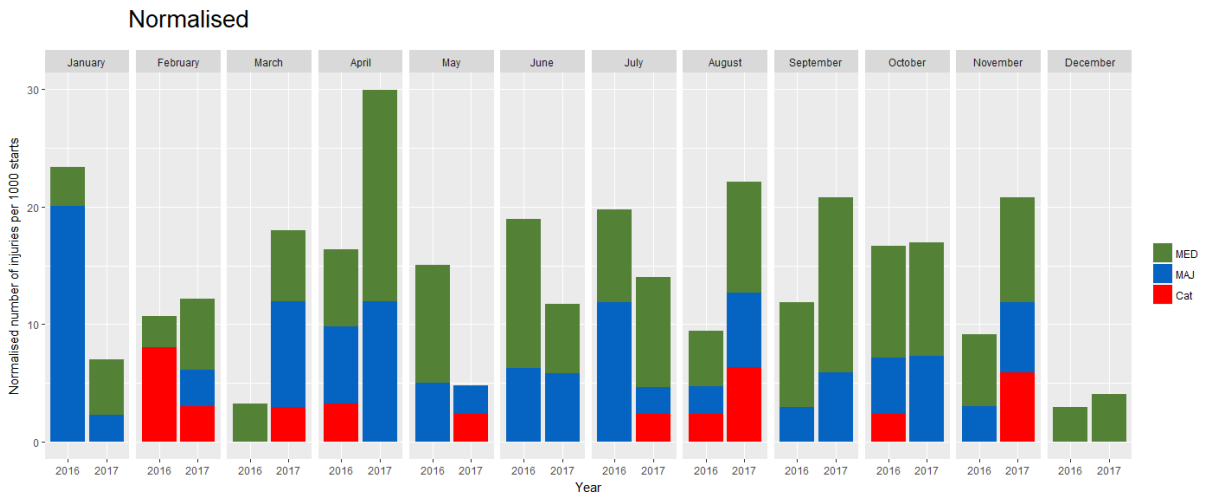

Figure 107: Bathurst track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

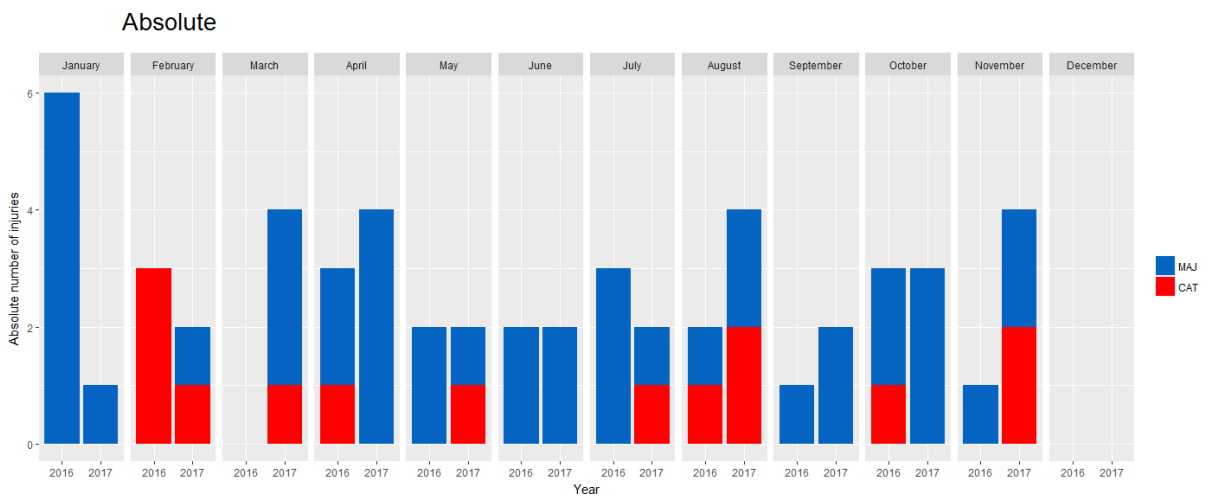

Figure 108: Bathurst track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

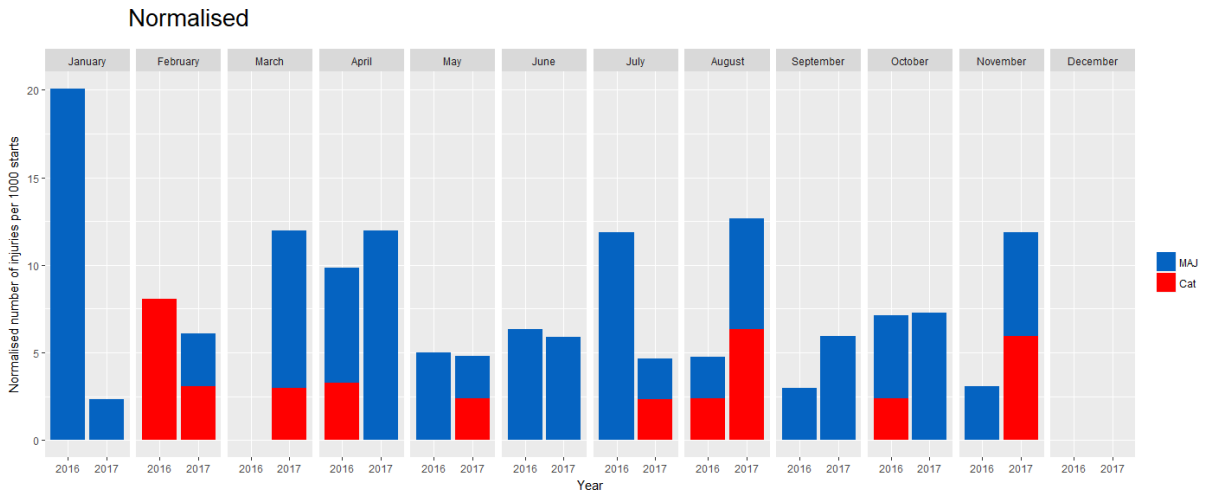

Figure 109: Bathurst track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

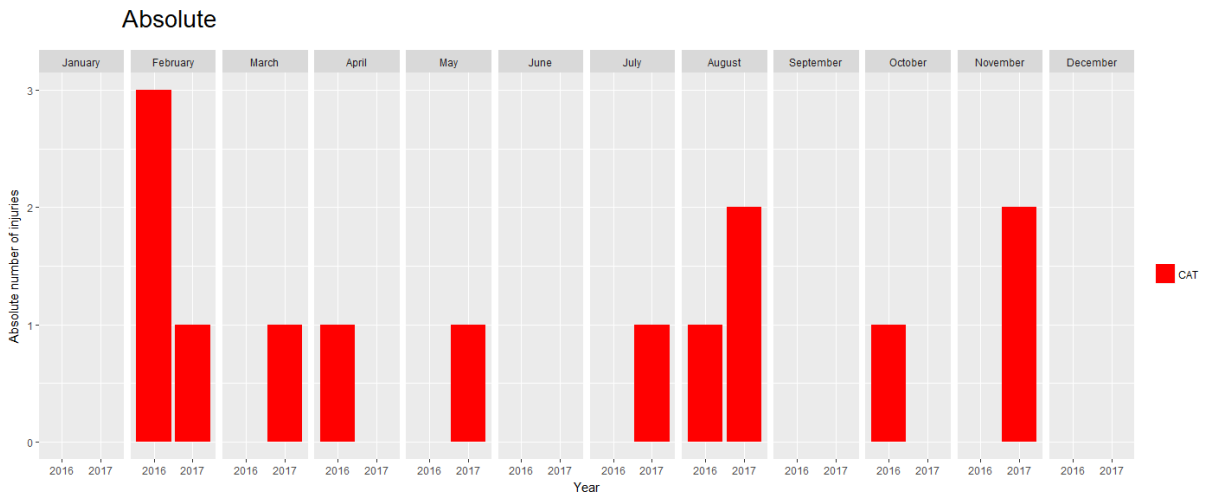

Figure 110: Bathurst track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

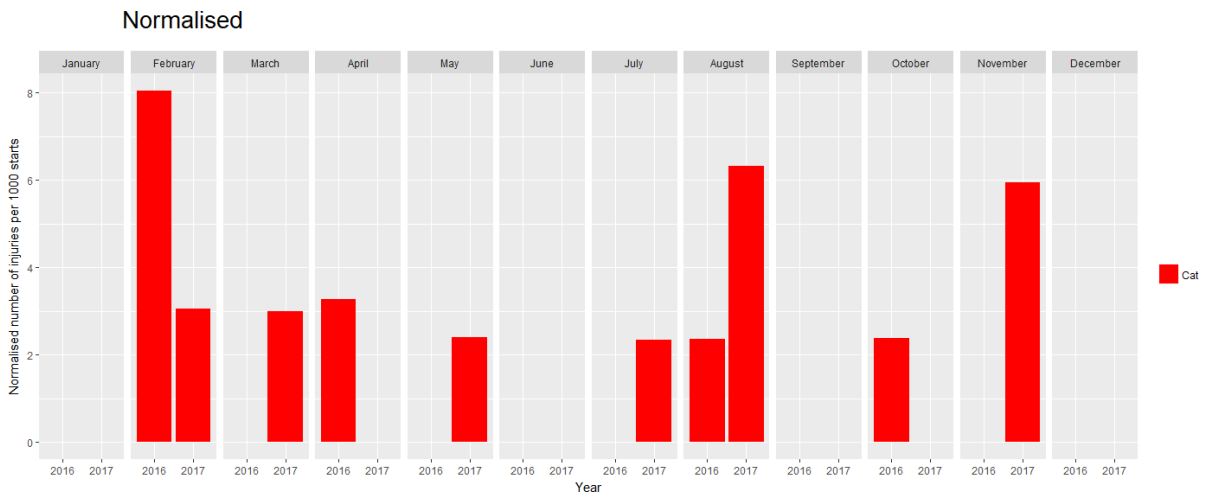

Figure 111: Bathurst track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

BATHURST: LOCATION OF INJURIES FOR 307 M - 1 JAN TO 31 DEC 2017

3.57 In this section, the injury locations of Bathurst track for 307 m race distances are presented.

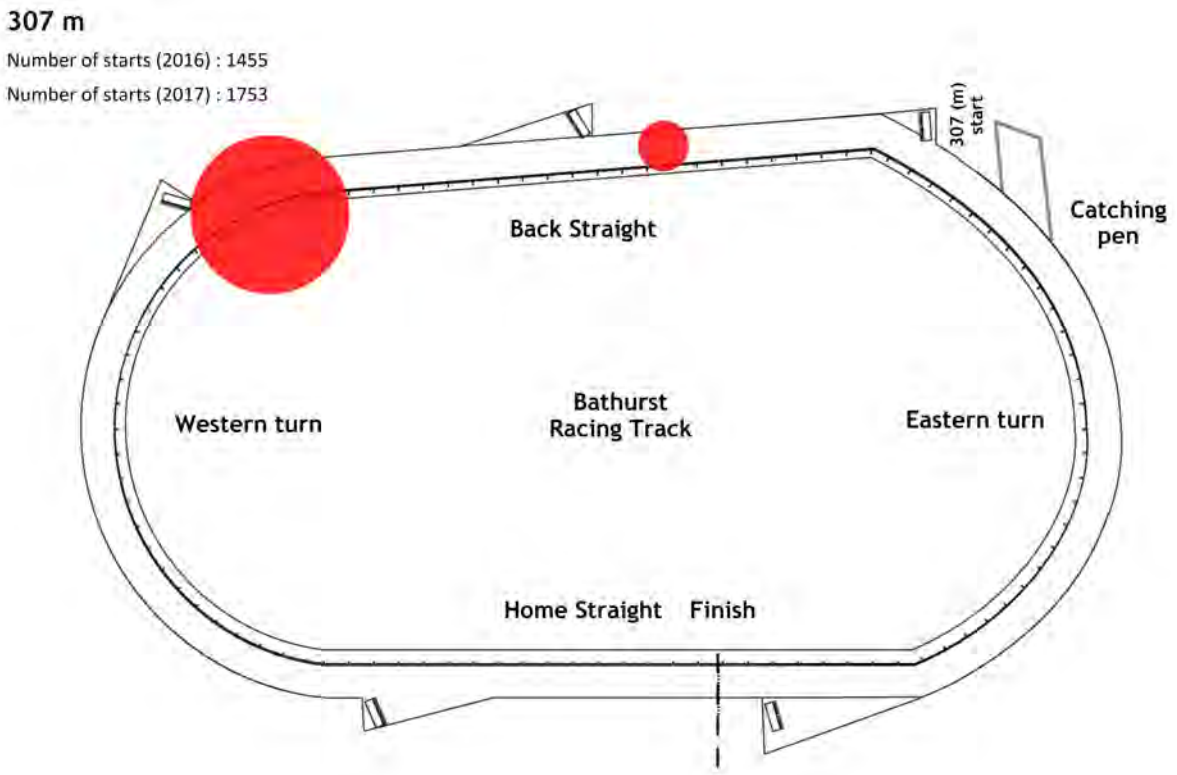

Figure 112: Bathurst track location of injuries for the 307 m distance

3.58 The location of injuries is similar to 2016.

BATHURST: LOCATION OF INJURIES FOR 450 M - 1 JAN TO 31 DEC 2017

3.59 In this section, the injury locations of Bathurst track for 450 m race distances are presented.

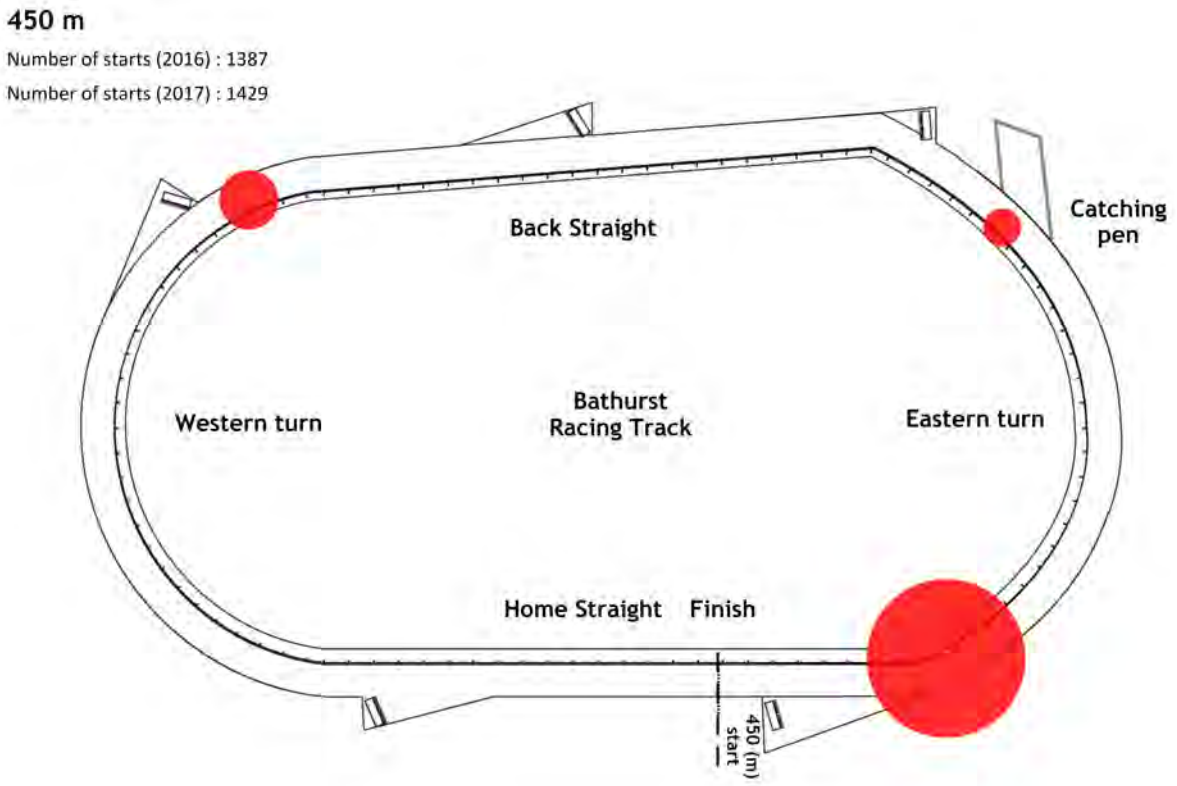

Figure 113: Bathurst track location of injuries for the 450 m distance

3.60 The location of injuries is similar to 2016.

BATHURST: LOCATION OF INJURIES FOR 520 M - 1 JAN TO 31 DEC 2017

3.61 In this section, the injury locations of Bathurst track for 520 m race distances are presented.

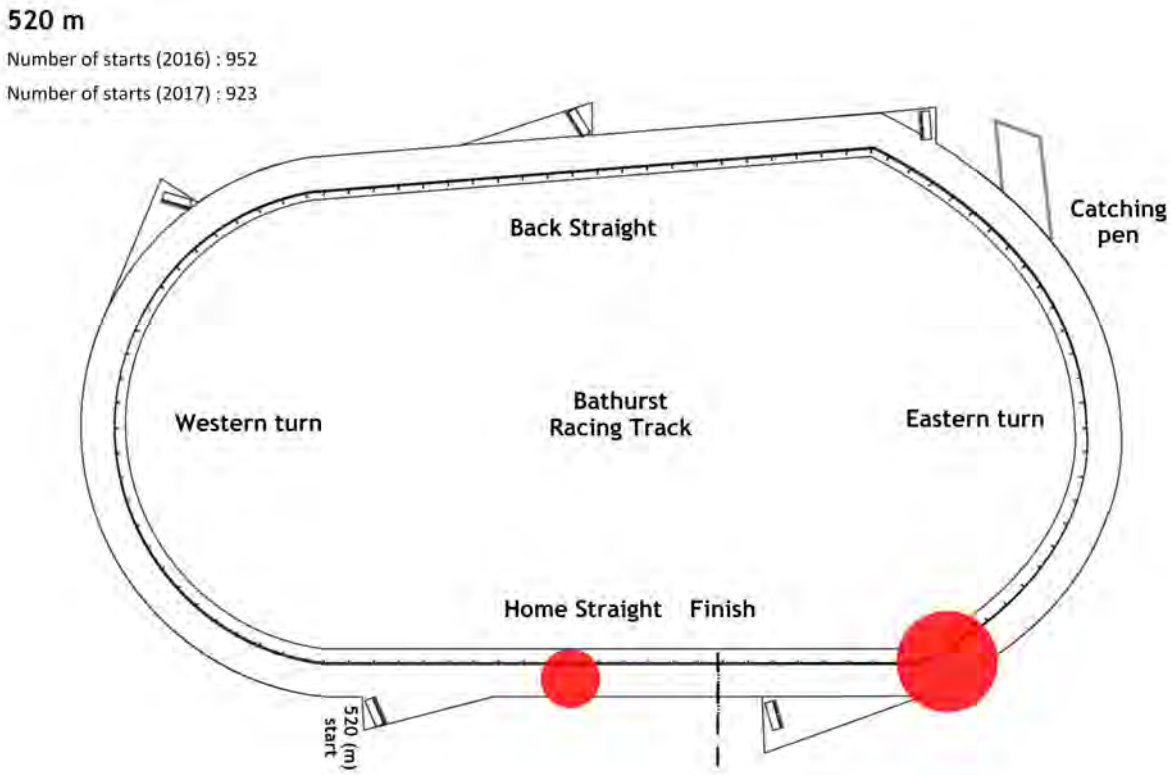

Figure 114: Bathurst track location of injuries for the 520 m distance

3.62 The location of injuries is similar to 2016.

DAPTO

DAPTO: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.63 Figures 115 to 122 contain Dapto Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

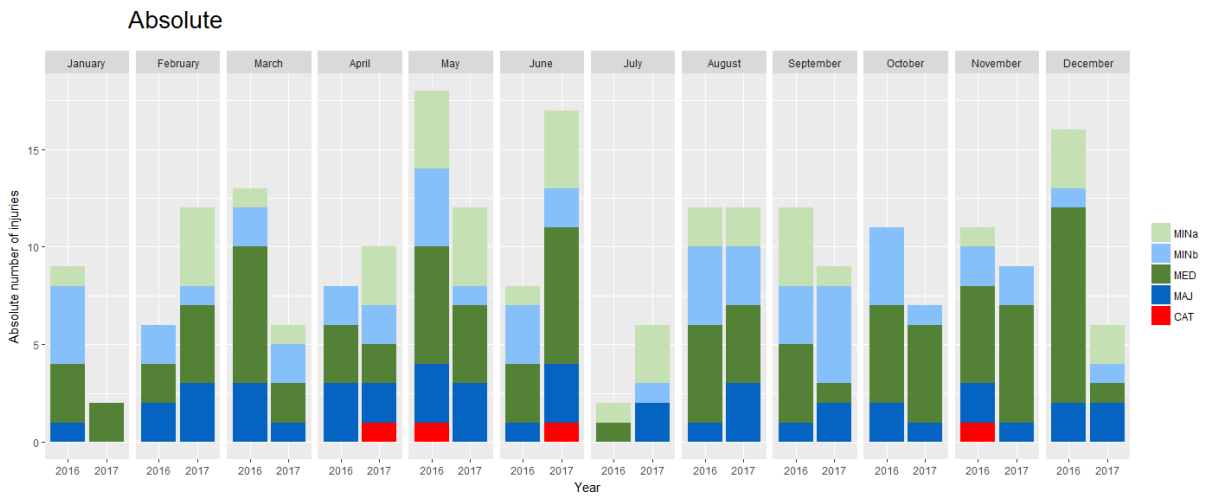

Figure 115: Dapto track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

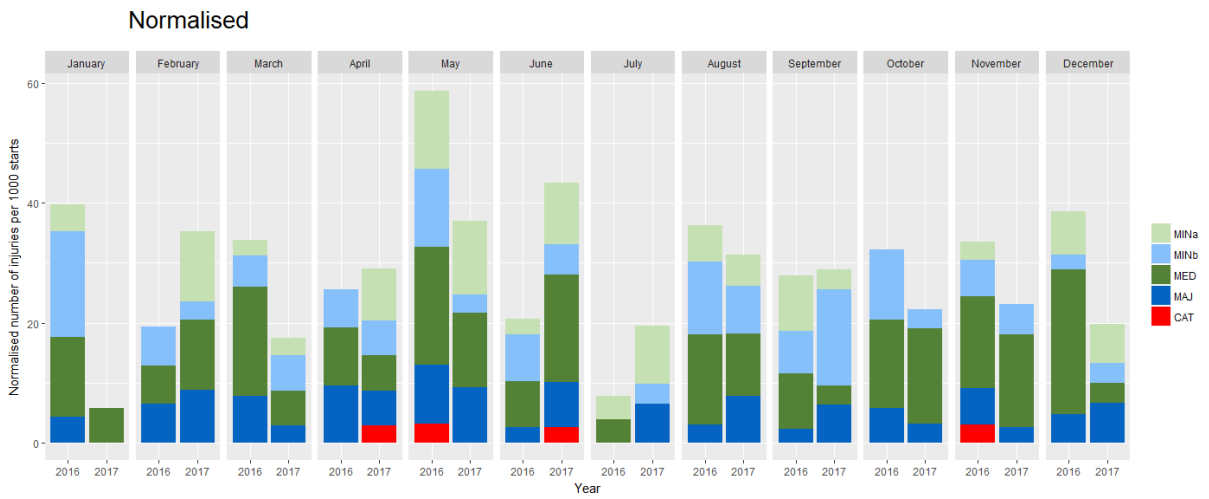

Figure 116: Dapto track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

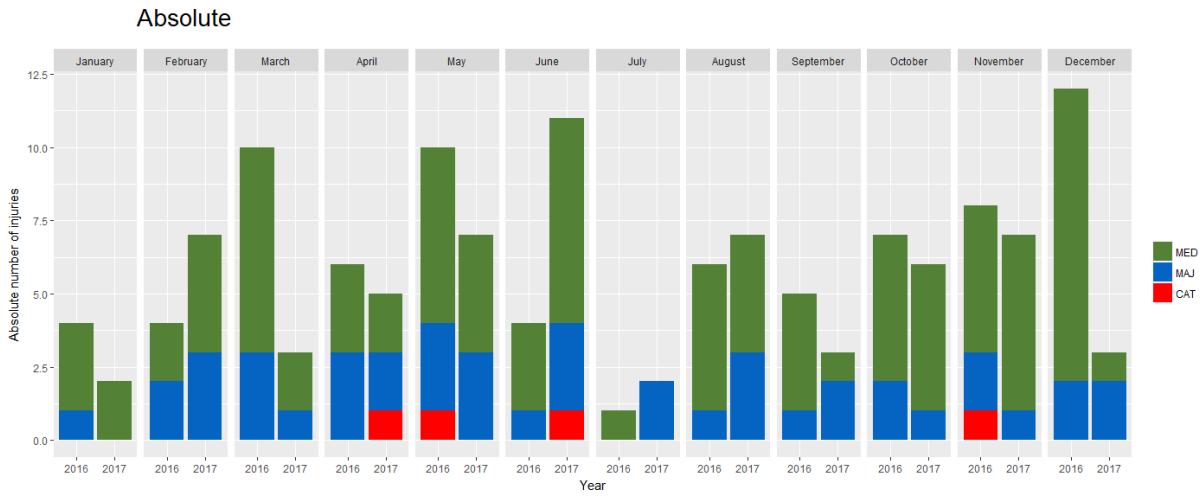

Figure 117: Dapto track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

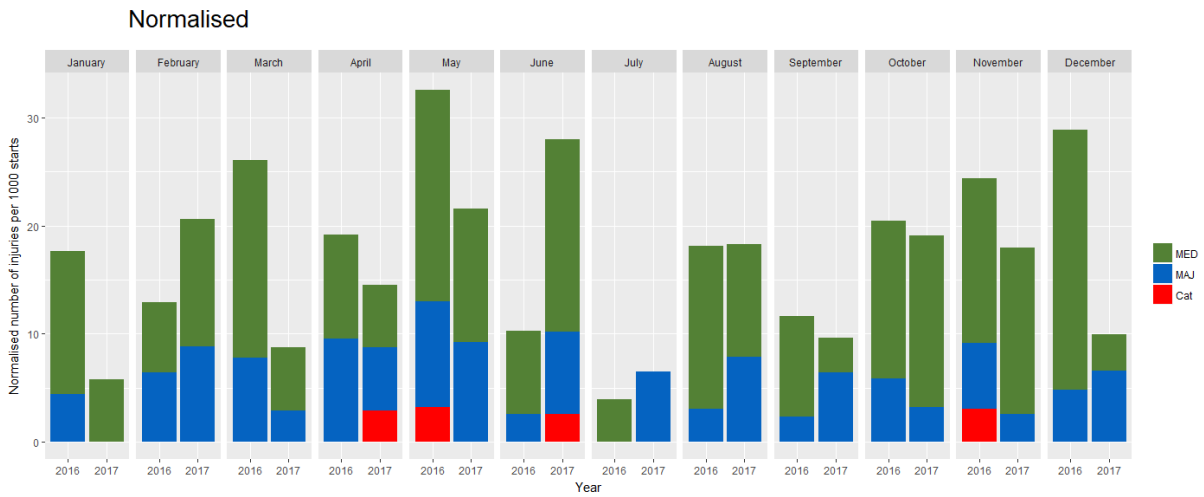

Figure 118: Dapto track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

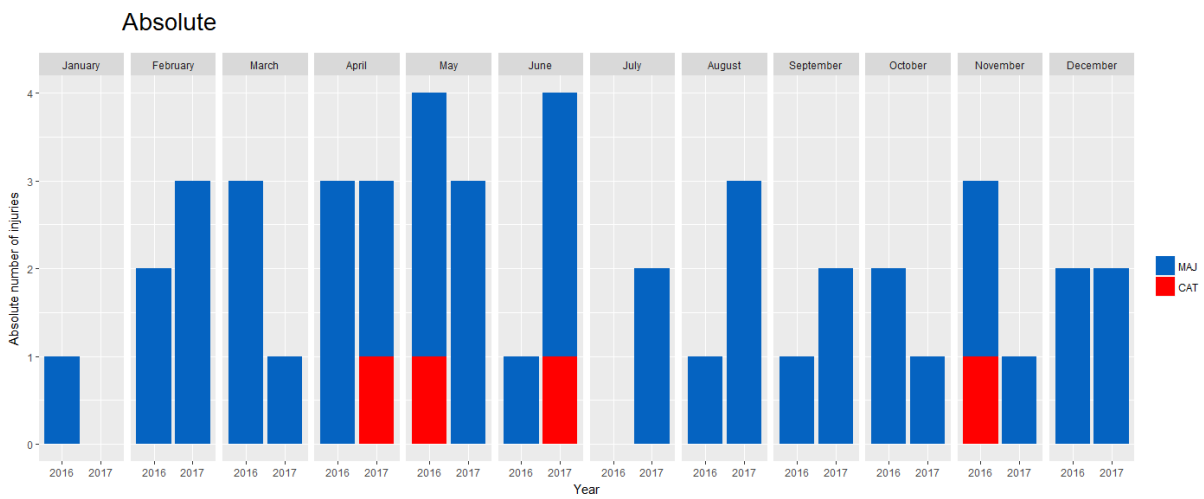

Figure 119: Dapto track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

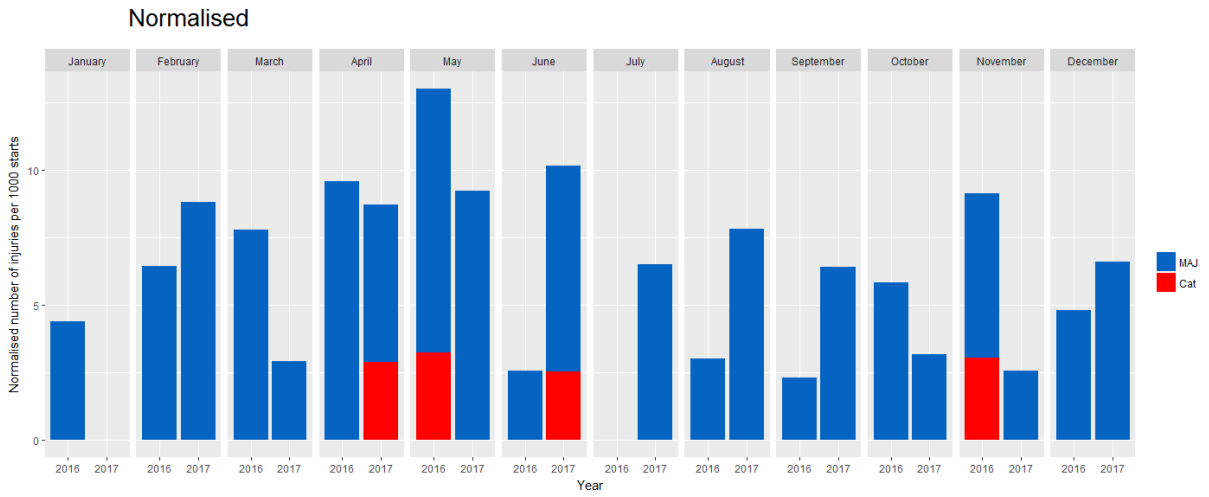

Figure 120: Dapto track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

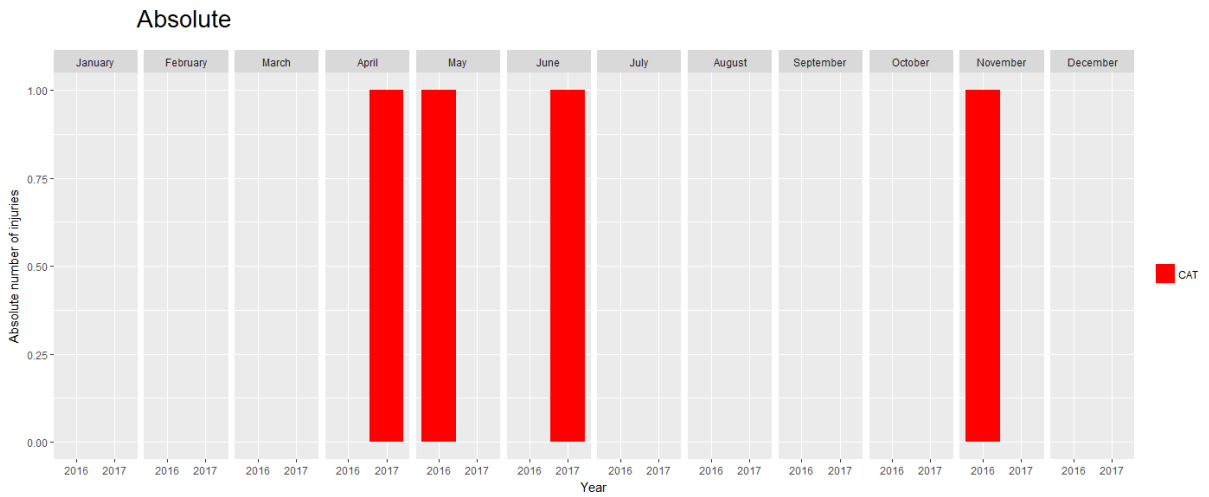

Figure 121: Dapto track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

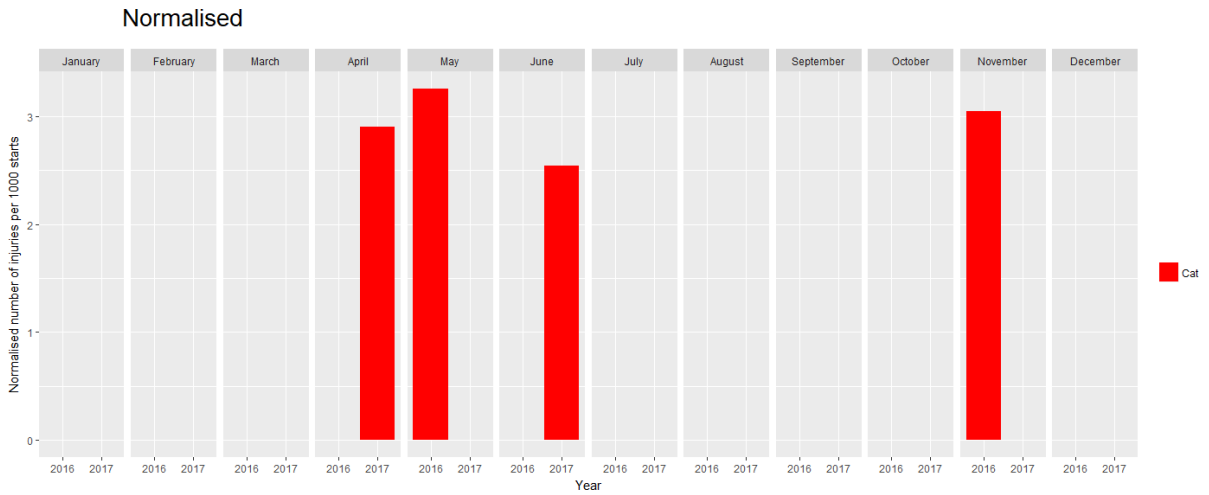

Figure 122: Dapto track Level 1 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

DAPTO: LOCATION OF INJURIES FOR 297 M - 1 JAN TO 31 DEC 2017

3.64 In this section, the injury locations of Dapto track for 297 m race distances are presented.

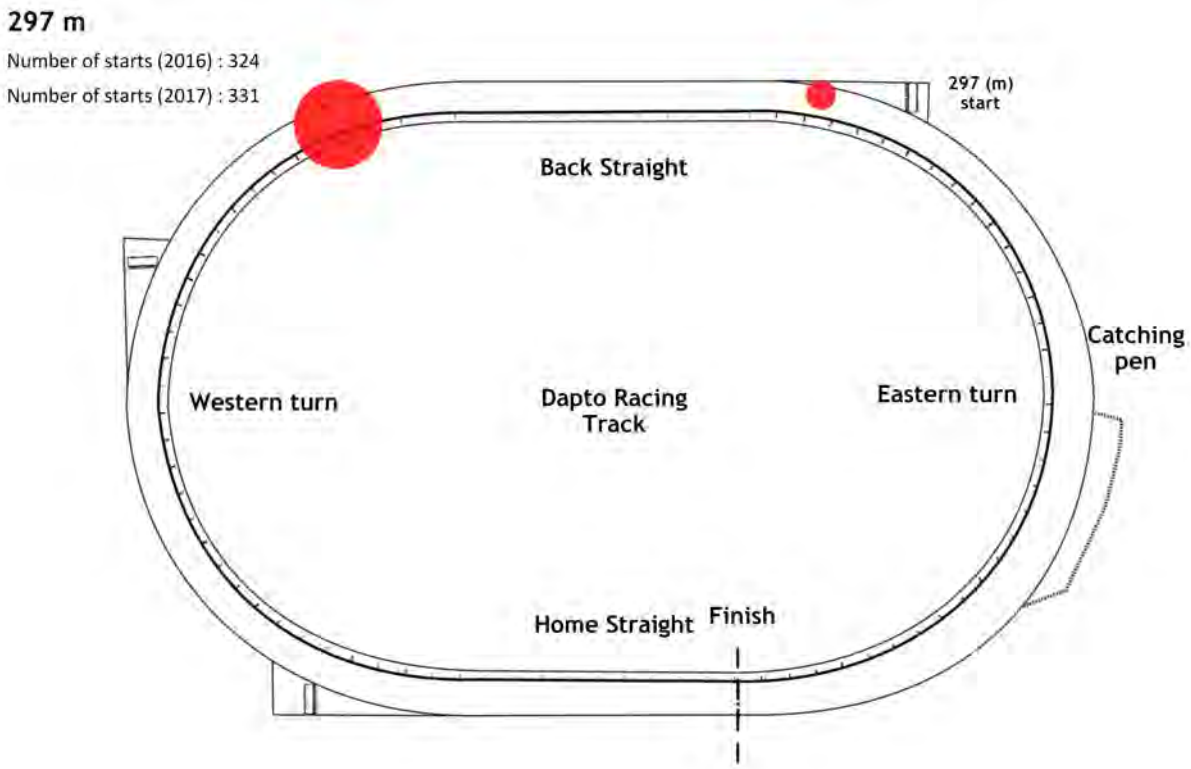

Figure 123: Dapto track location of injuries for the 297 m distance

3.65 The location of injuries is similar to 2016.

DAPTO: LOCATION OF INJURIES FOR 520 M - 1 JAN TO 31 DEC 2017

3.66 In this section, the injury locations of Dapto track for 520 m race distances are presented.

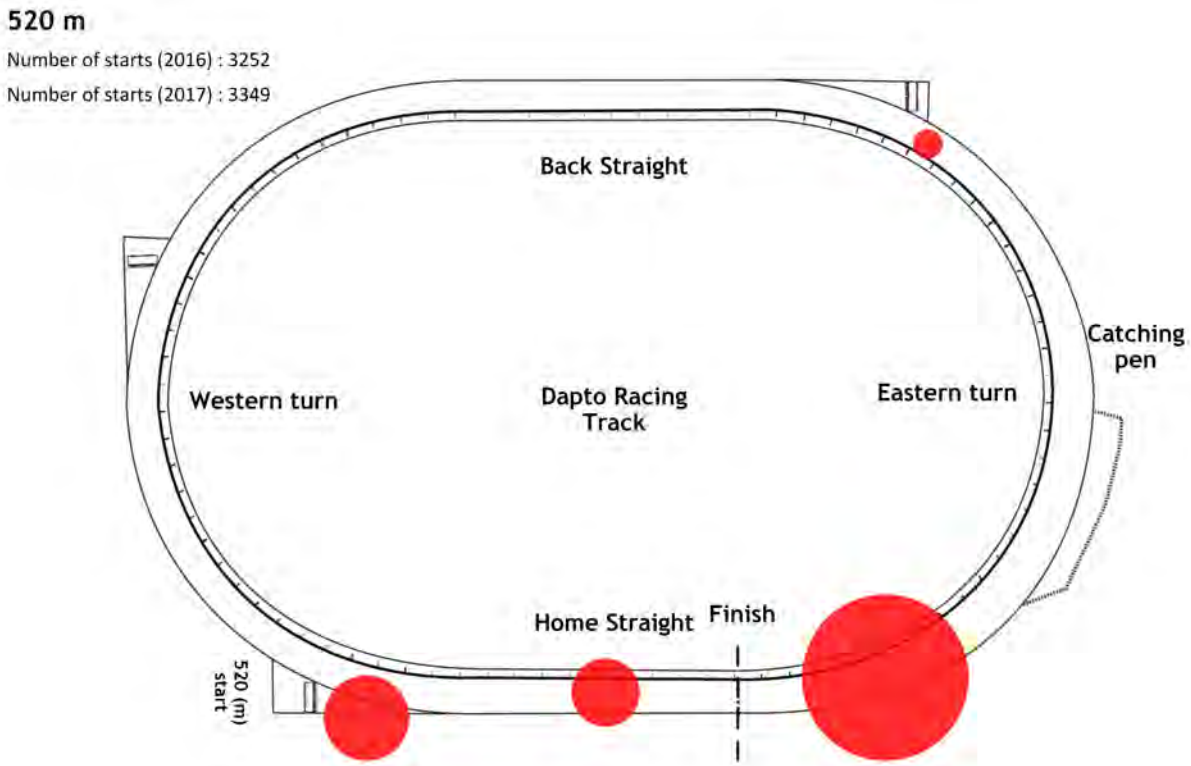

Figure 124: Dapto track location of injuries for the 600 m distance

3.67 The location of injuries is similar to 2016.

DAPTO: LOCATION OF INJURIES FOR 600 M - 1 JAN TO 31 DEC 2017

3.68 In this section, the injury locations of Dapto track for 600 m race distances are presented.

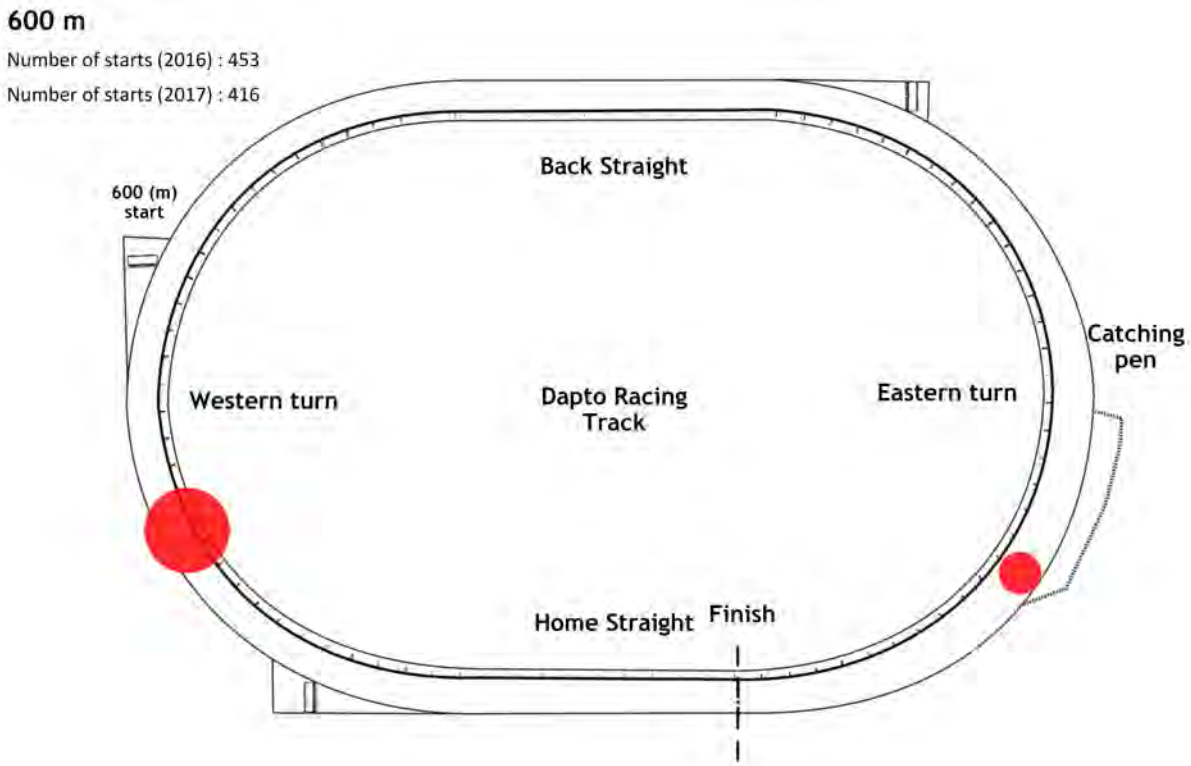

Figure 125: Dapto track location of injuries for the 520 m distance

3.69 The location of injuries is similar to 2016.

BULLI

BULLI: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.70 Figures 126 to 133 contain Bulli Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

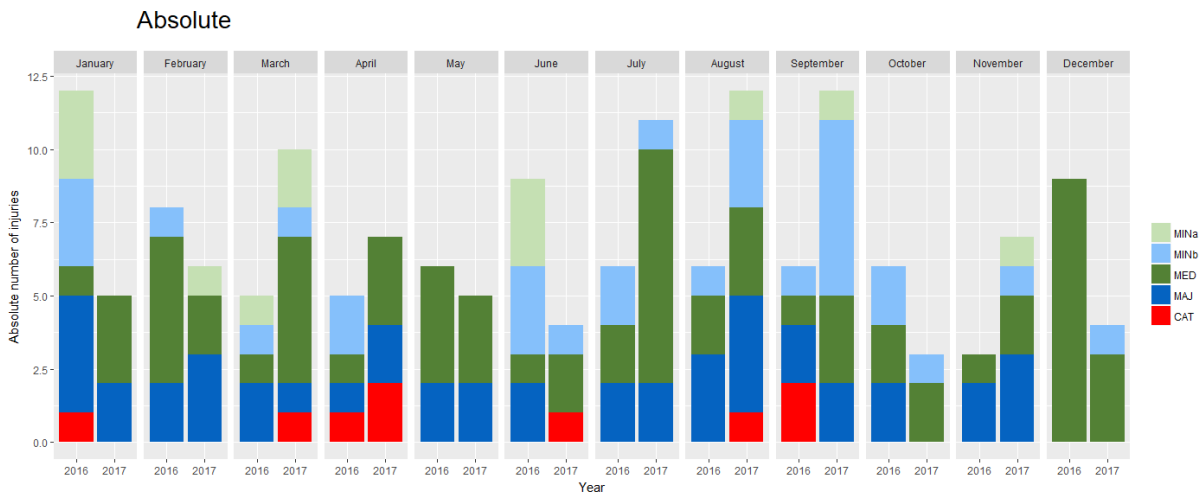

Figure 126: Bulli track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

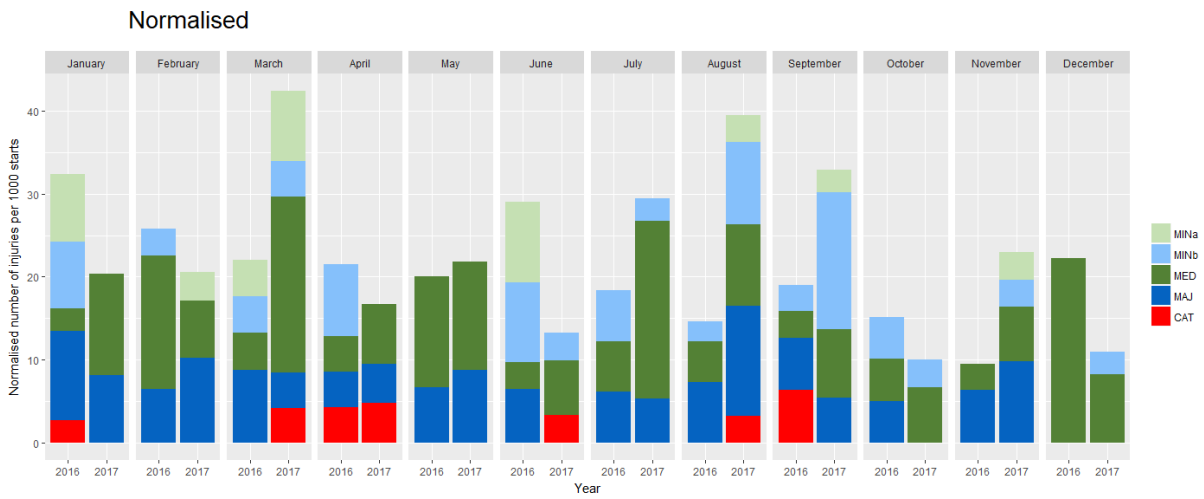

Figure 127: Bulli track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

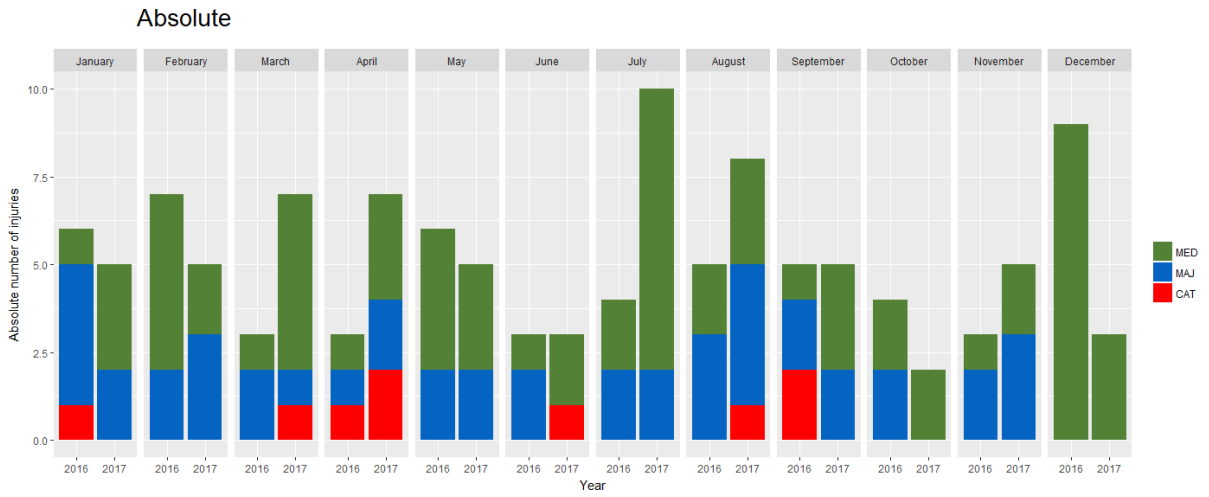

Figure 128: Bulli track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

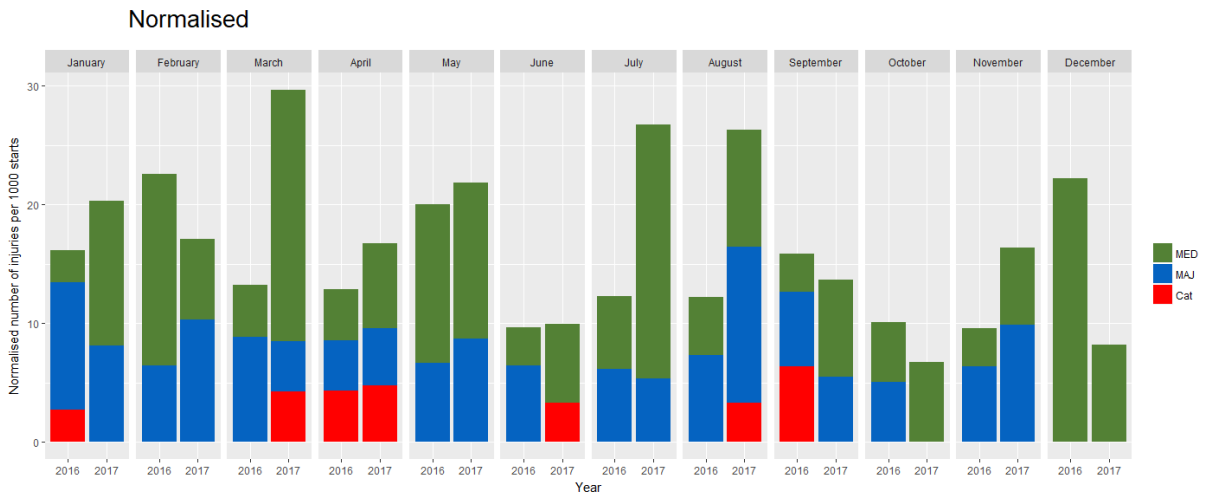

Figure 129: Bulli track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

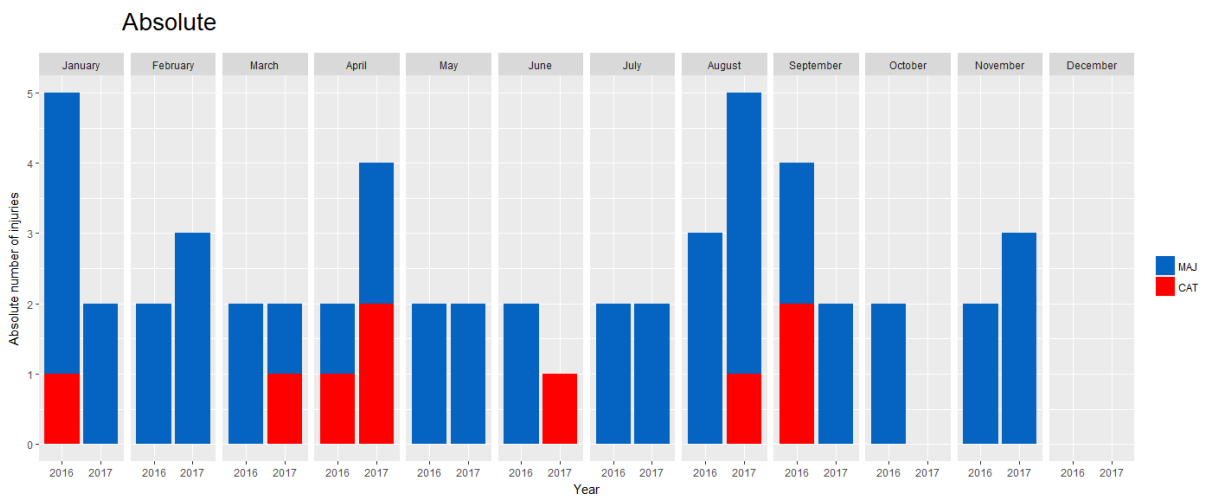

Figure 130: Bulli track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

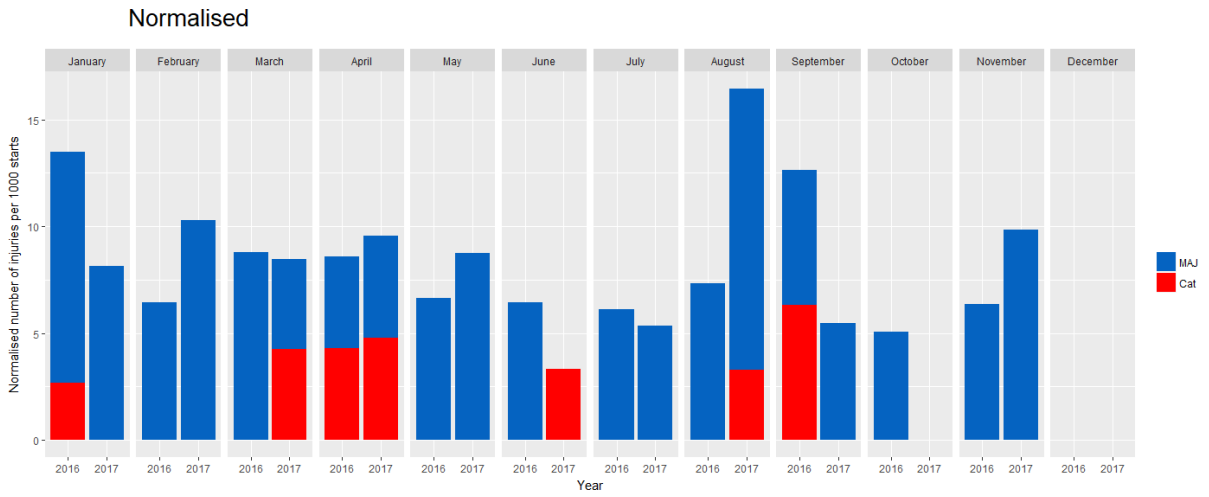

Figure 131: Bulli track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

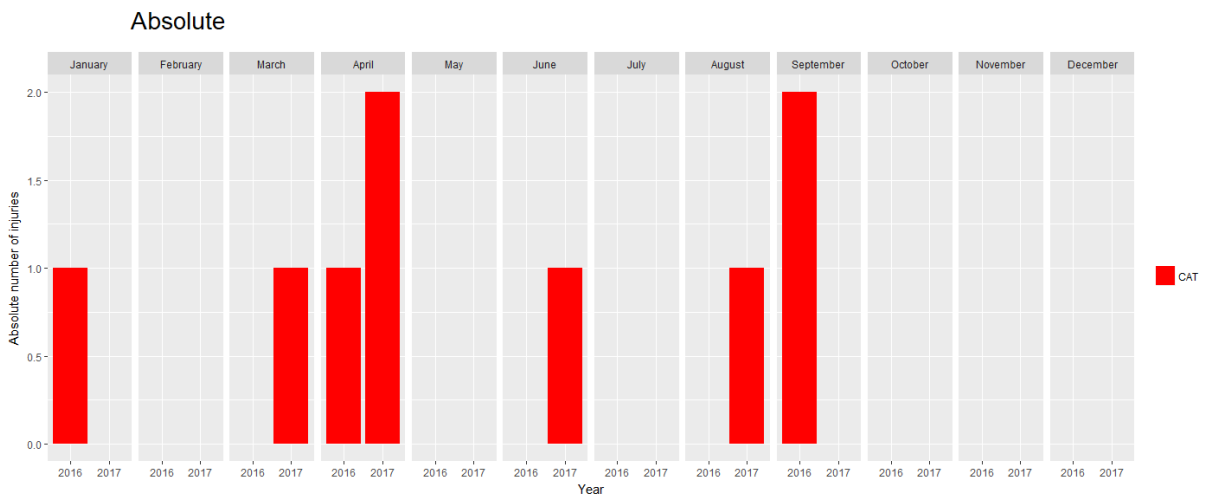

Figure 132: Bulli track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

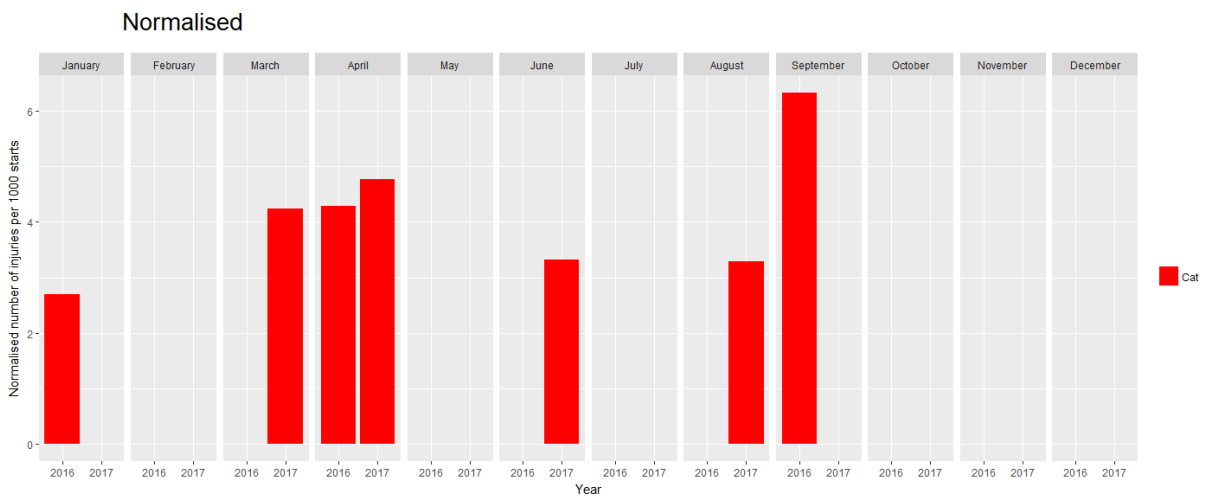

Figure 133: Bulli track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

BULLI: LOCATION OF INJURIES FOR 400 M - 1 JAN TO 31 DEC 2017

3.71 In this section, the injury locations of Bulli track for 400 m race distances are presented.

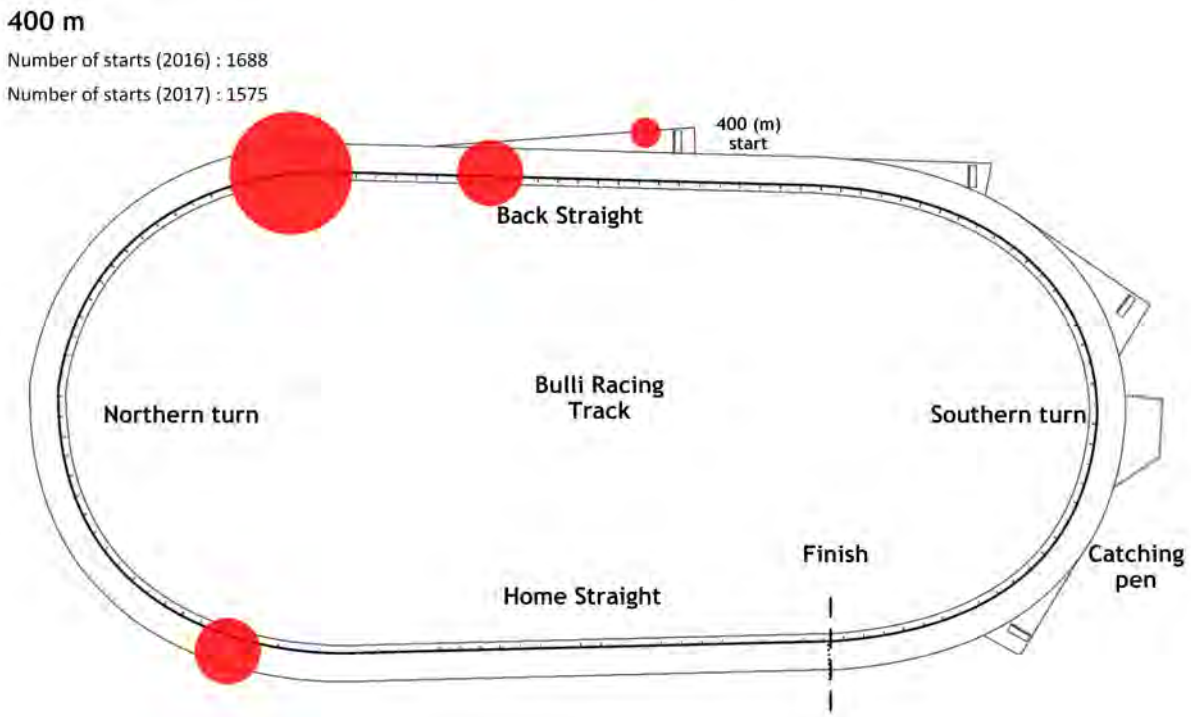

Figure 134: Bulli track location of injuries for the 400 m distance

3.72 The location of injuries is similar to 2016.

BULLI: LOCATION OF INJURIES FOR 472 M - 1 JAN TO 31 DEC 2017

3.73 In this section, the injury locations of Bulli track for 472 m race distances are presented.

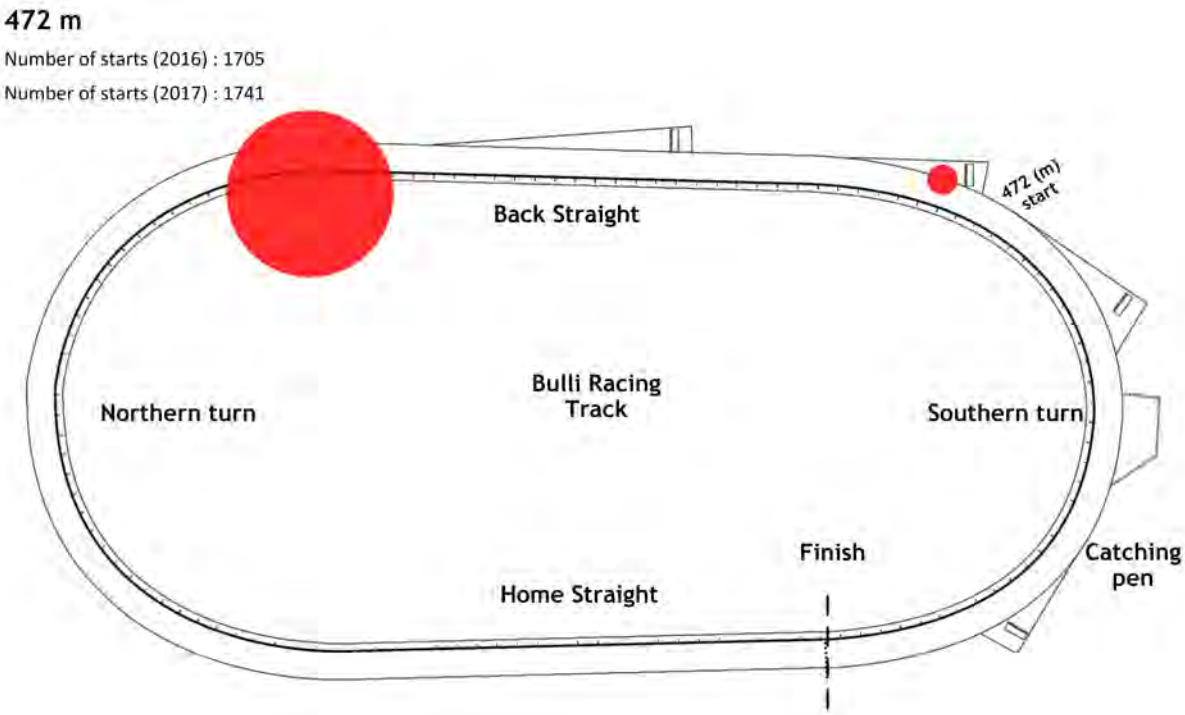

Figure 135: Bulli track location of injuries for the 472 m distance

3.74 The location of injuries is similar to 2016.

BULLI: LOCATION OF INJURIES FOR 515 M - 1 JAN TO 31 DEC 2017

3.75 In this section, the injury locations of Bulli track for 515 m race distances are presented.

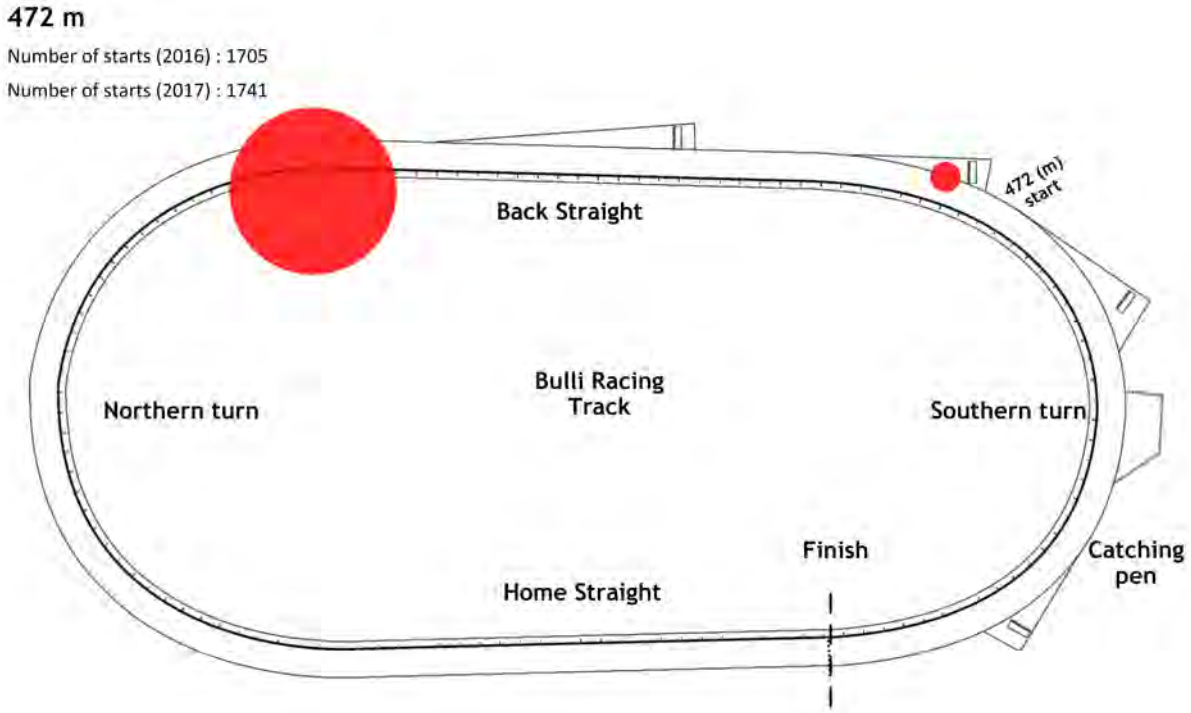

Figure 136: Bulli track location of injuries for the 472 m distance

3.76 The location of injuries is similar to 2016.

DUBBO

DUBBO: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.77 Figures 137 to 144 contain Dubbo Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

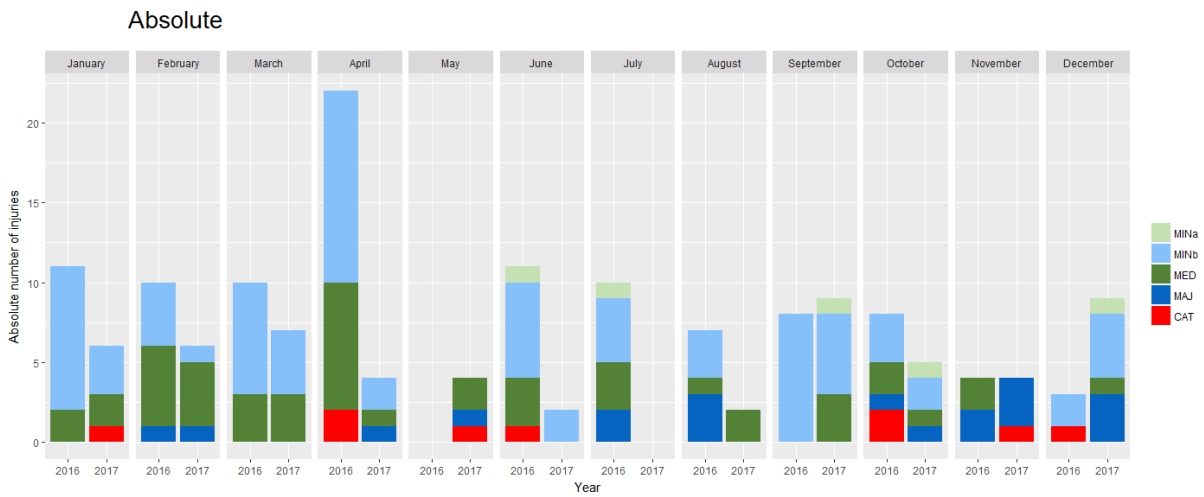

Figure 137: Dubbo track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

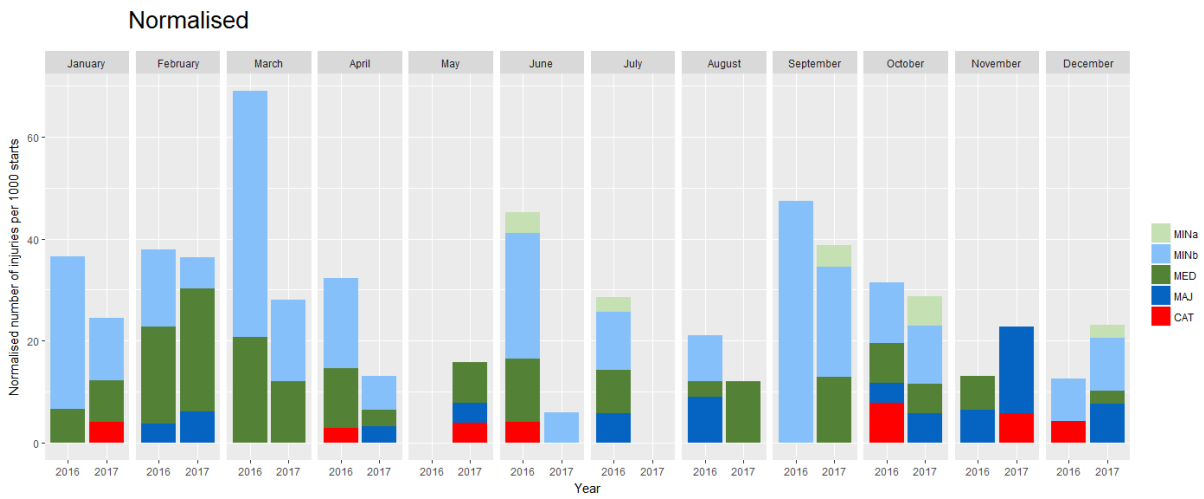

Figure 138: Dubbo track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

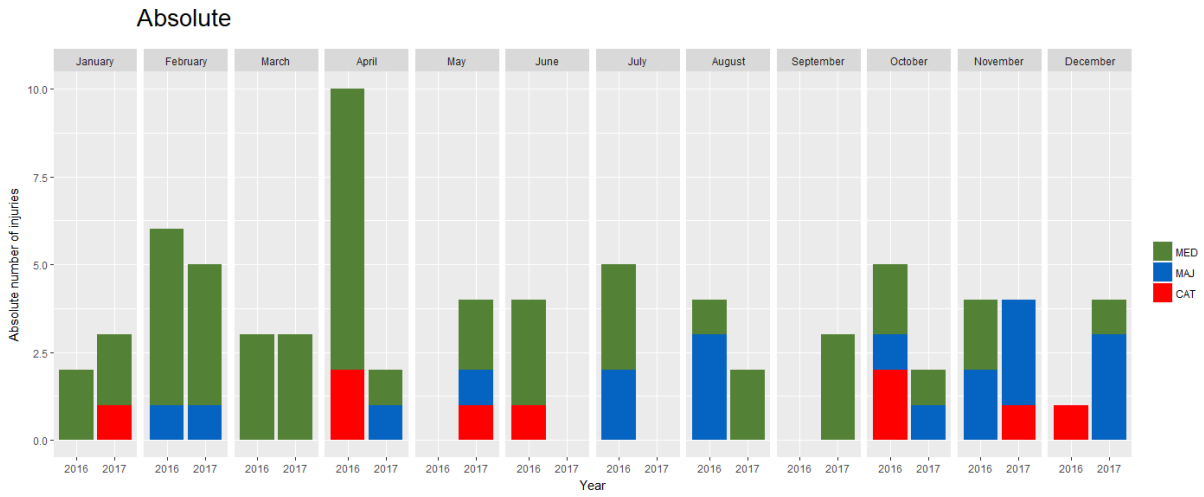

Figure 139: Dubbo track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

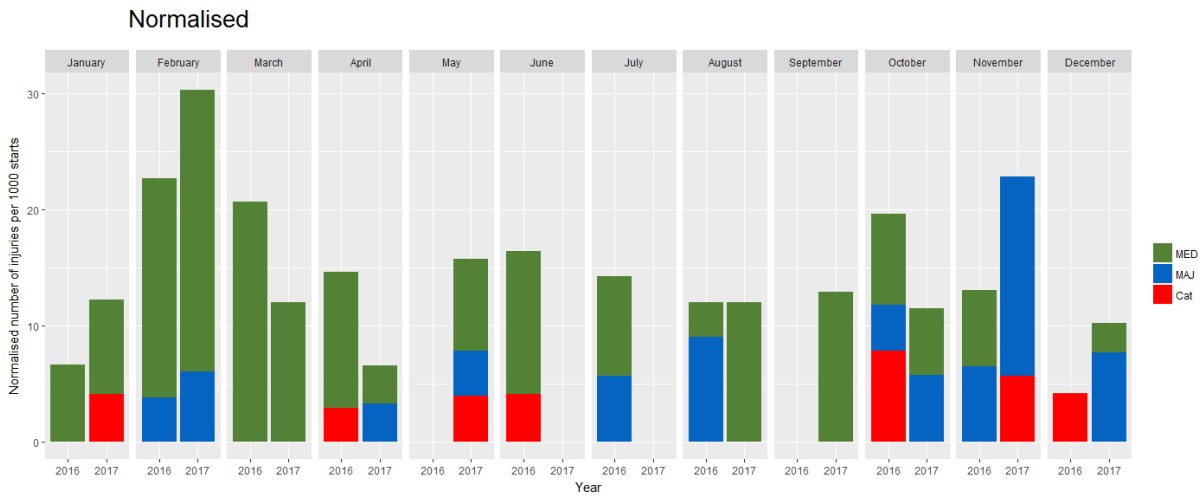

Figure 140: Dubbo track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

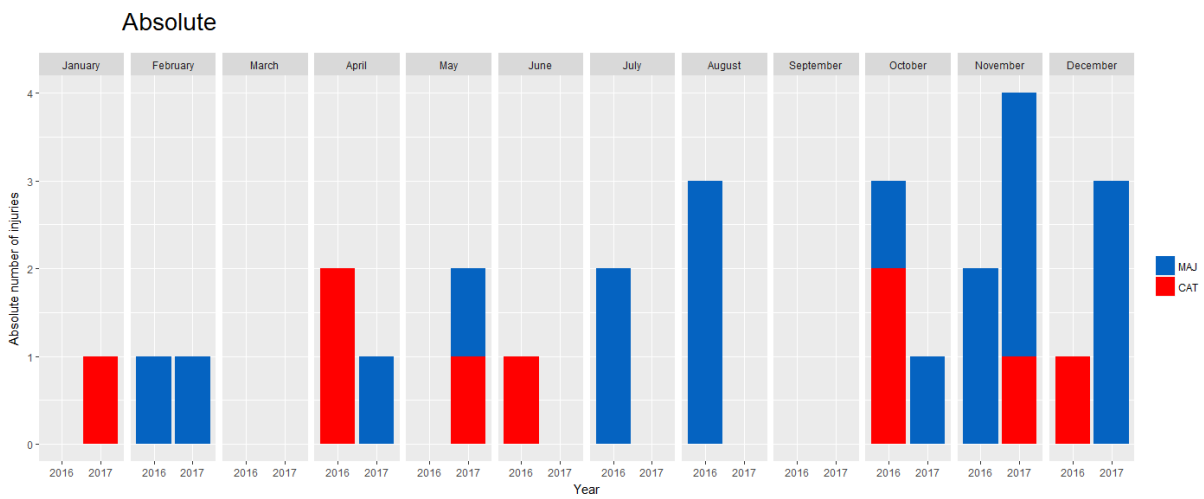

Figure 141: Dubbo track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

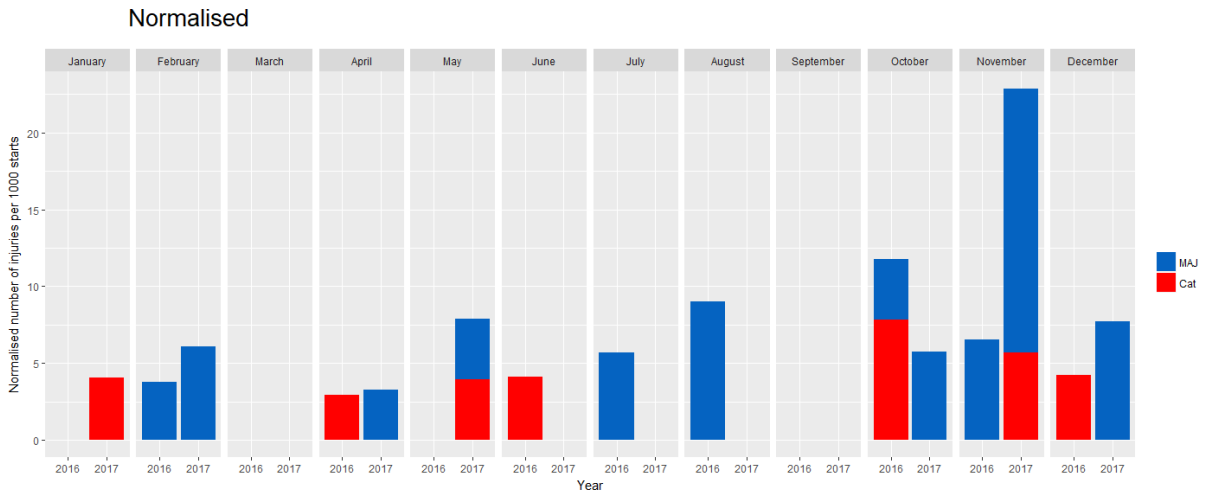

Figure 142: Dubbo track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

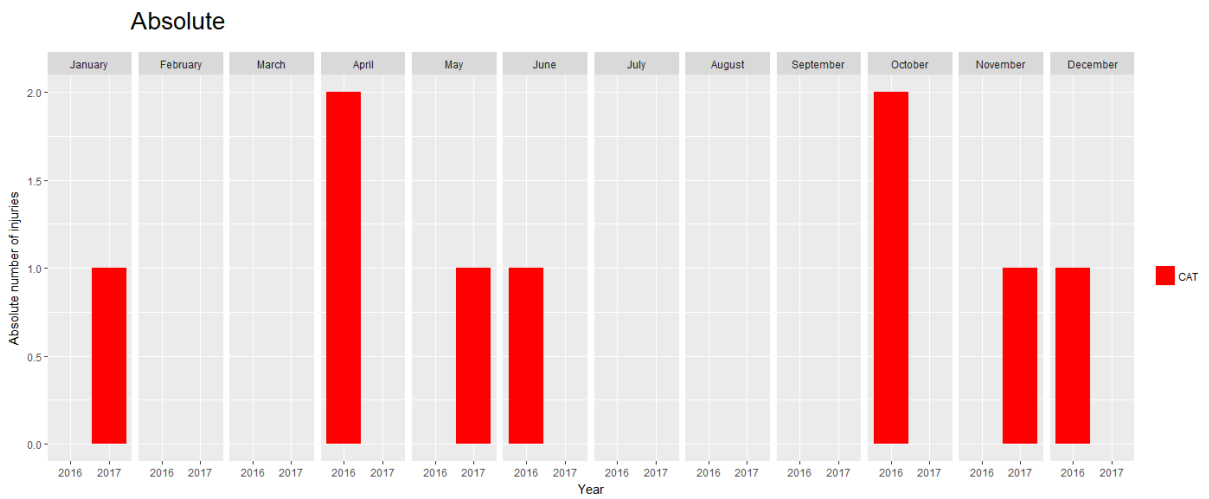

Figure 143: Dubbo track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

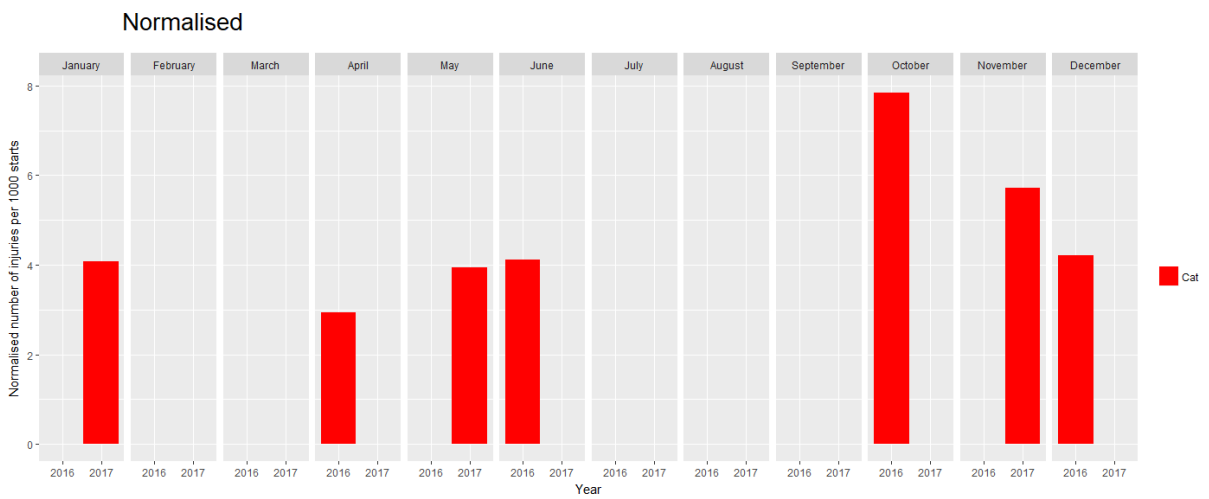

Figure 144: Dubbo track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

DUBBO: LOCATION OF INJURIES FOR 318 M - 1 JAN TO 31 DEC 2017

3.78 In this section, the injury locations of Dubbo track for 318 m race distances are presented.

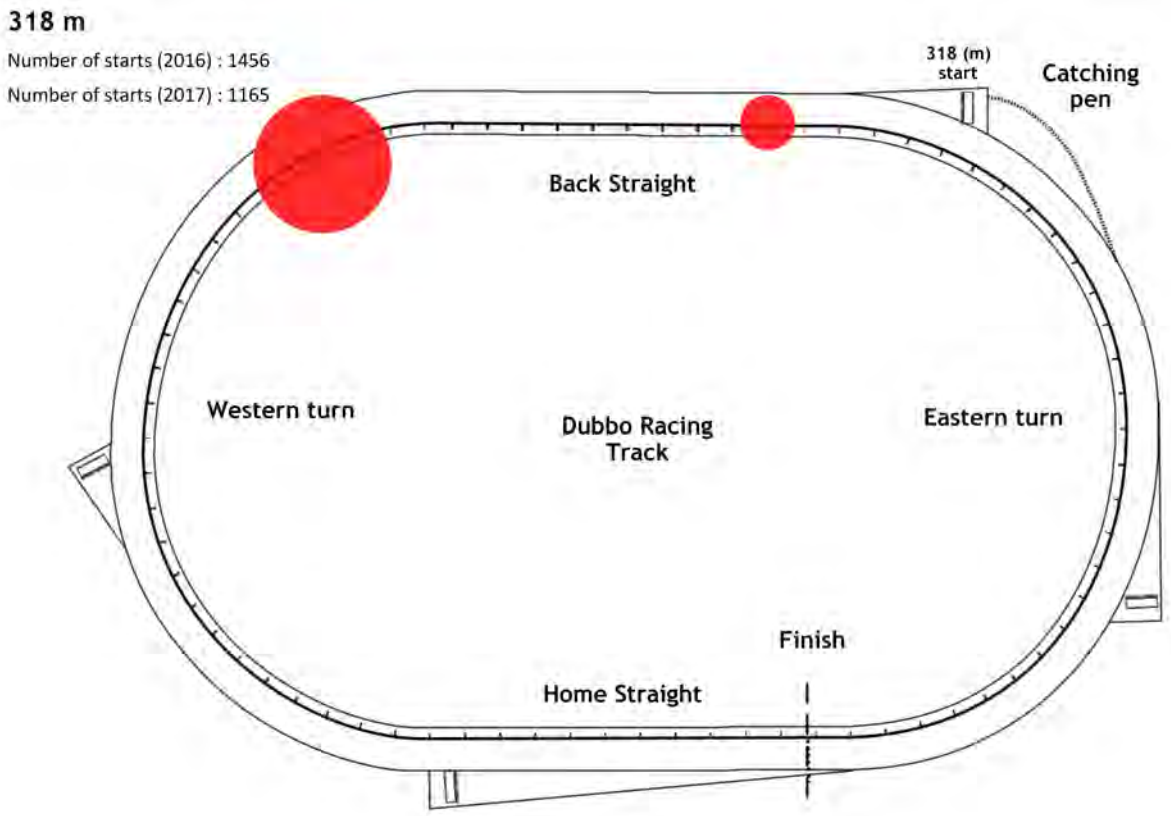

Figure 145: Dubbo track location of injuries for the 318 m distance

3.79 The location of injuries is similar to that of last year.

DUBBO: LOCATION OF INJURIES FOR 400 M - 1 JAN TO 31 DEC 2017

3.80 In this section, the injury locations of Dubbo track for 400 m race distances are presented.

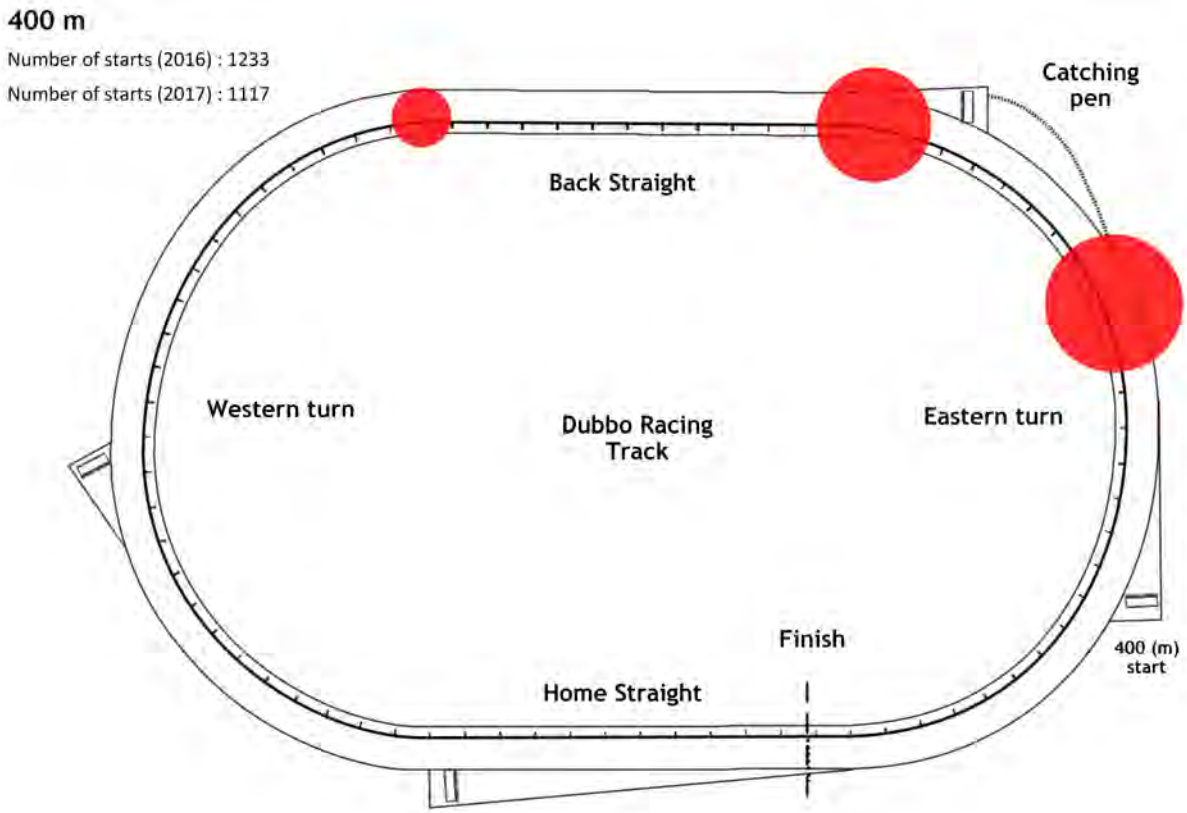

Figure 146: Dubbo track location of injuries for the 400 m distance

3.81 The location of injuries is similar to that of last year.

DUBBO: LOCATION OF INJURIES FOR 516 M - 1 JAN TO 31 DEC 2017

3.82 In this section, the injury locations of Dubbo track for 516 m race distances are presented.

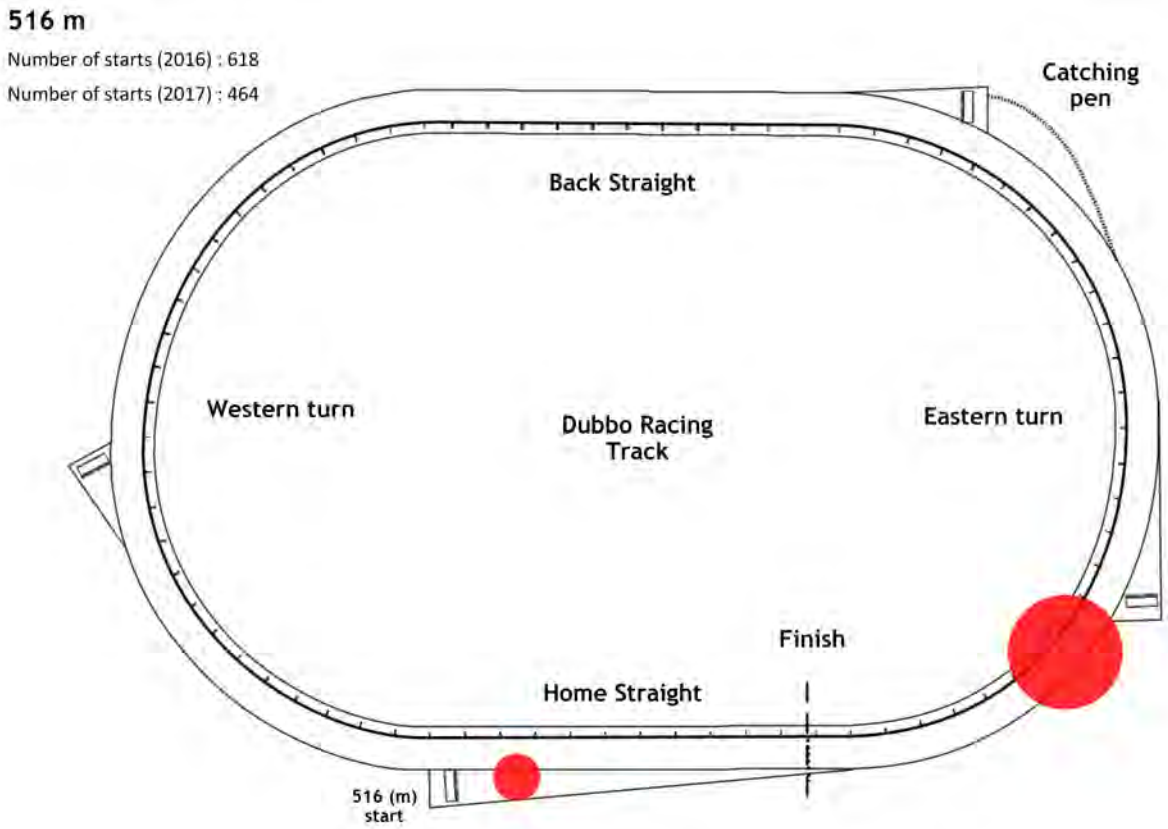

Figure 147: Dubbo track location of injuries for the 516 m distance

3.83 The location of injuries is similar to 2016.

GOULBURN

GOULBURN: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.84 Figures 148 to 155 contain Goulburn Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

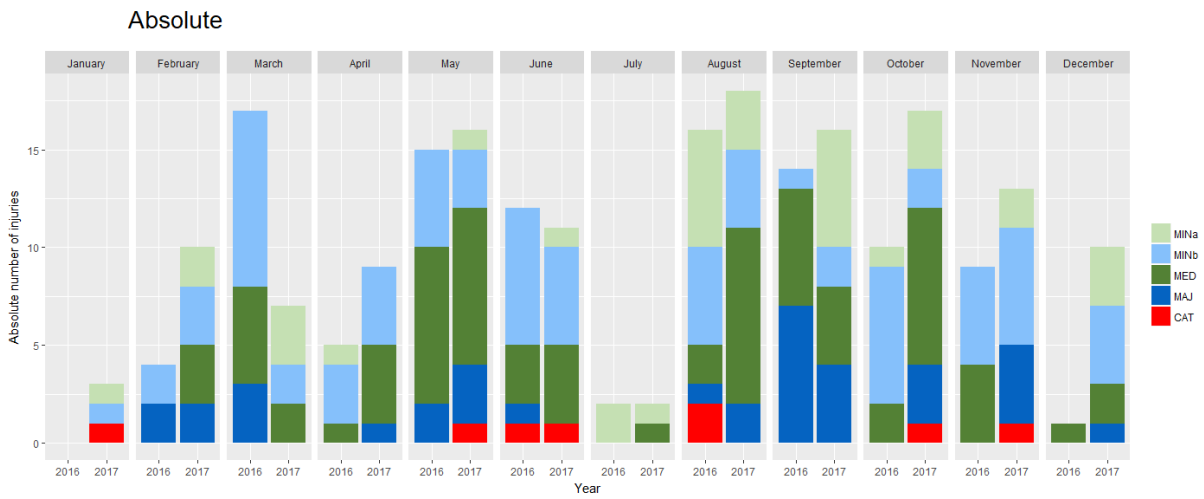

Figure 148: Goulburn track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

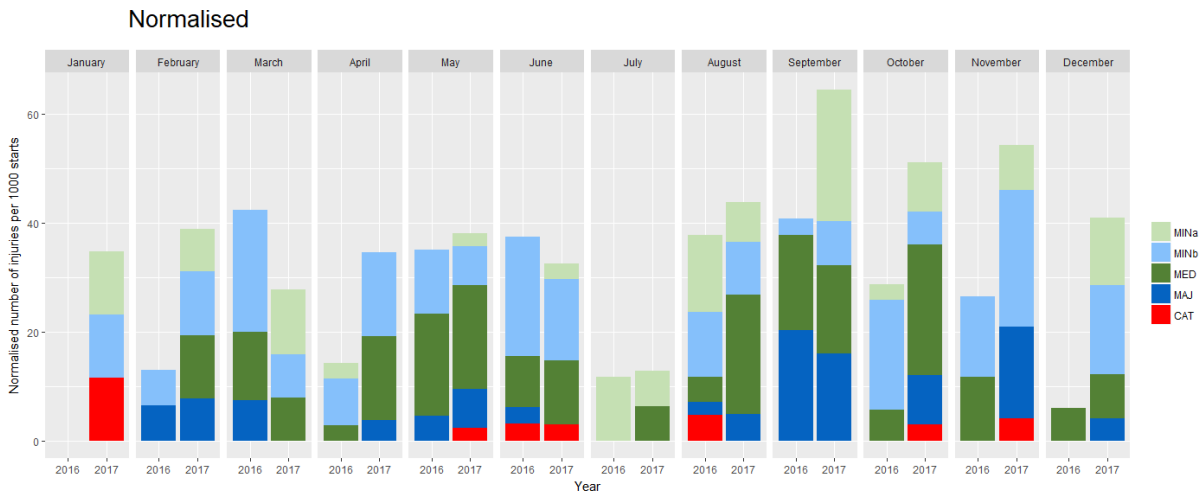

Figure 149: Goulburn track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

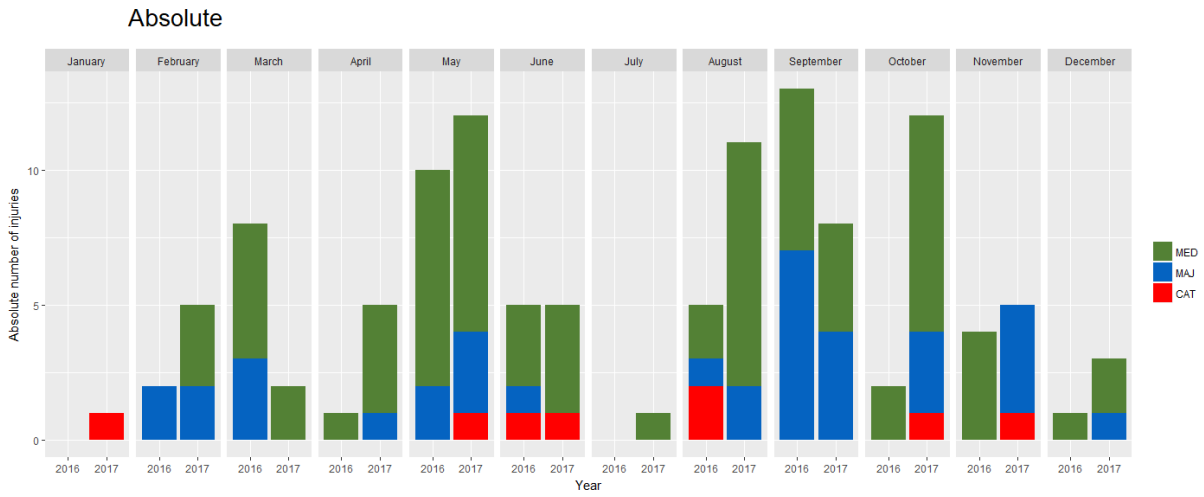

Figure 150: Goulburn track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

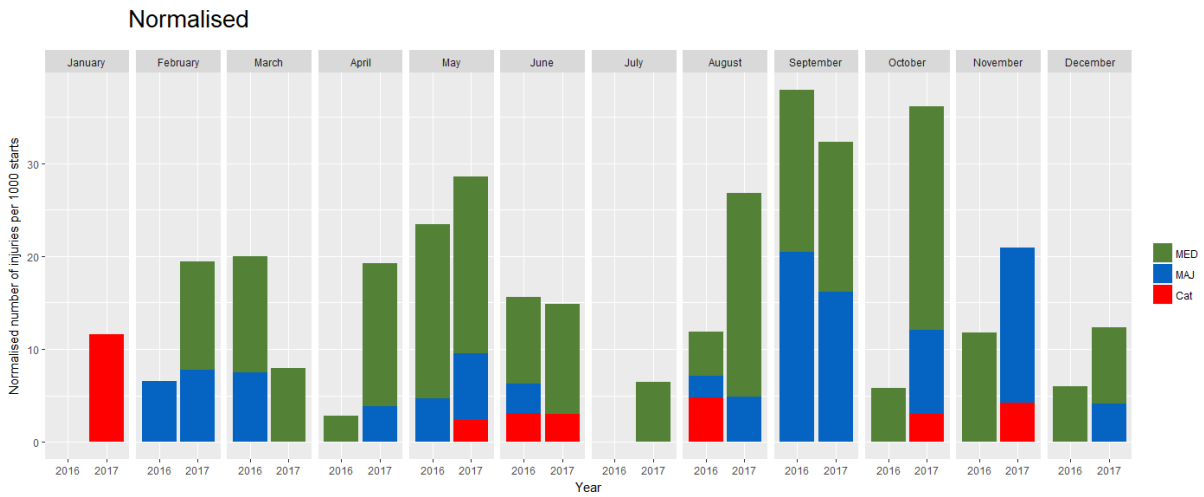

Figure 151: Goulburn track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

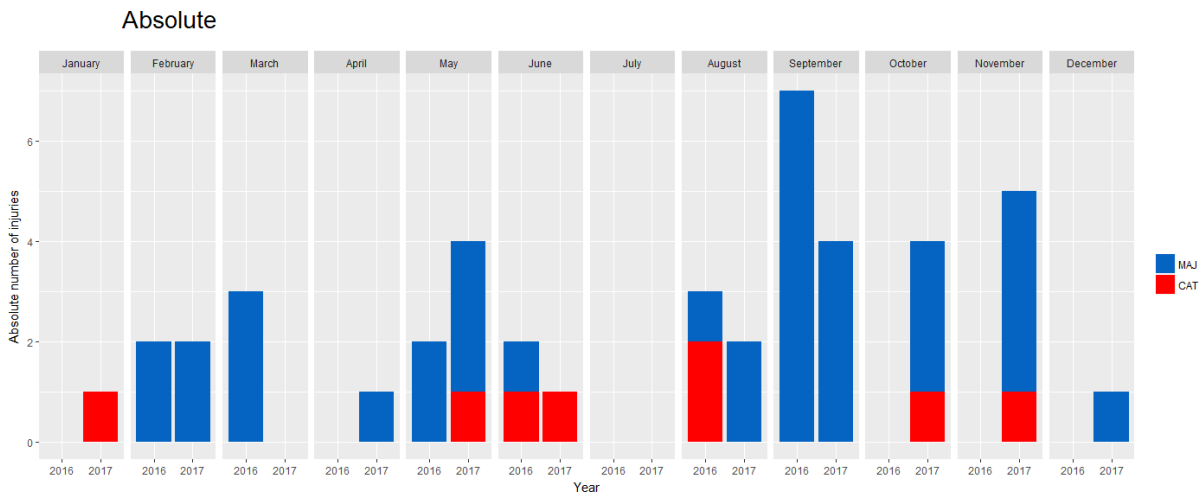

Figure 152: Goulburn track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

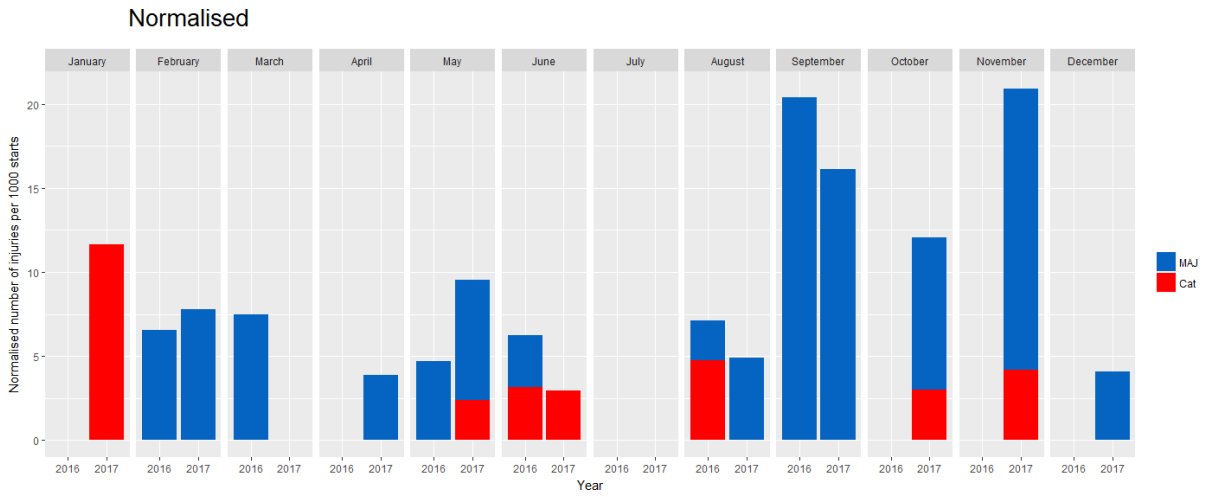

Figure 153: Goulburn track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

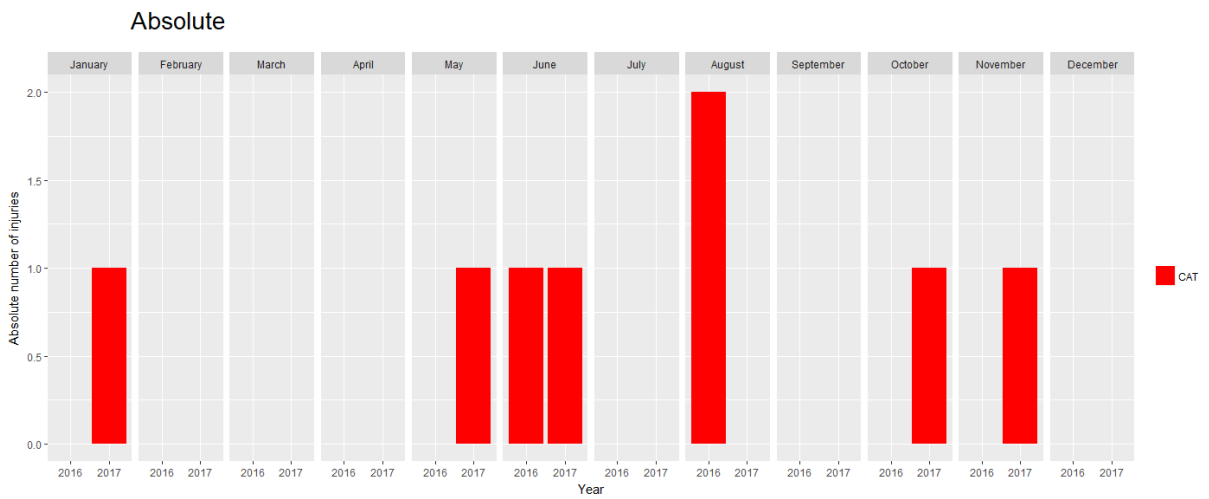

Figure 154: Goulburn track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

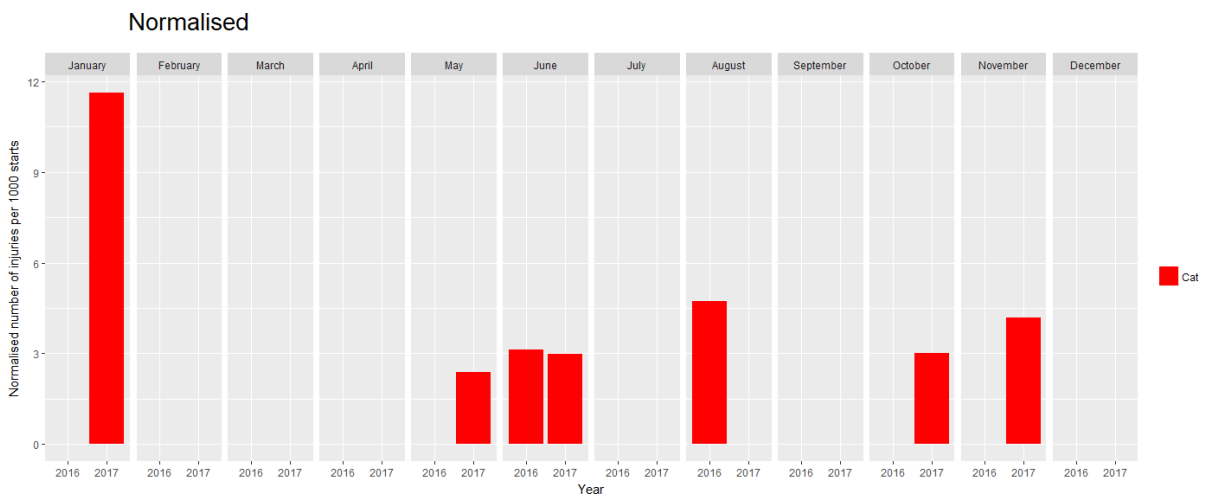

Figure 155: Goulburn track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

GOULBURN: LOCATION OF INJURIES FOR 350 M - 1 JAN TO 31 DEC 2017

3.85 In this section, the injury locations of Goulburn track for 350 m race distances are presented.

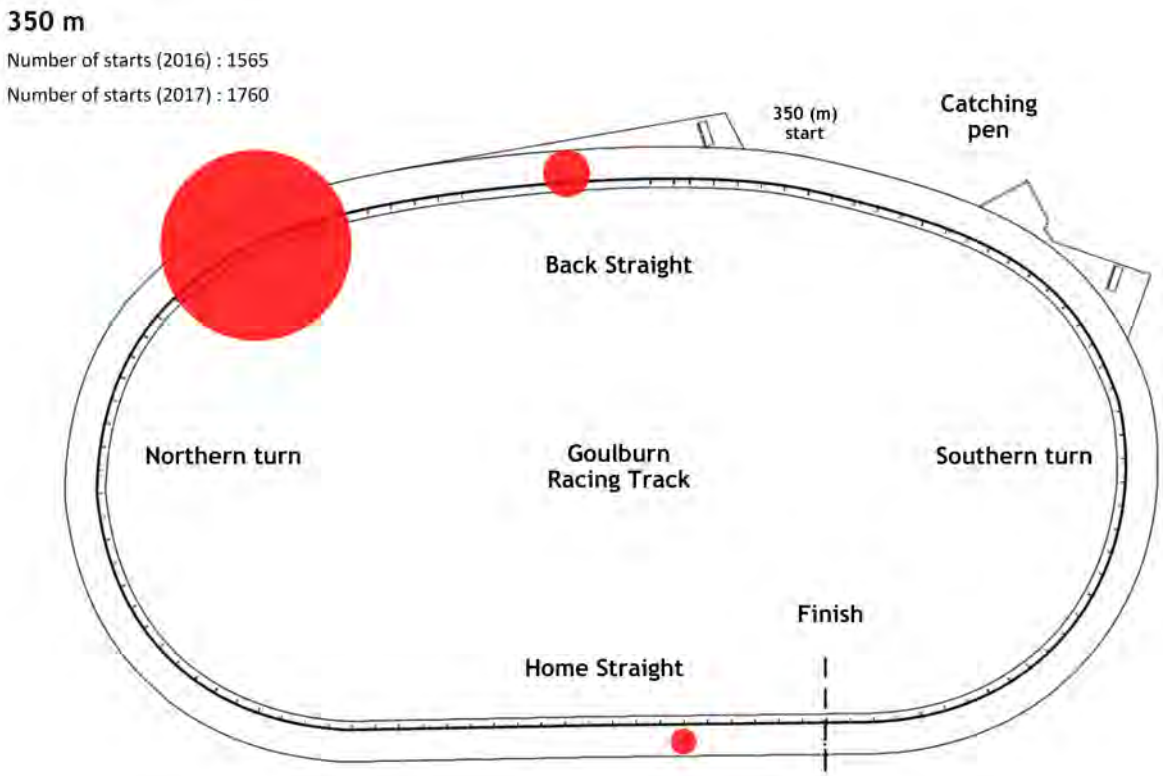

Figure 156: Goulburn track location of injuries for the 350 m distance

3.86 The location of injuries is similar to that of last year.

GOULBURN: LOCATION OF INJURIES FOR 440 M - 1 JAN TO 31 DEC 2017

3.87 In this section, the injury locations of Goulburn track for 440 m race distances are presented.

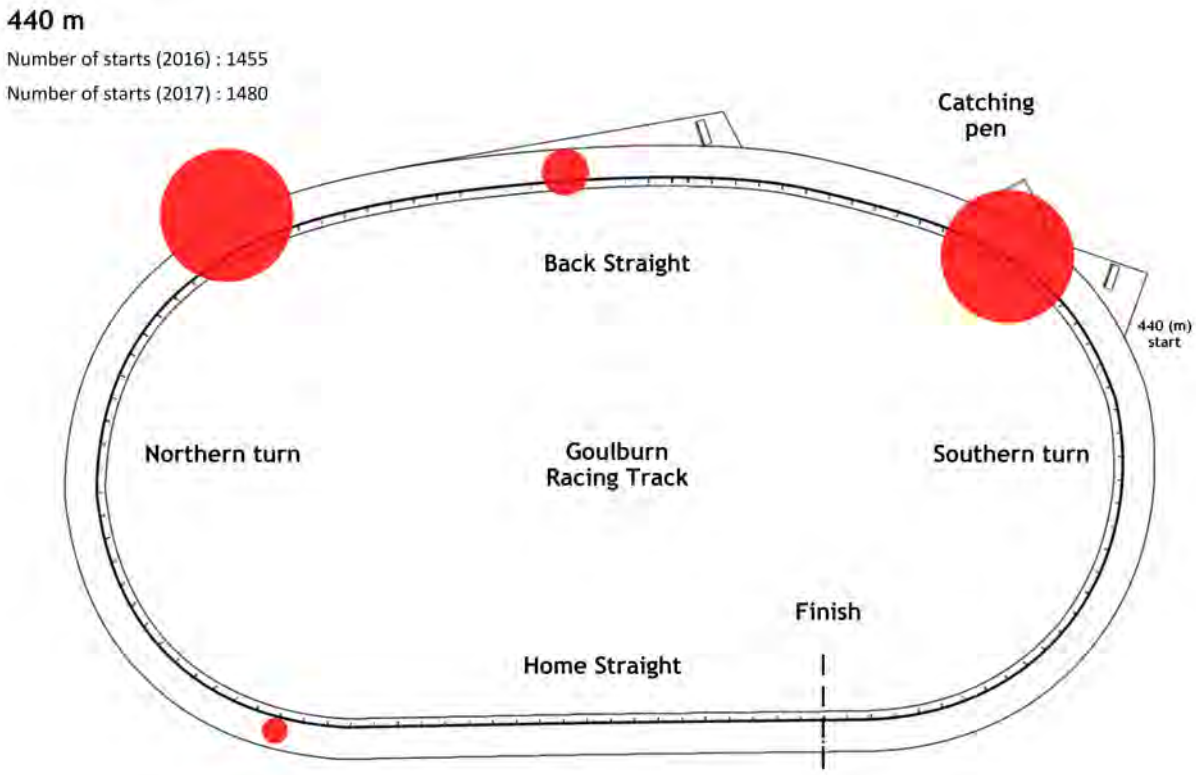

Figure 157: Goulburn track location of injuries for the 440 m distance

3.88 The location of injuries is similar to 2016.

LISMORE

LISMORE: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.89 Figures 158 to 165 contain Lismore Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

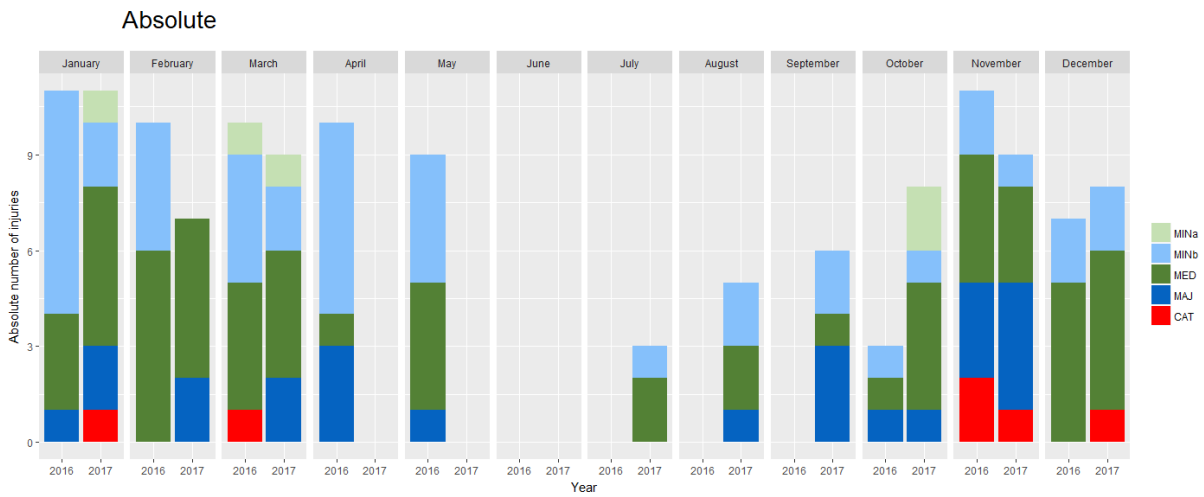

Figure 158: Lismore track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

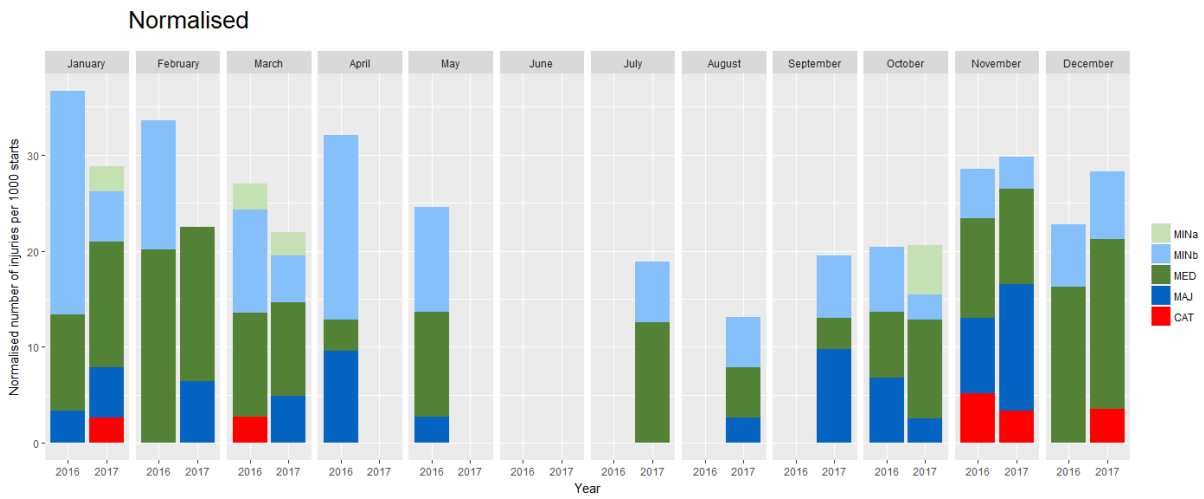

Figure 159: Lismore track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

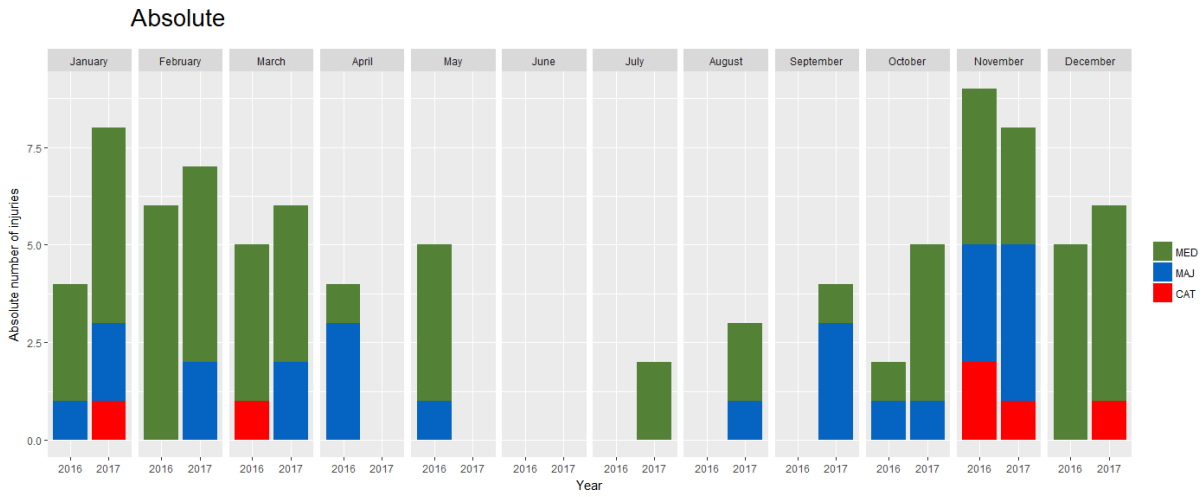

Figure 160: Lismore track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

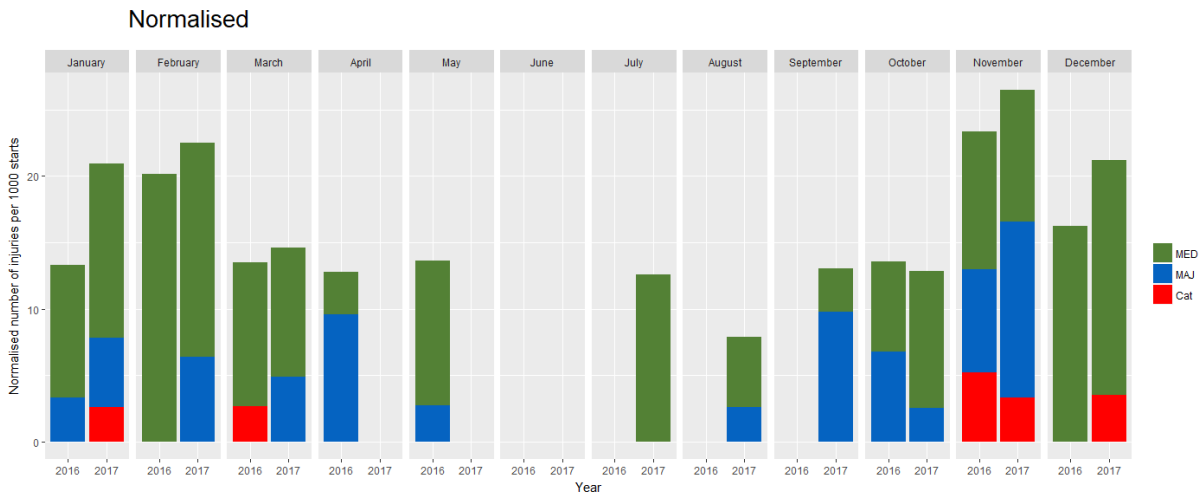

Figure 161: Lismore track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

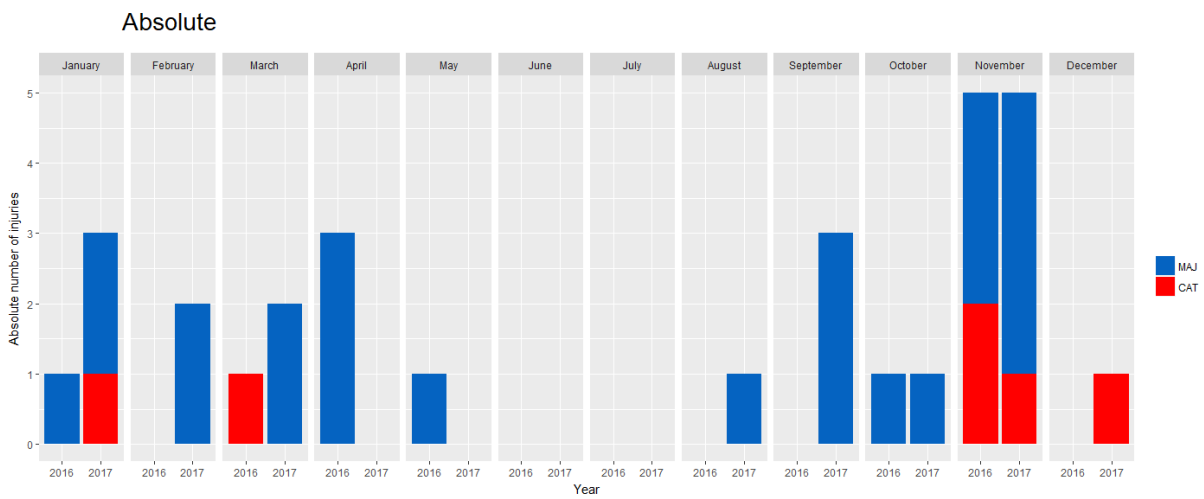

Figure 162: Lismore track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

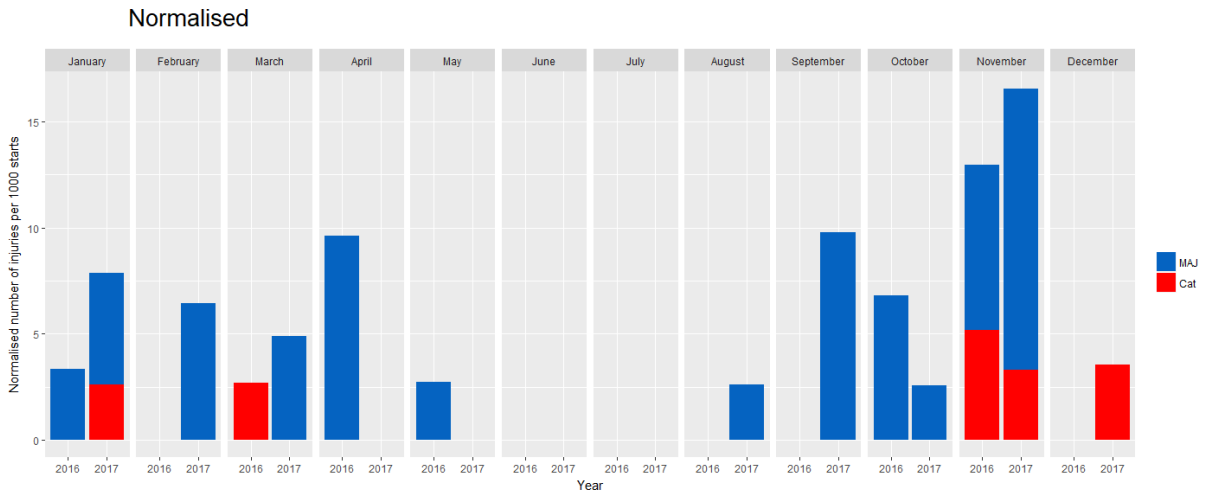

Figure 163: Lismore track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

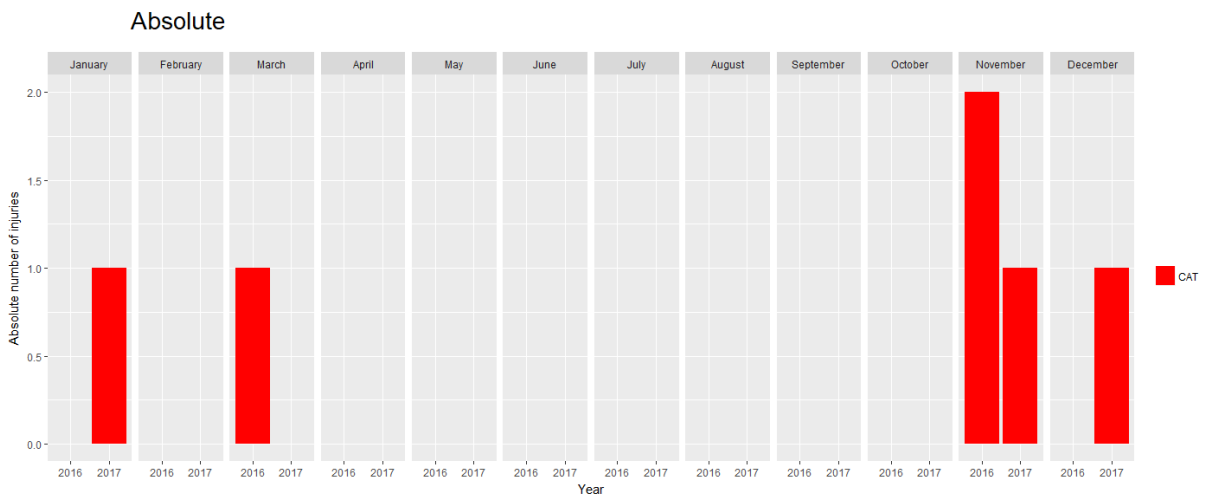

Figure 164: Lismore track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

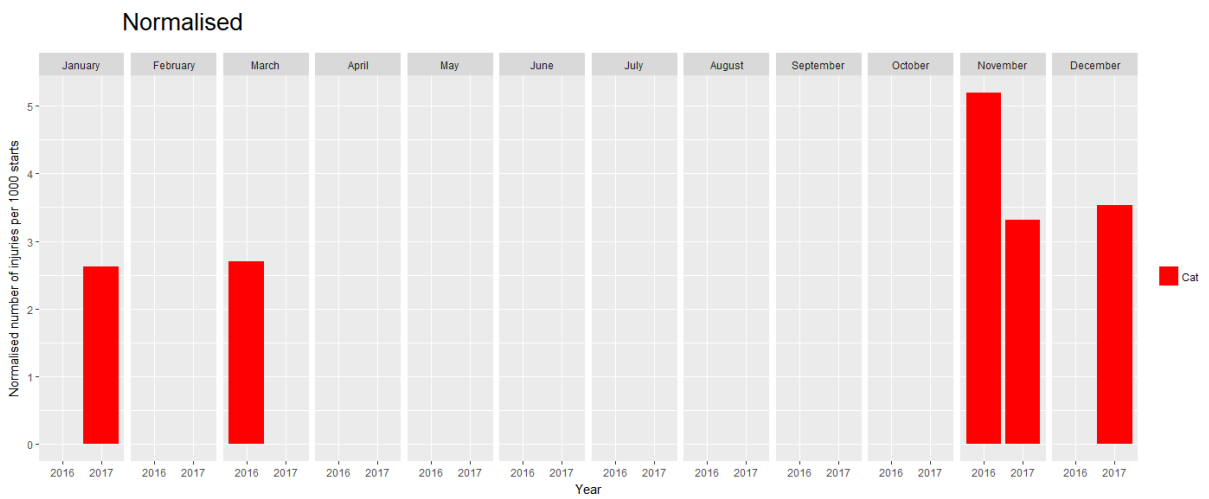

Figure 165: Lismore track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

LISMORE: LOCATION OF INJURIES FOR 420 M - 1 JAN TO 31 DEC 2017

3.90 In this section, the injury locations of Lismore track for 420 m race distances are presented.

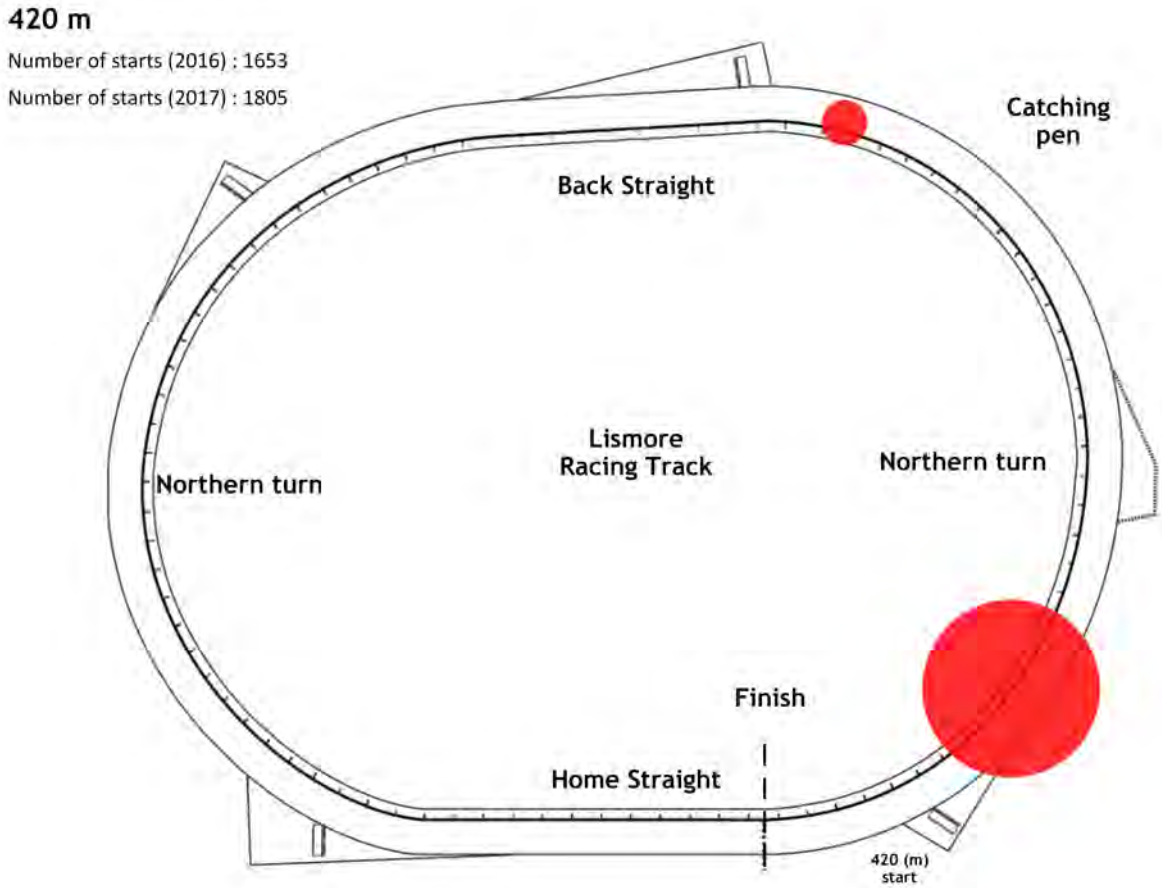

Figure 166: Lismore track location of injuries for the 420 m distance

3.91 The location of injuries is similar to 2016.

LISMORE: LOCATION OF INJURIES FOR 520 M - 1 JAN TO 31 DEC 2017

3.92 In this section, the injury locations of Lismore track for 520 m race distances are presented.

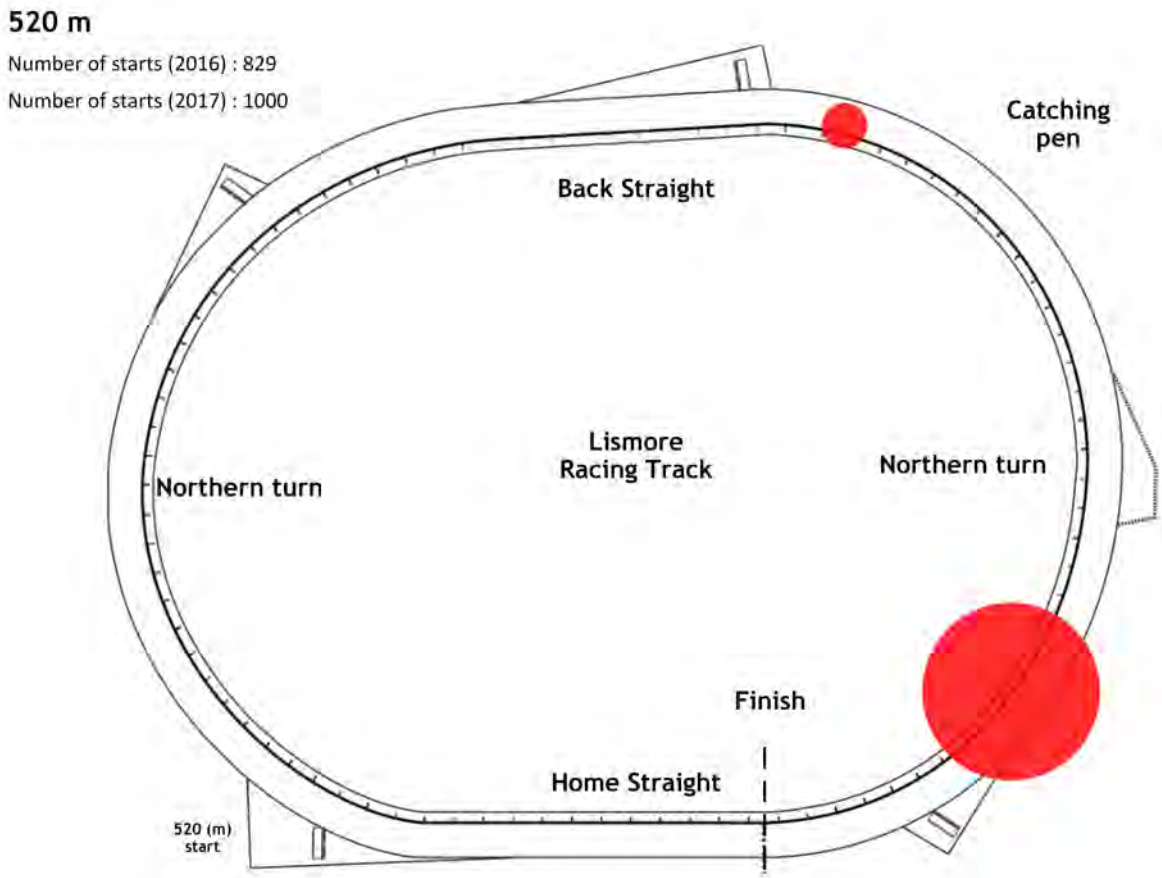

Figure 167: Lismore track location of injuries for the 520 m distance

3.93 The location of injuries is similar to 2016.

COONAMBLE

COONAMBLE: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.94 Figures 168 to 175 contain Coonamble Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

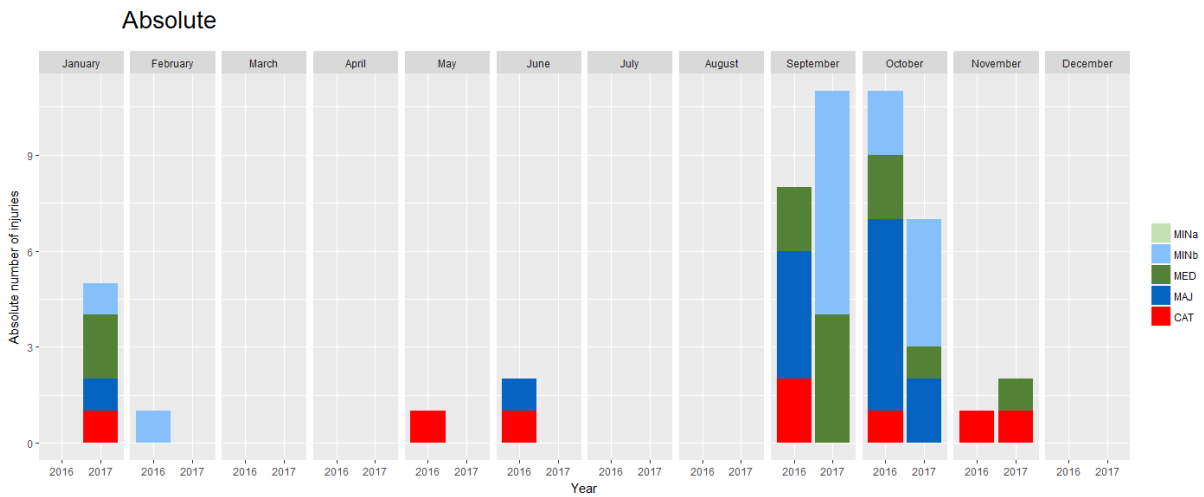

Figure 168: Coonamble track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

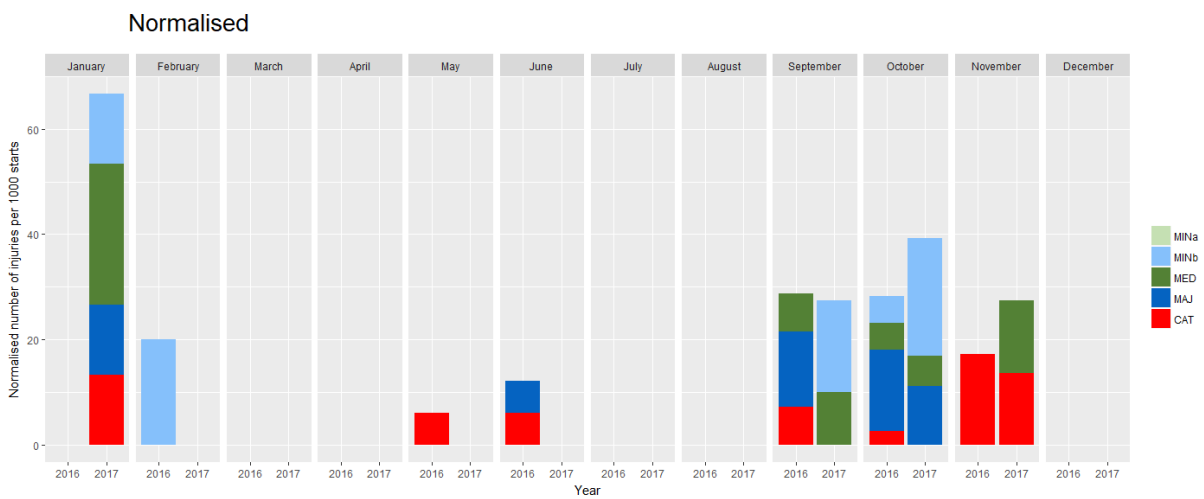

Figure 169: Coonamble track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

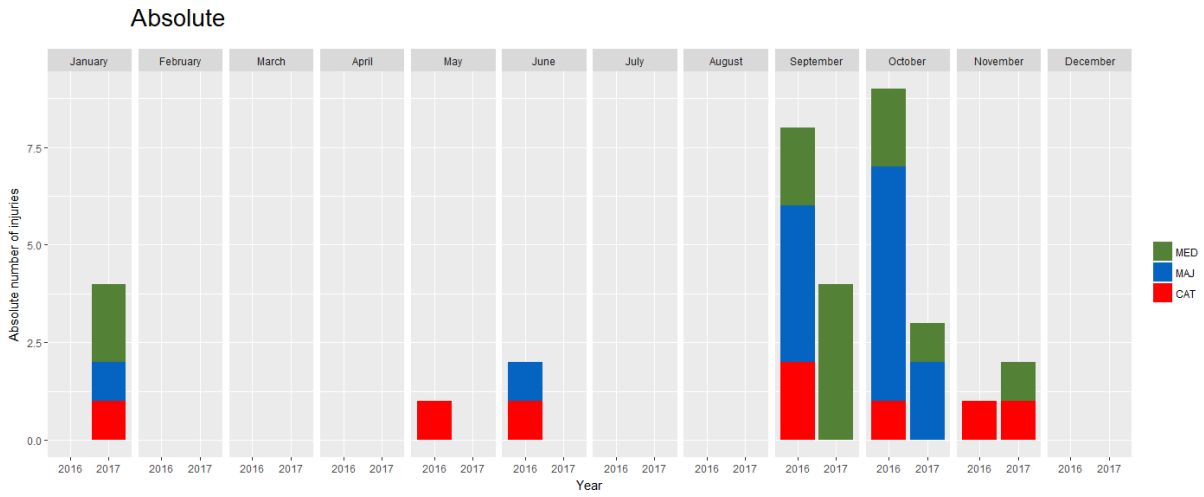

Figure 170: Coonamble track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

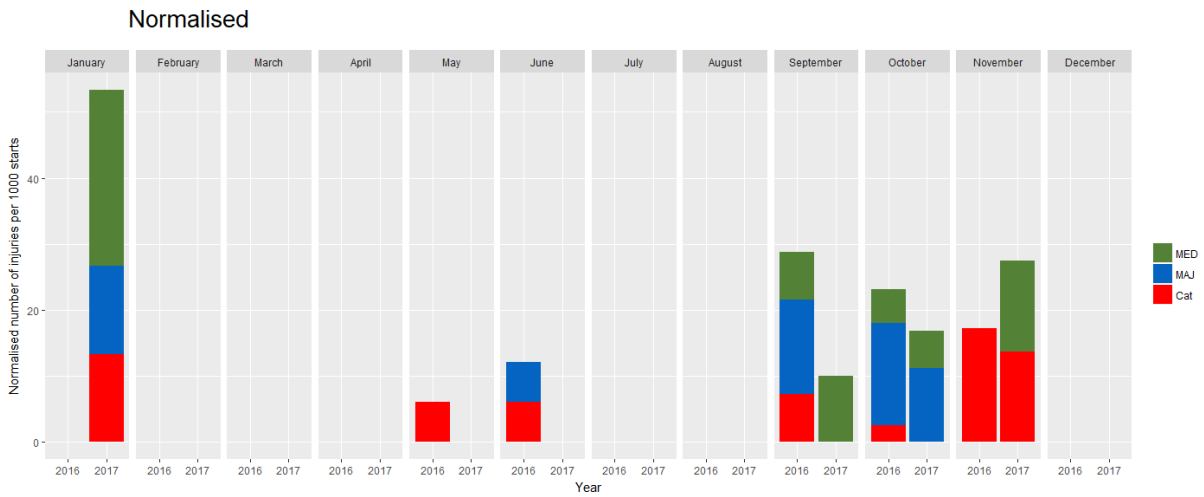

Figure 171: Coonamble track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

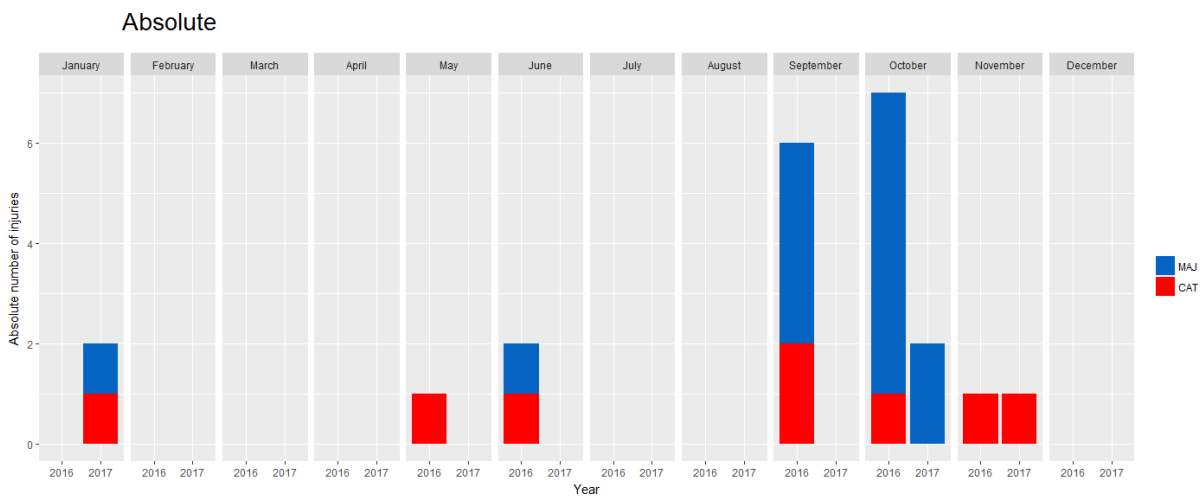

Figure 172: Coonamble track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

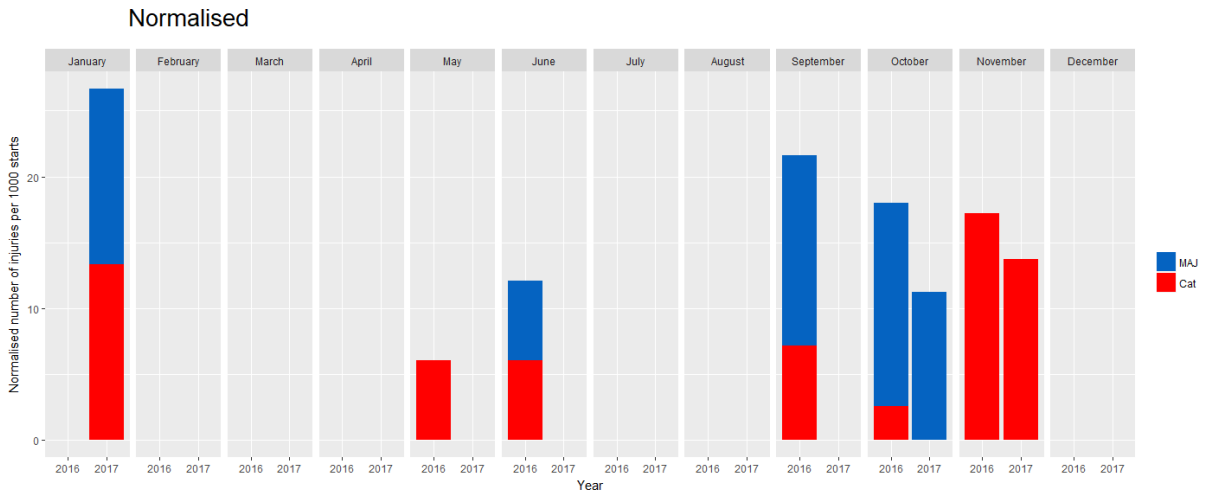

Figure 173: Coonamble track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

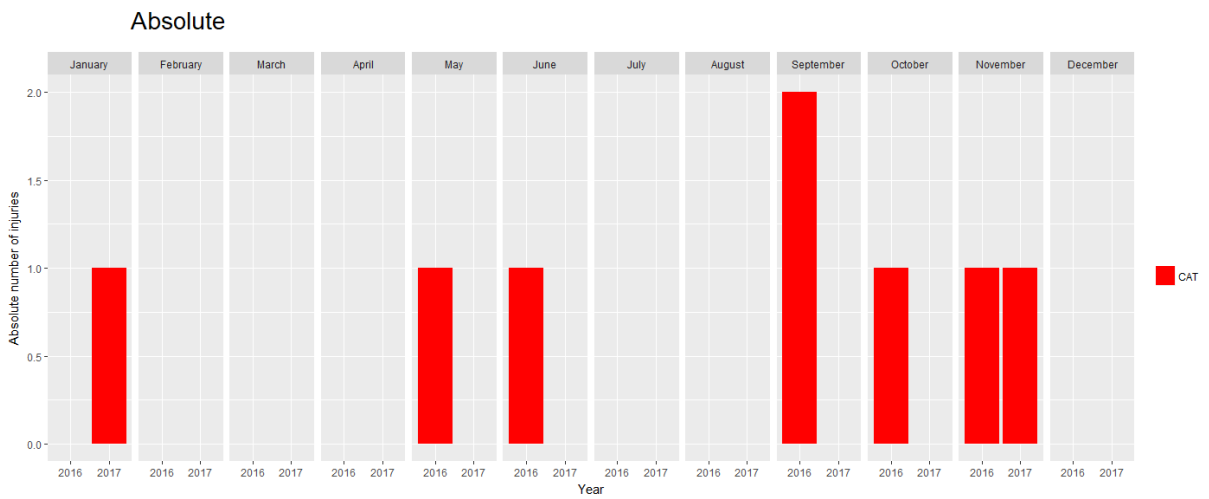

Figure 174: Coonamble track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

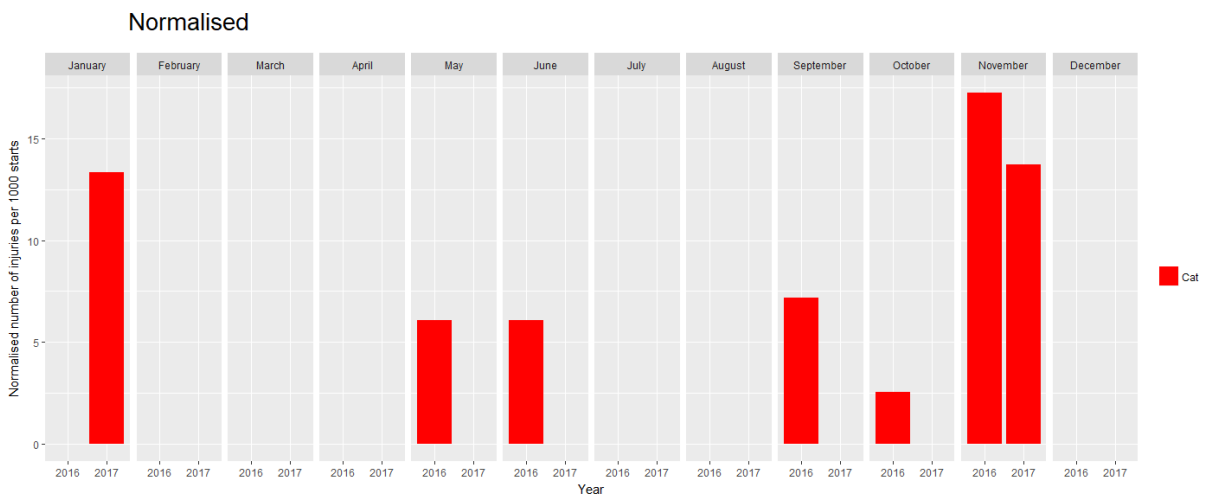

Figure 175: Coonamble track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

TWEED HEADS

TWEED HEADS: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.95 Figures 176 to 183 contain Tweed Heads Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

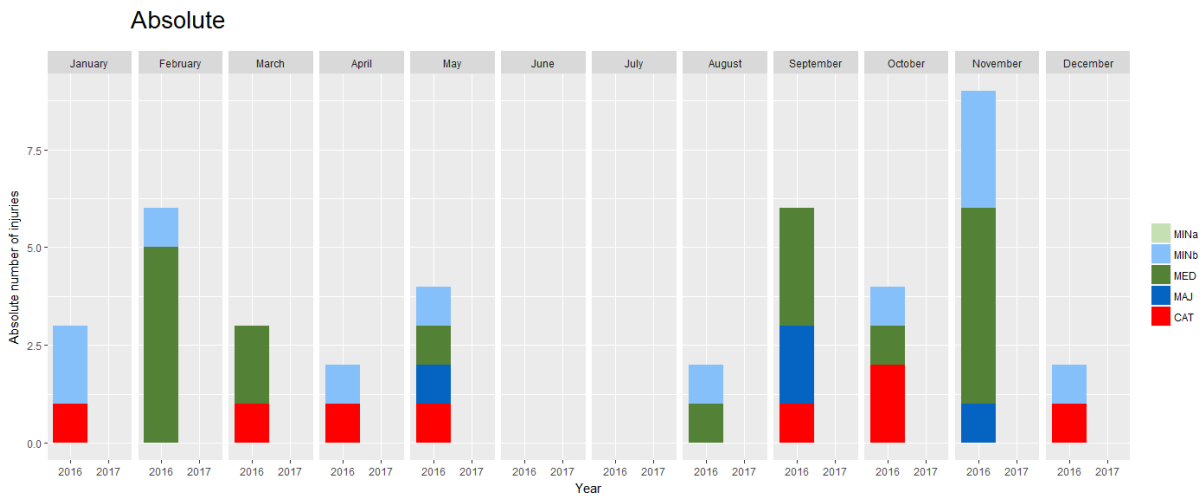

Figure 176: Tweed Heads track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

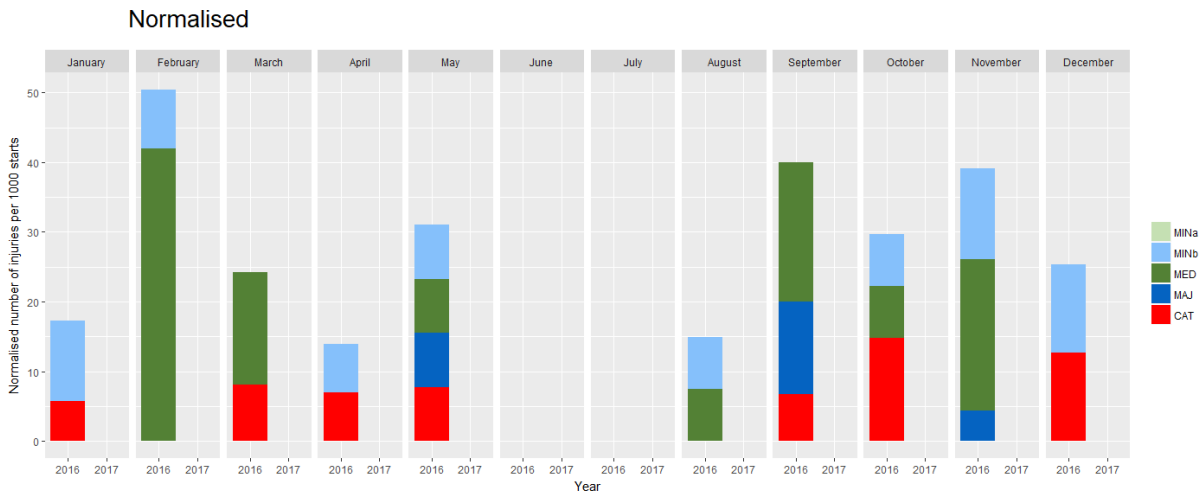

Figure 177: Tweed Heads track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

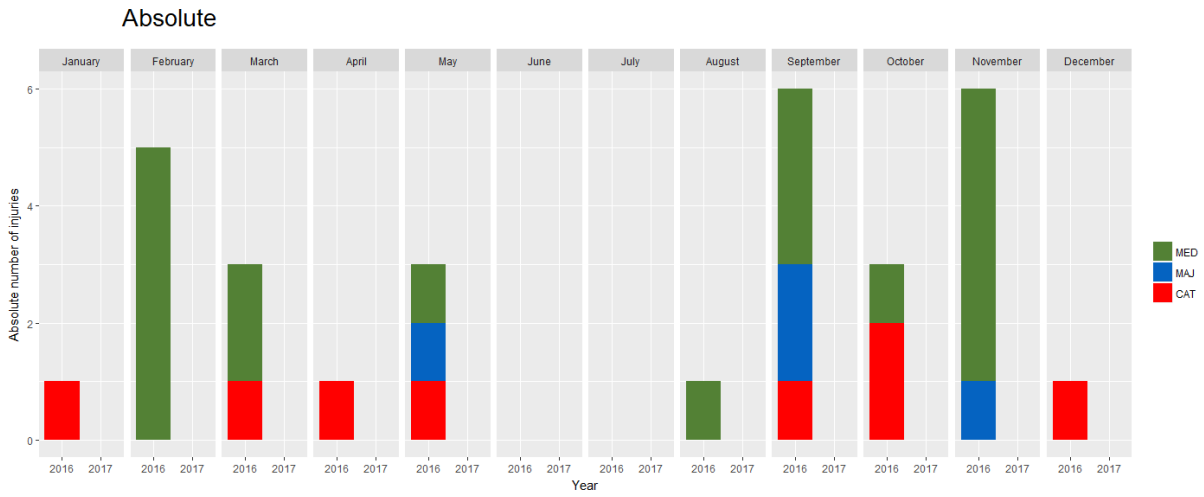

Figure 178: Tweed Heads track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

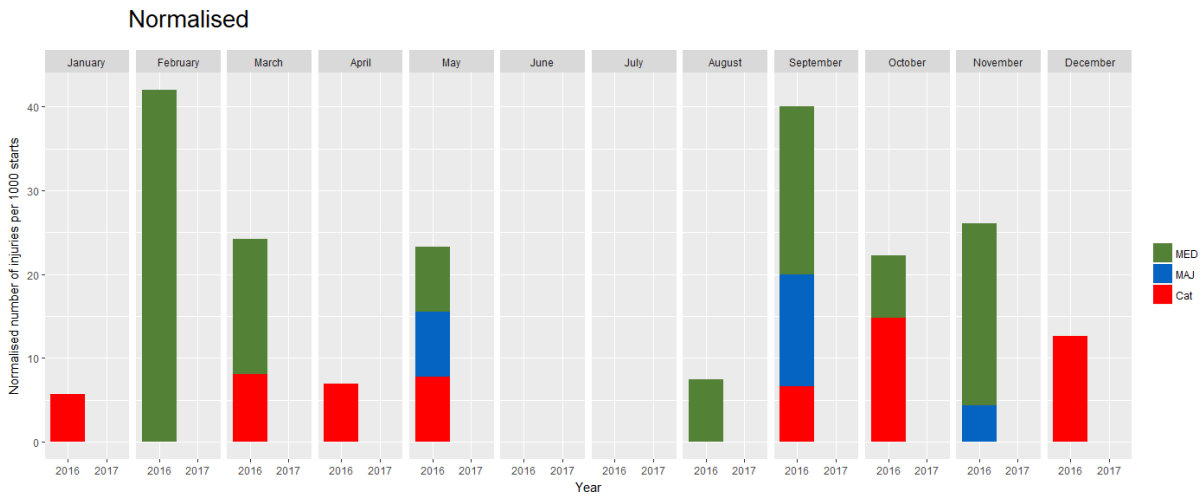

Figure 179: Tweed Heads track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

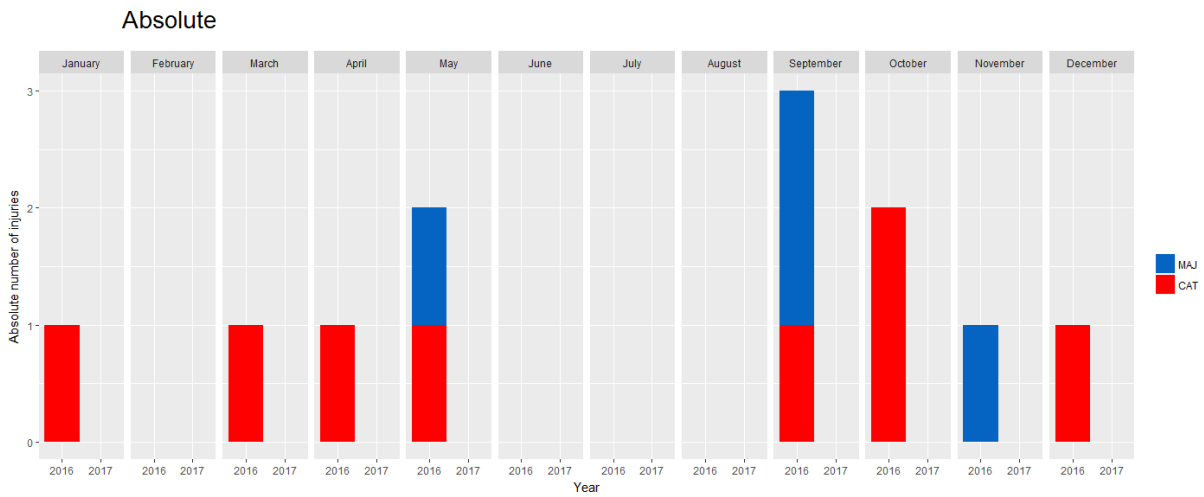

Figure 180: Tweed Heads track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

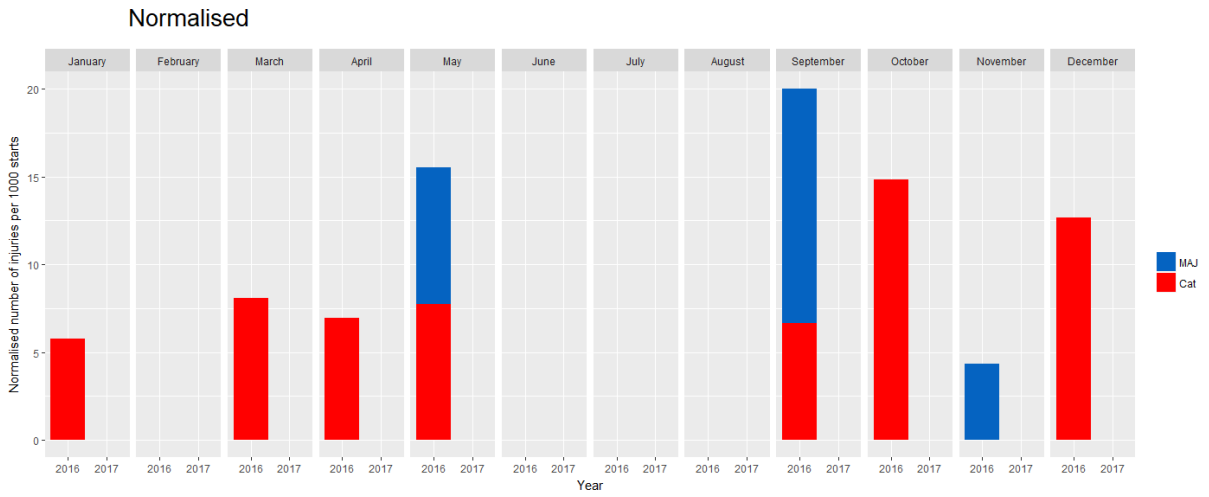

Figure 181: Tweed Heads track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

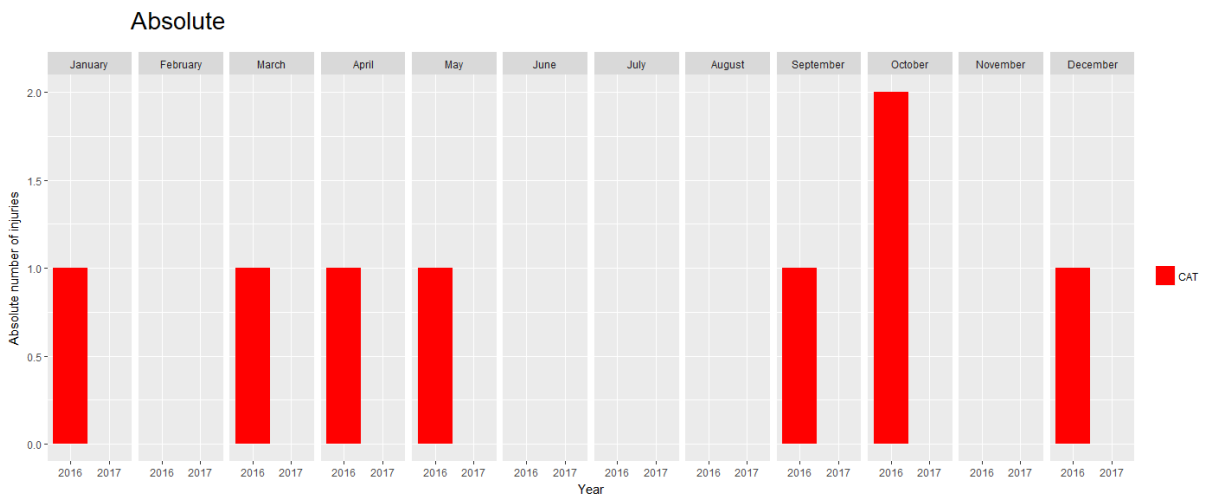

Figure 182: Tweed Heads track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

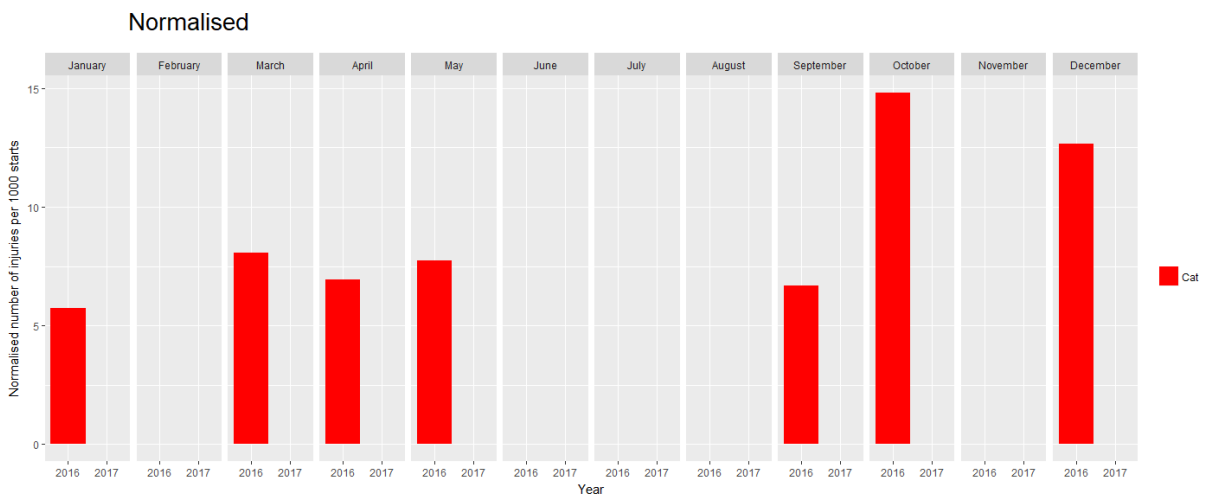

Figure 183: Tweed Heads track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

POTTS PARK

POTTS PARK: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.96 Figures 184 to 191 contain Potts Park Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

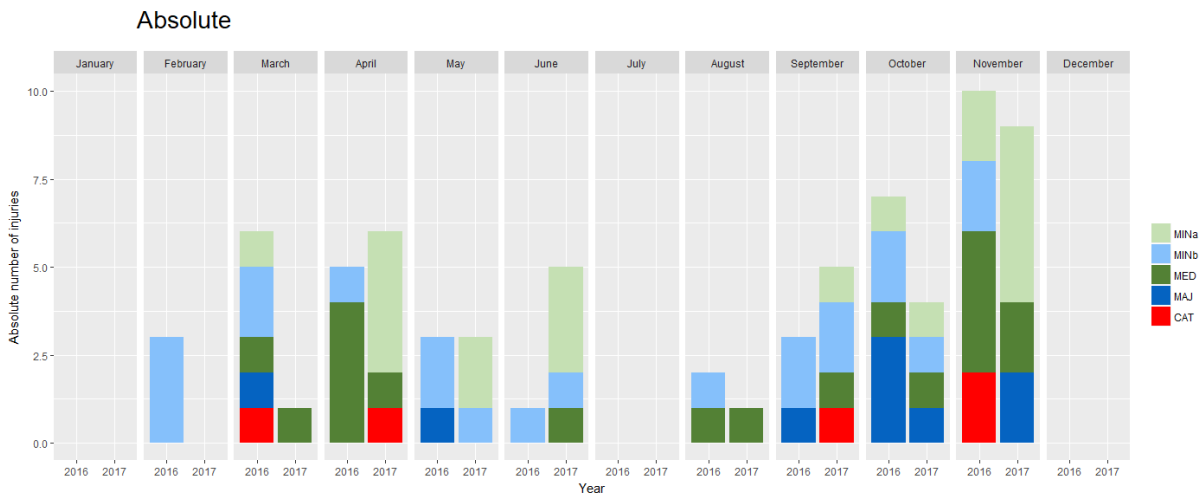

Figure 184: Potts Park track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

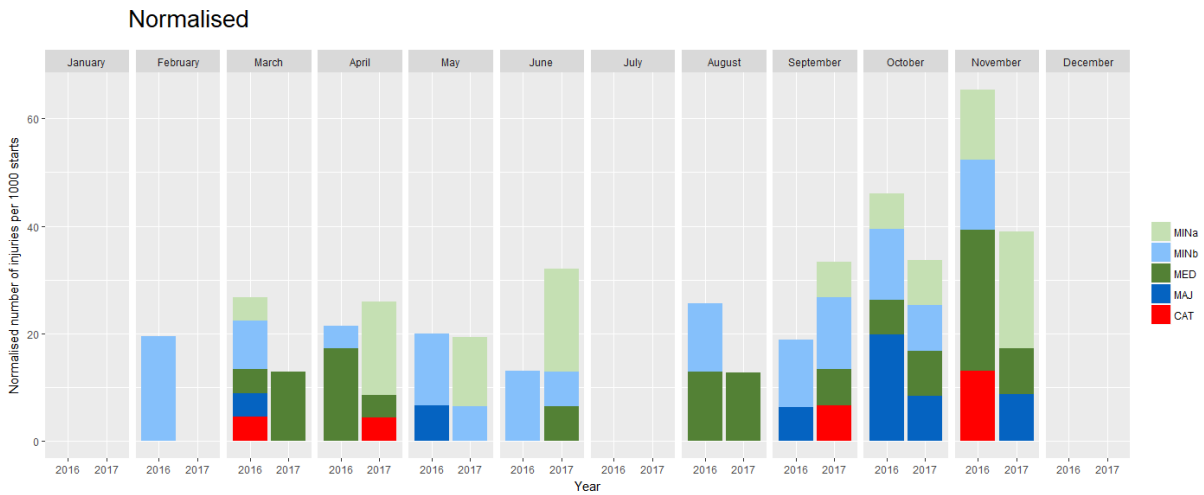

Figure 185: Potts park track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

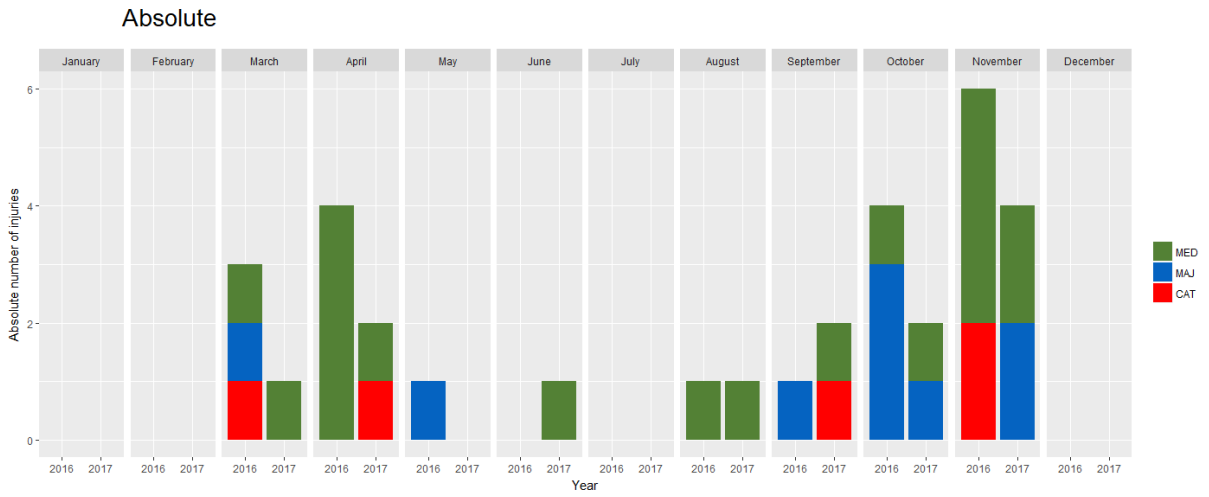

Figure 186: Potts Park track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

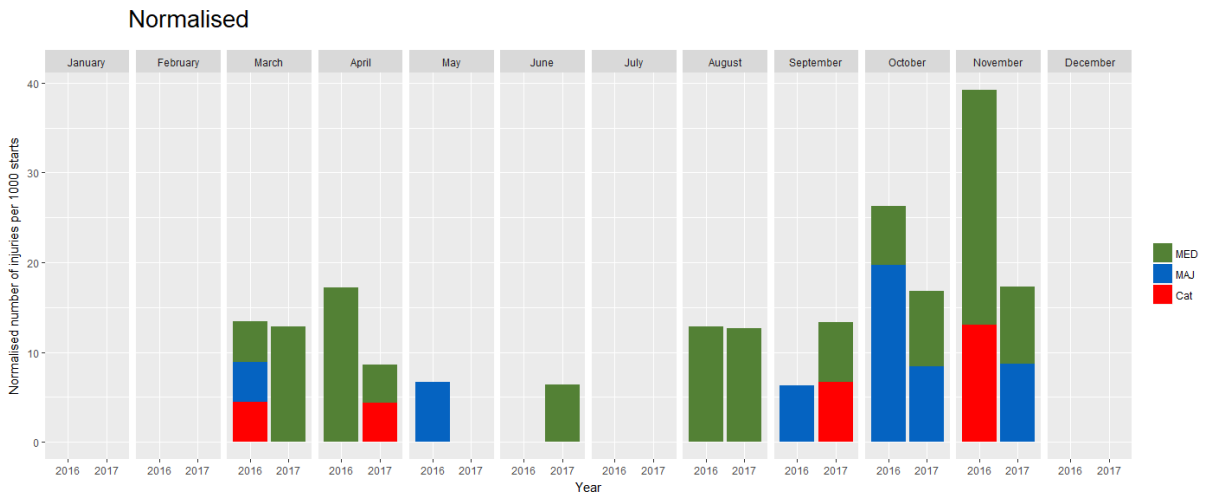

Figure 187: Potts Park track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

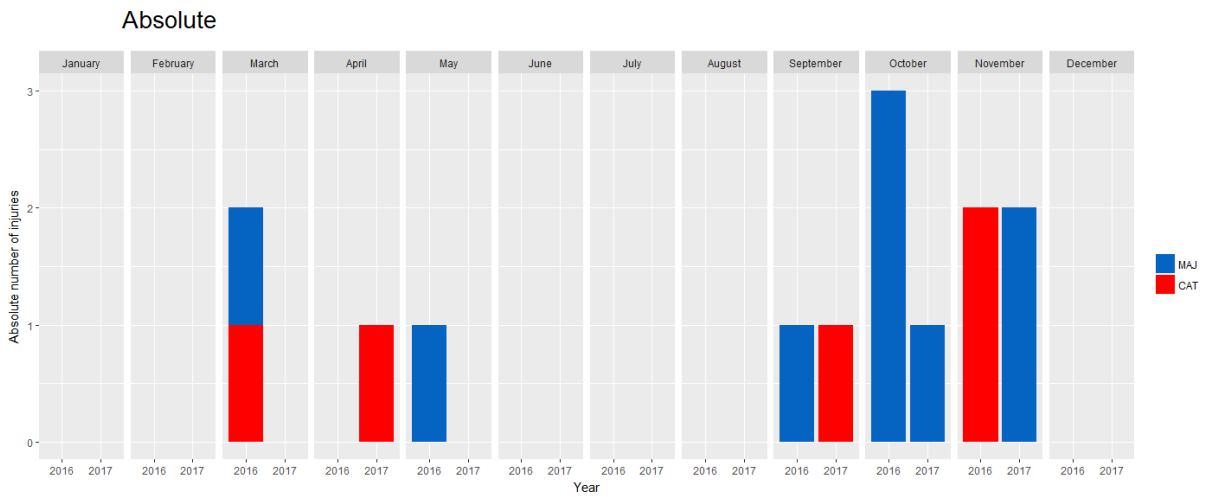

Figure 188: Potts Park track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

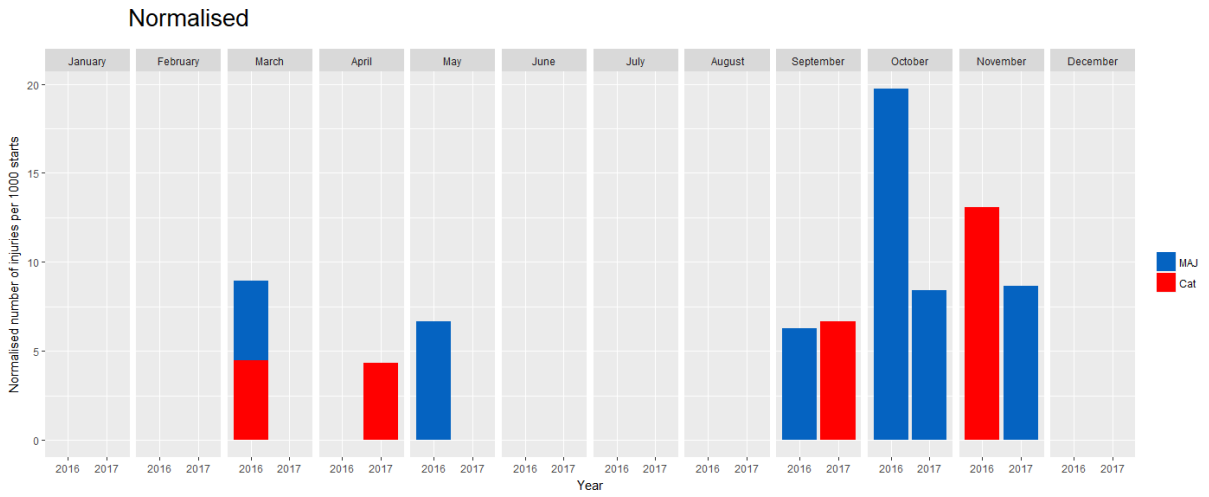

Figure 189: Potts Park track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

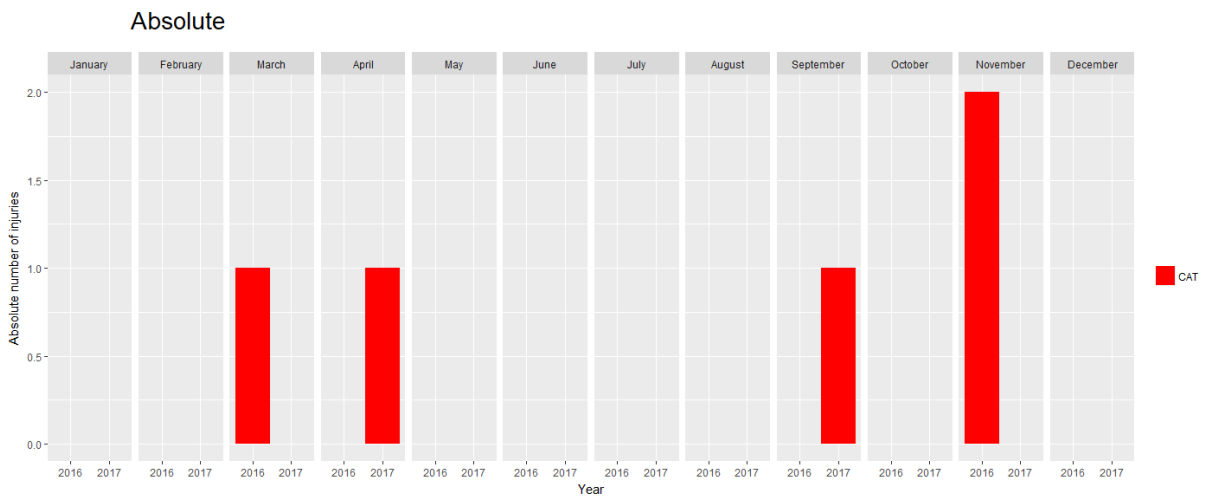

Figure 190: Potts Park track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

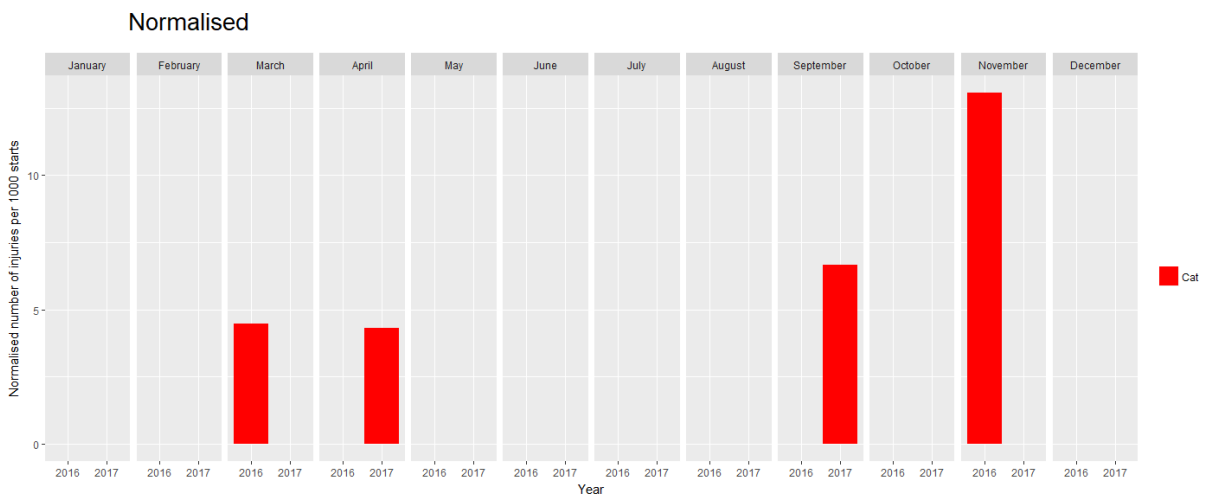

Figure 191: Potts Park track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

TAMWORTH

TAMWORTH: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.97 Figures 192 to 199 contain Tamworth Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

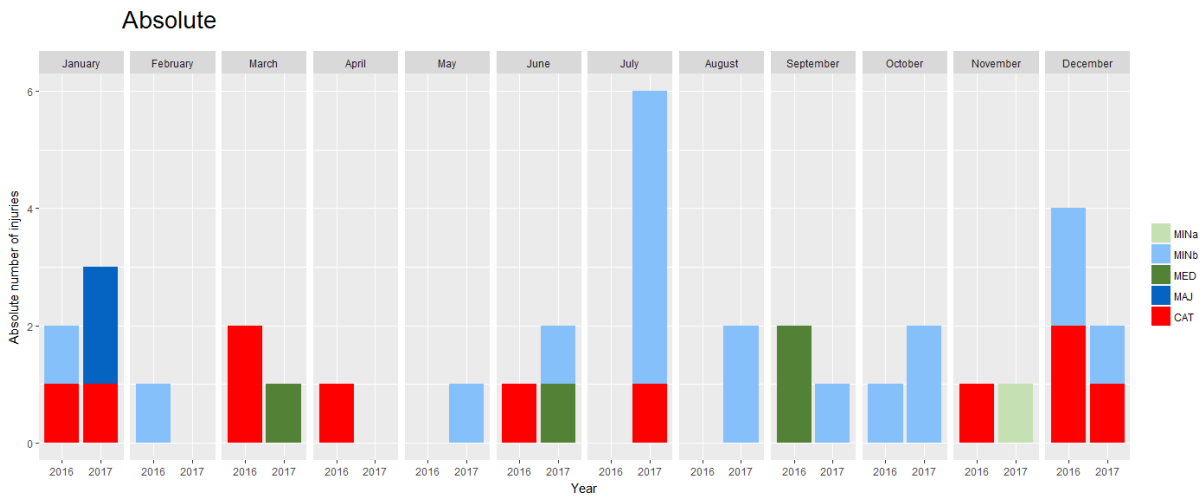

Figure 192: Tamworth track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

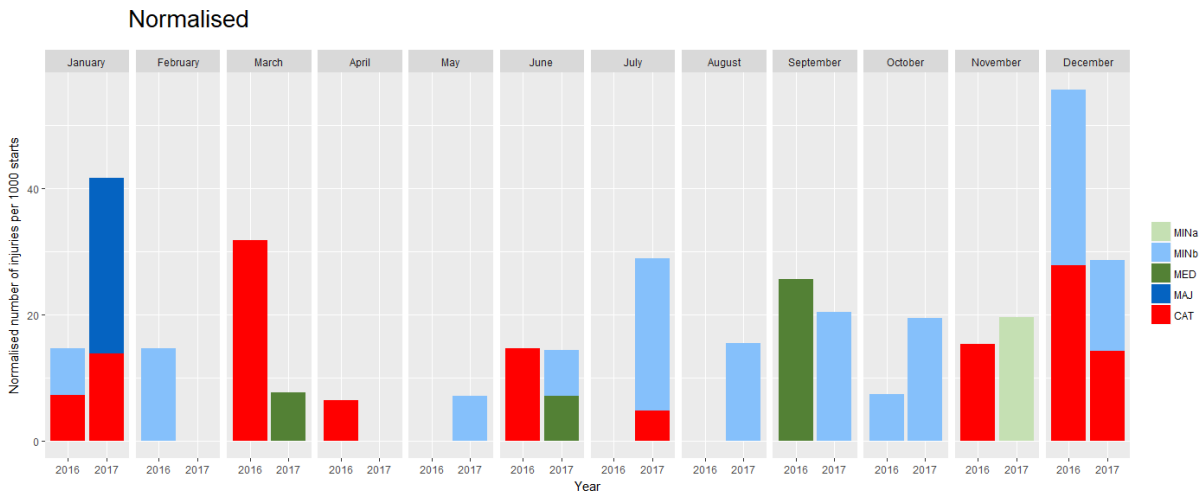

Figure 193: Tamworth track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

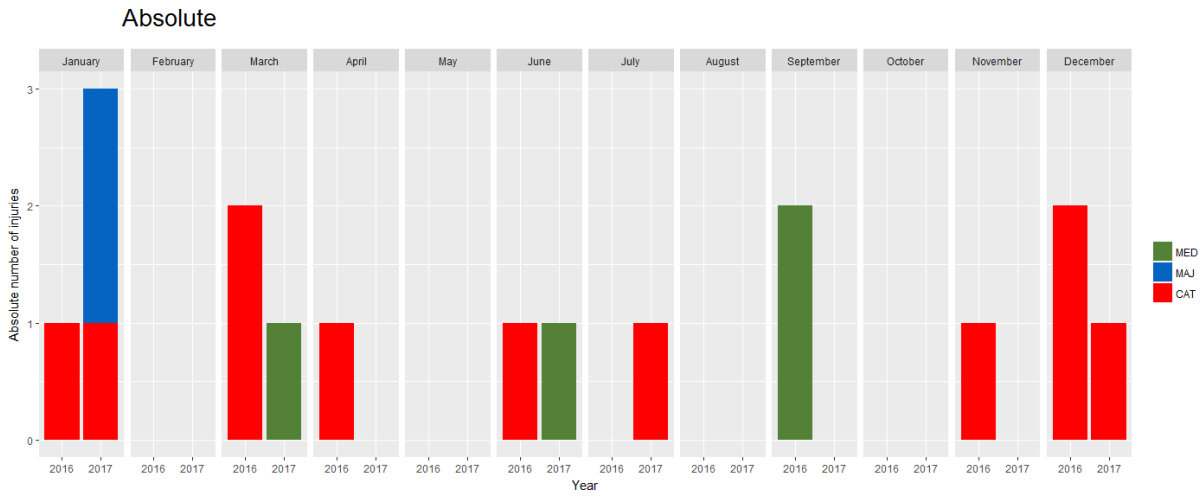

Figure 194: Tamworth track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

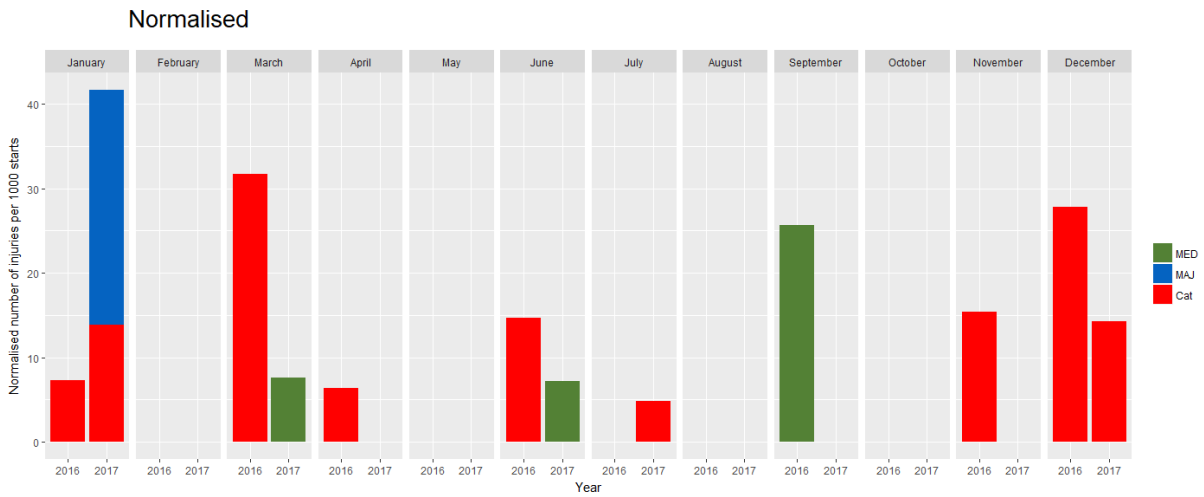

Figure 195: Tamworth track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

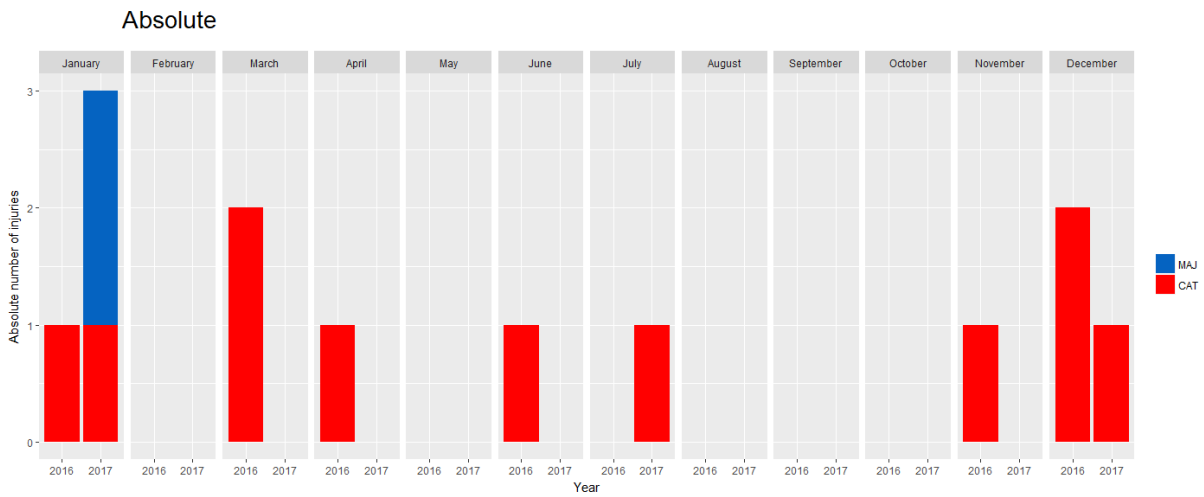

Figure 196: Tamworth track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

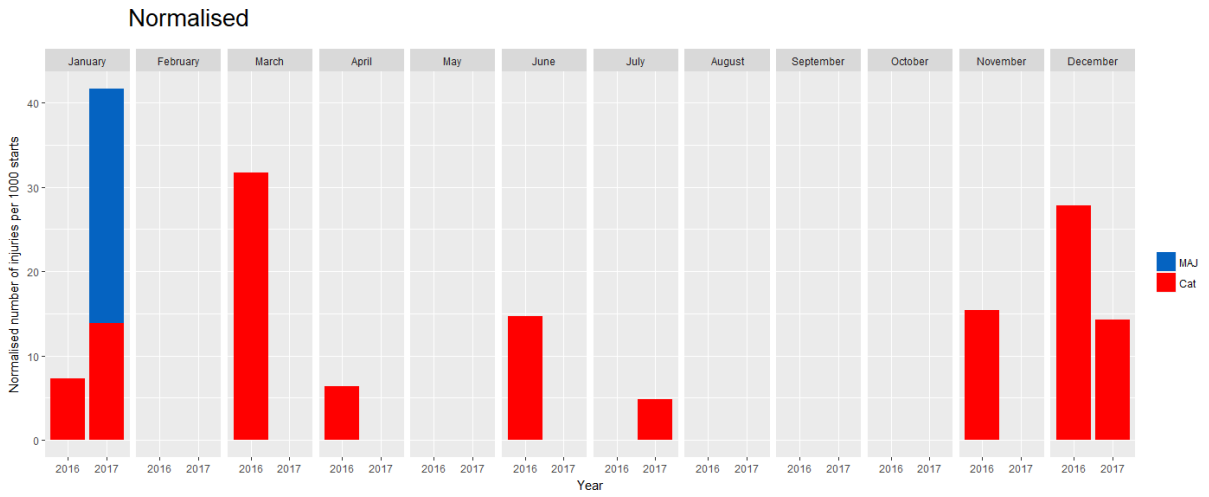

Figure 197: Tamworth track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

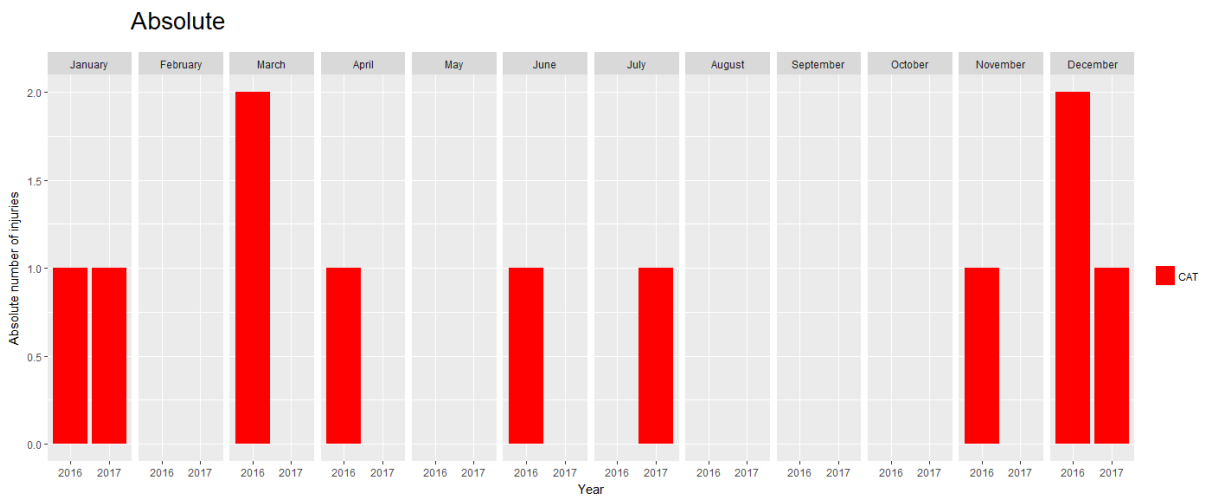

Figure 198: Tamworth track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

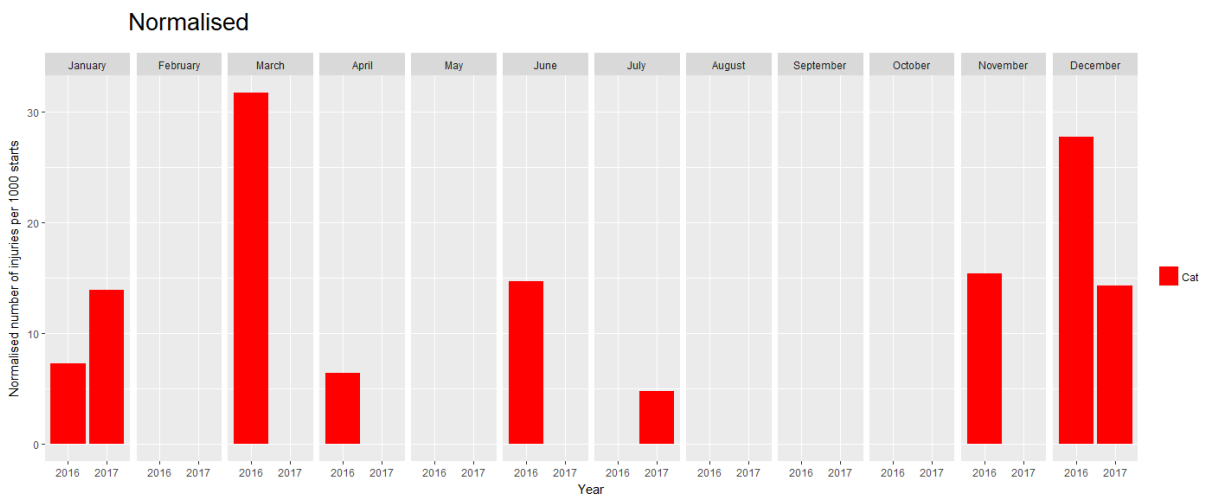

Figure 199: Tamworth track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

TAREE

TAREE: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.98 Figures 200 to 207 contain Taree Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

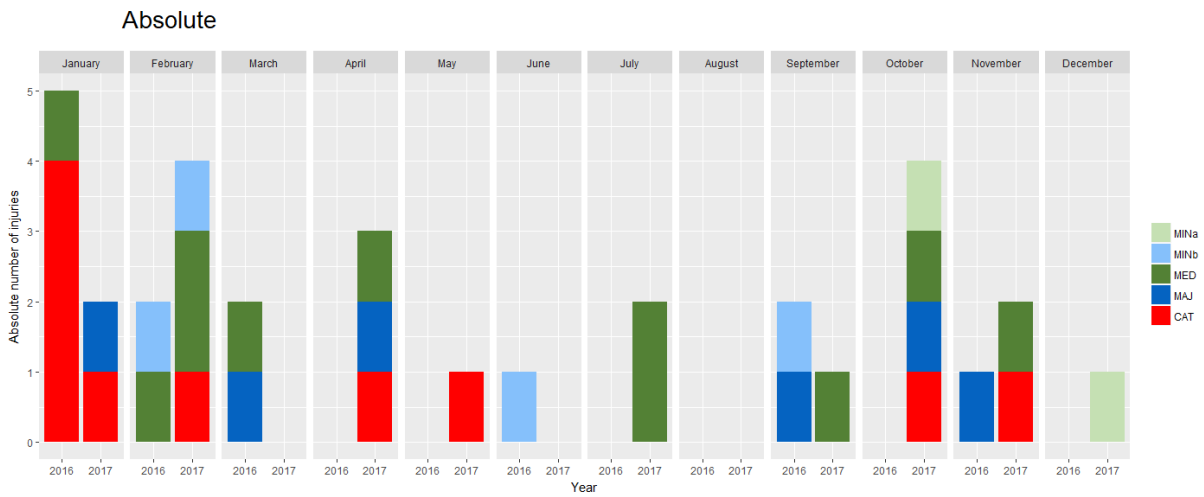

Figure 200: Taree track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

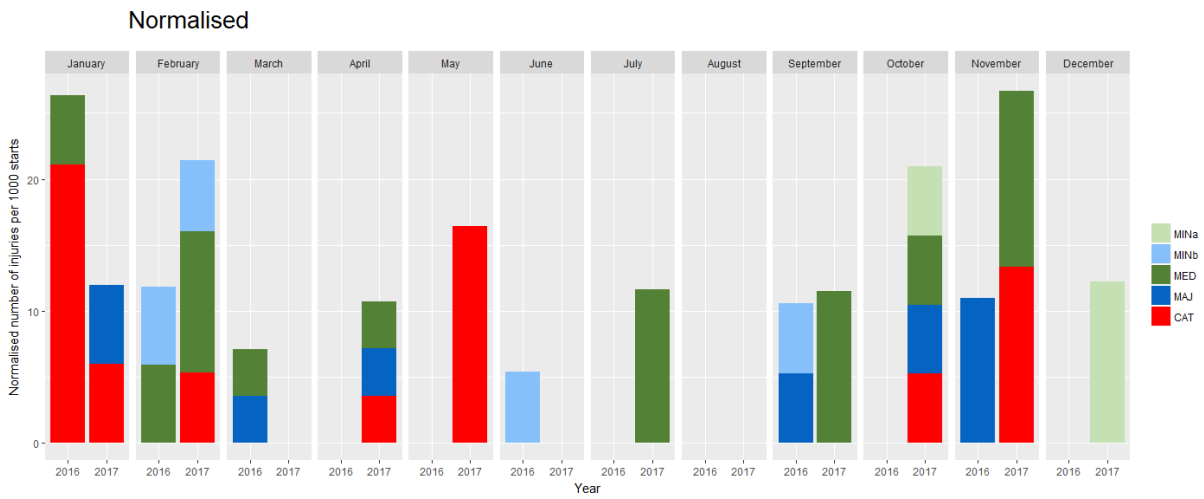

Figure 201: Taree track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

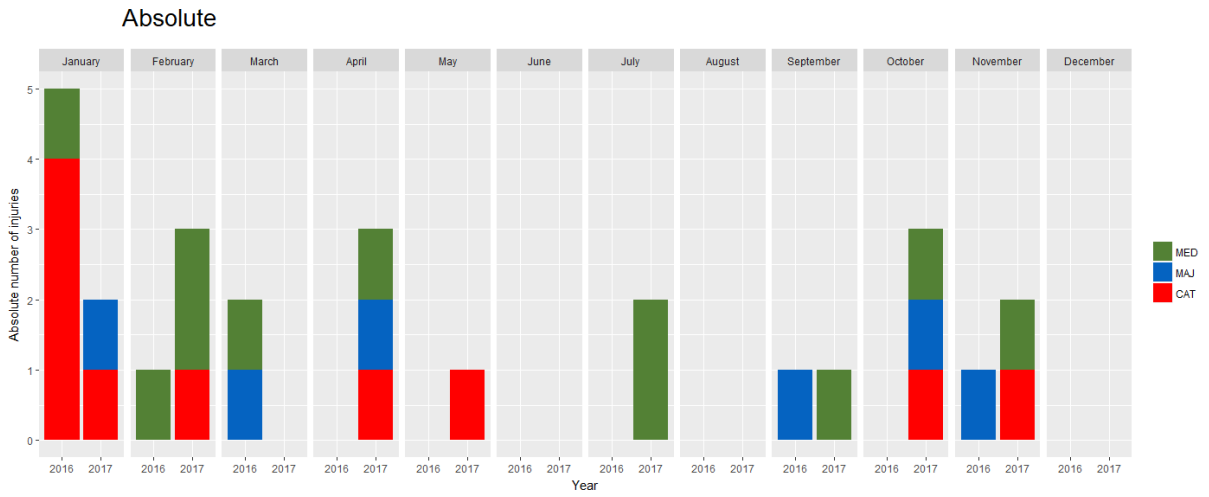

Figure 202: Taree track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

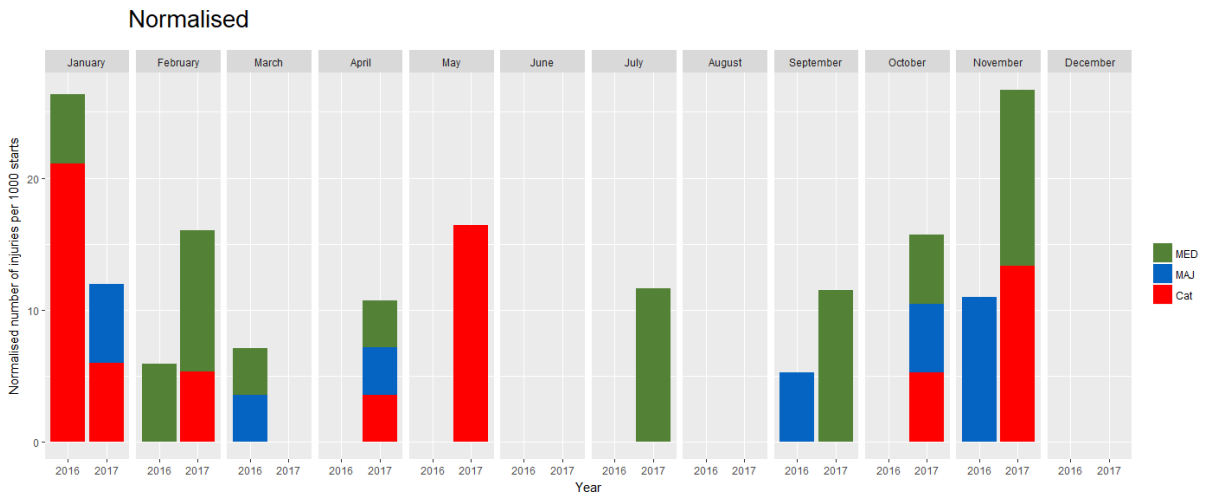

Figure 203: Taree track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

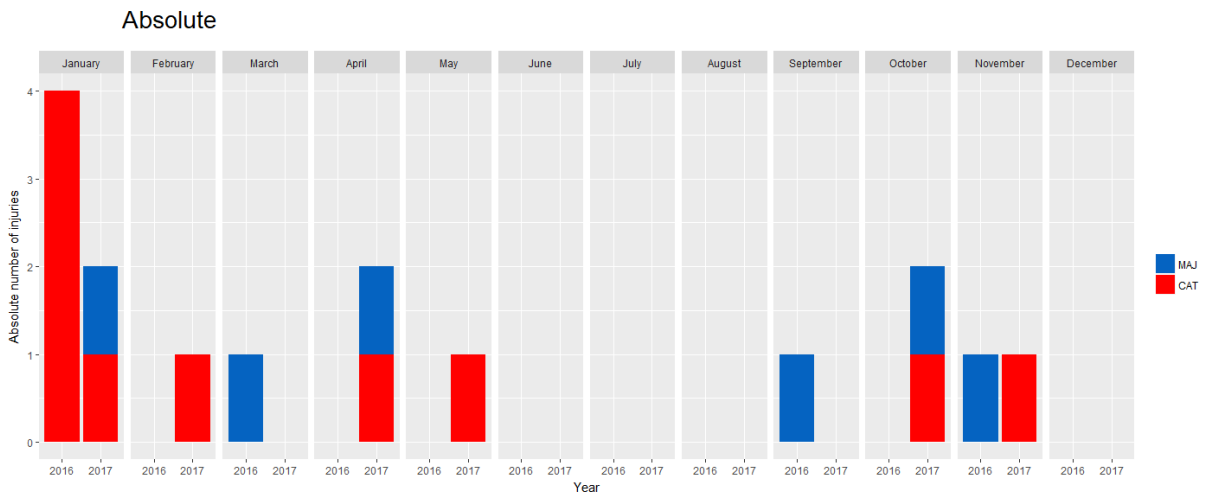

Figure 204: Taree track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

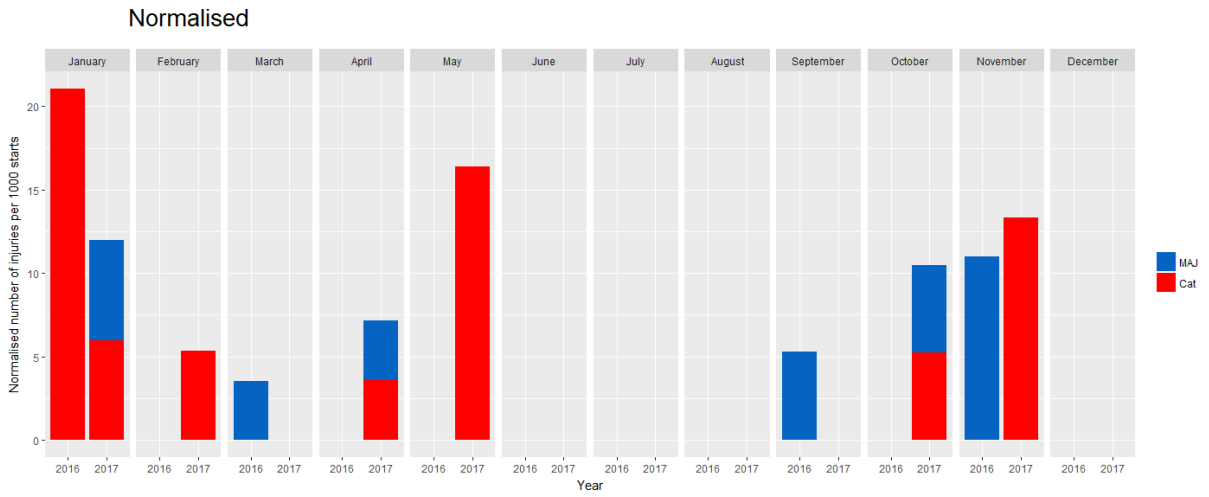

Figure 205: Taree track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

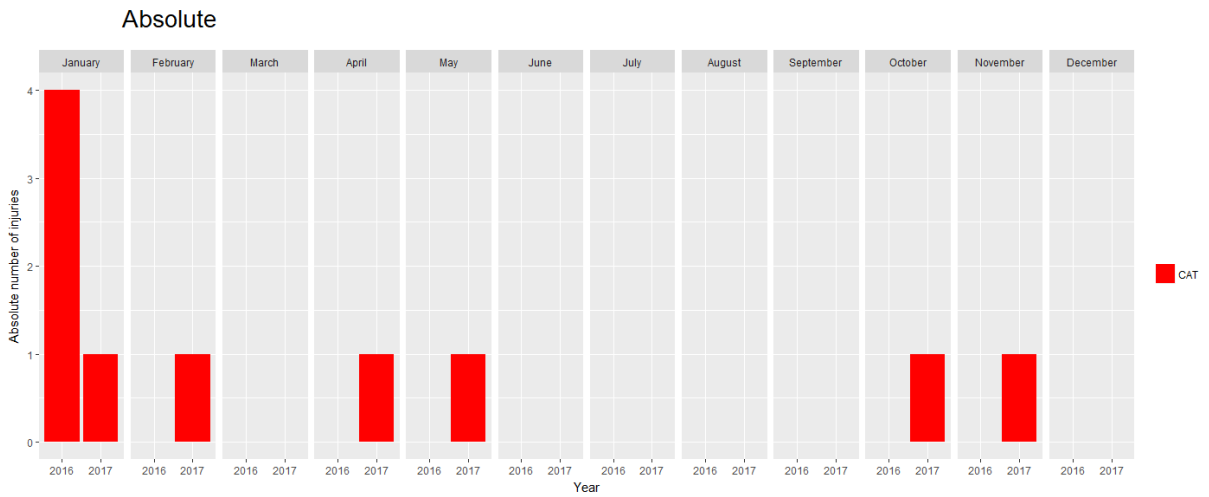

Figure 206: Taree track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

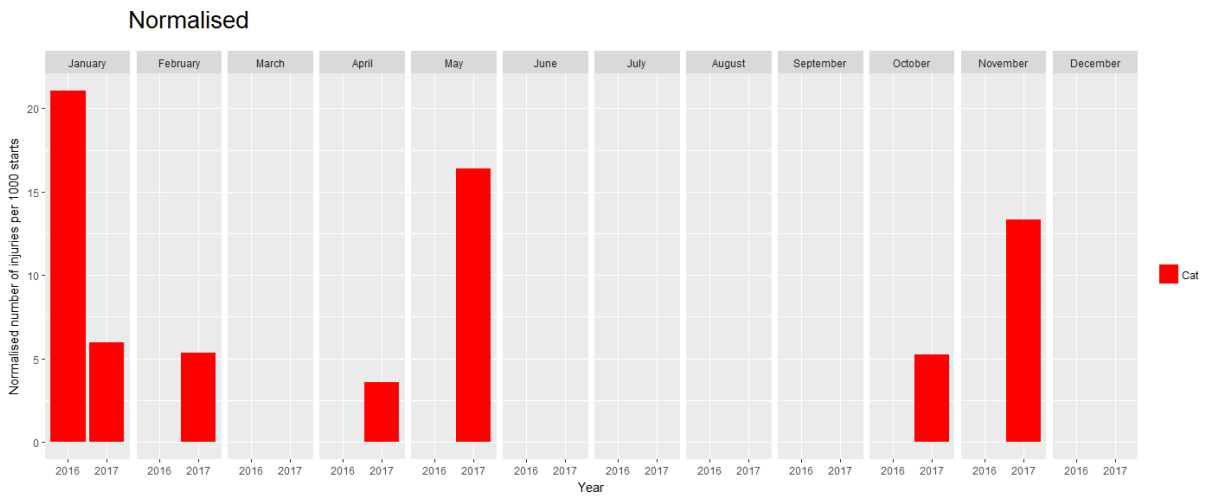

Figure 207: Taree track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

WAGGA WAGGA

WAGGA WAGGA: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.99 Figures 208 to 215 contain Wagga Wagga Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

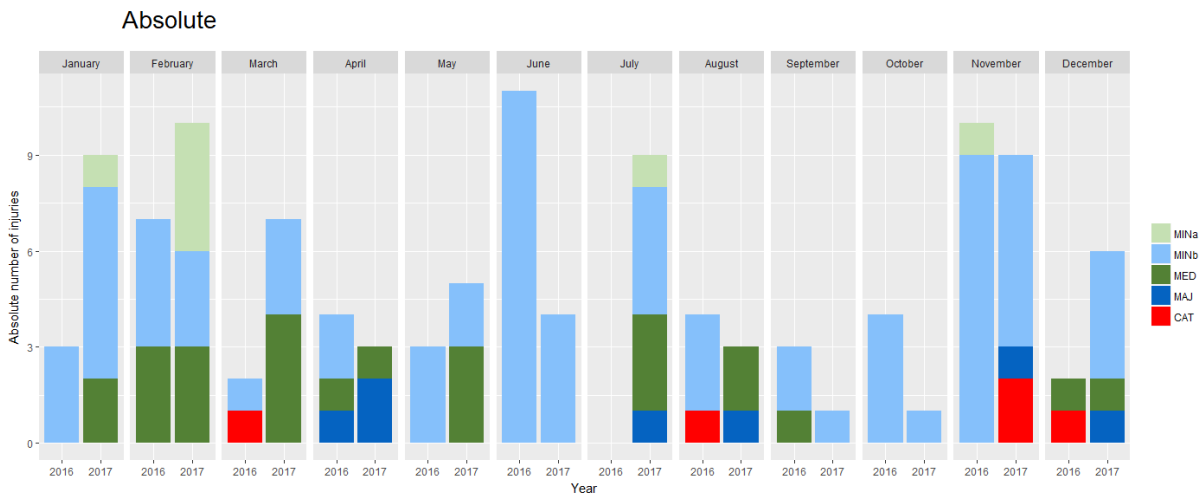

Figure 208: Wagga Wagga track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

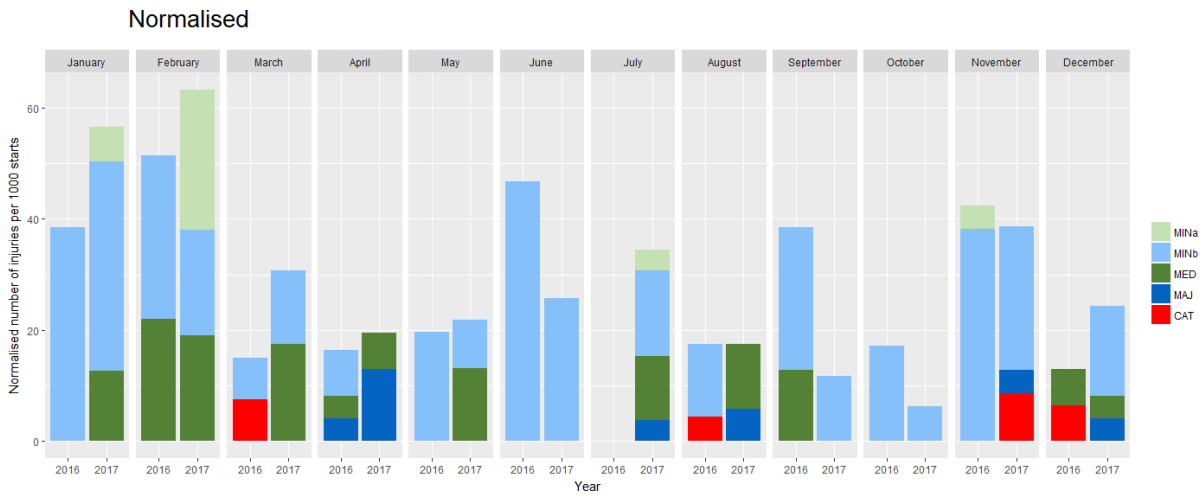

Figure 209: Wagga Wagga track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

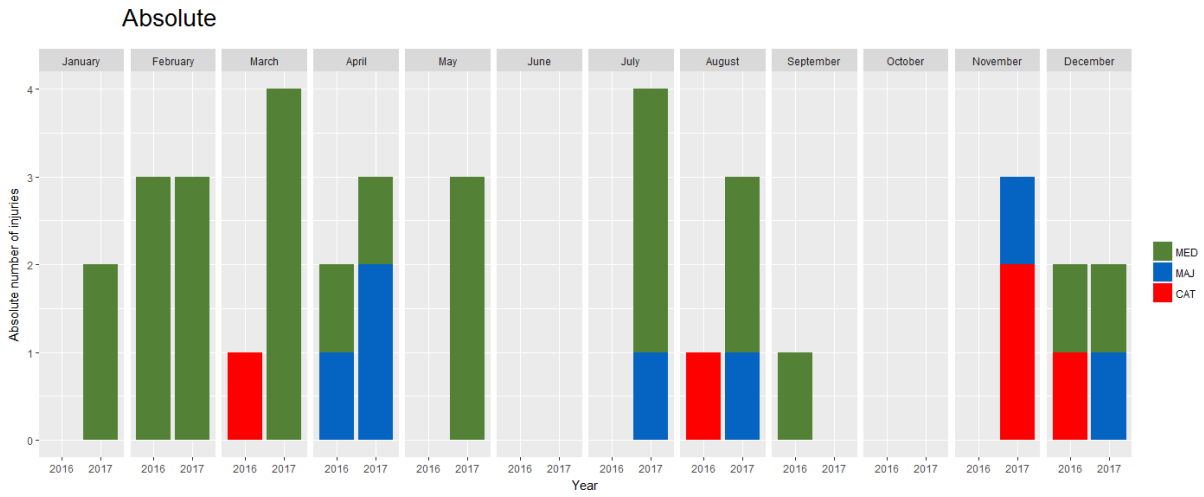

Figure 210: Wagga Wagga track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

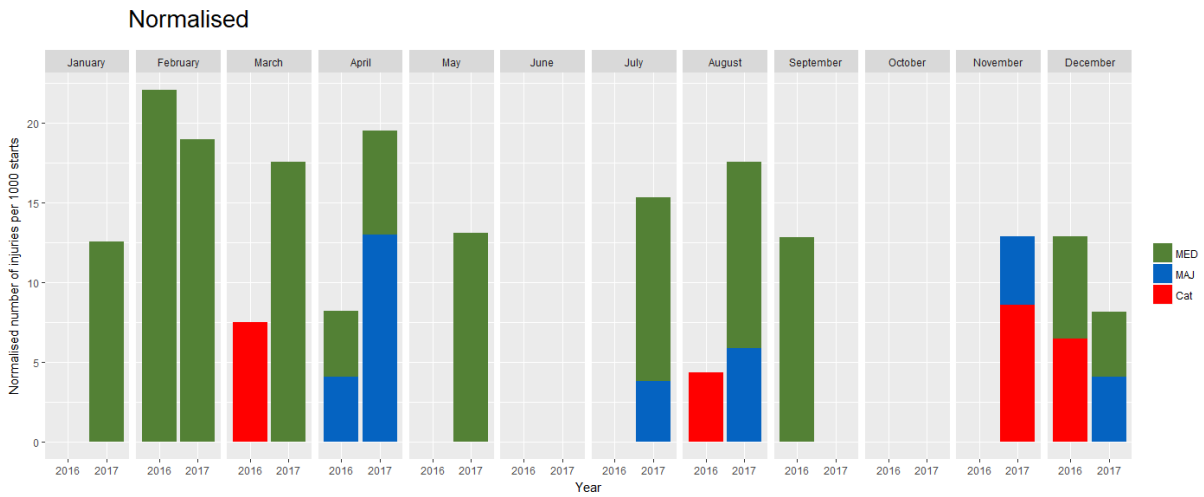

Figure 211: Wagga Wagga track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

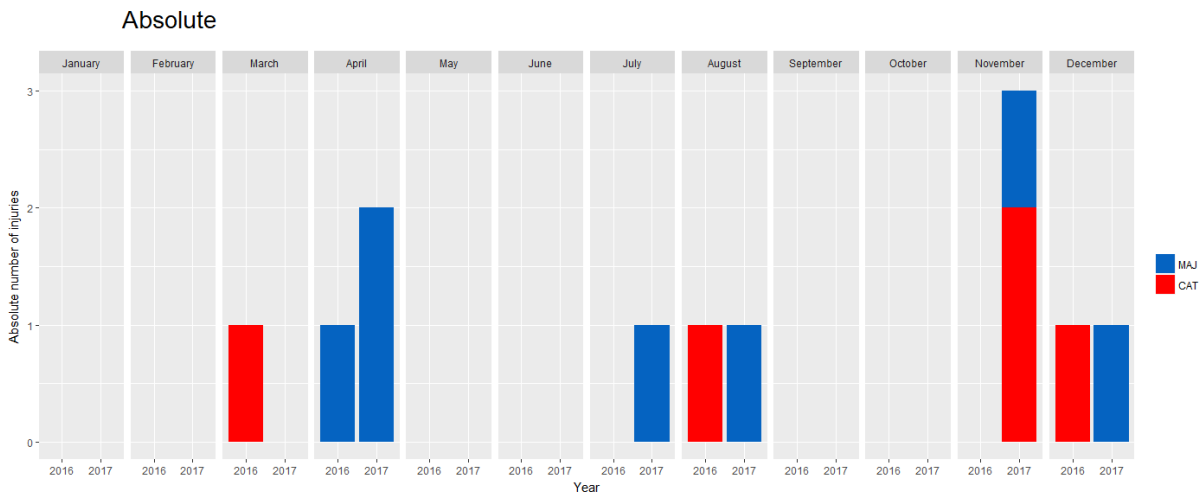

Figure 212: Wagga Wagga track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

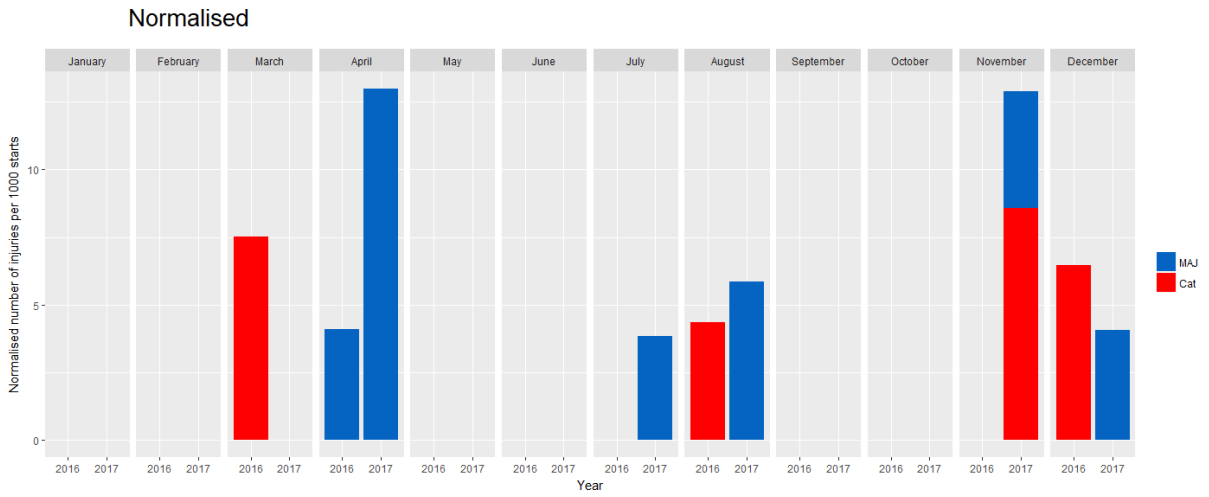

Figure 213: Wagga Wagga track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

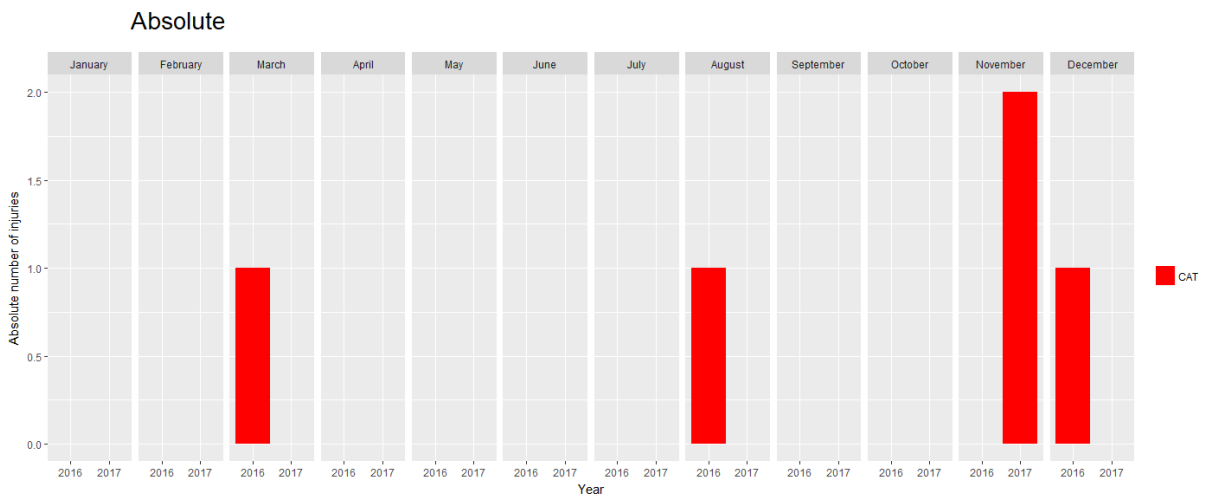

Figure 214: Wagga Wagga track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

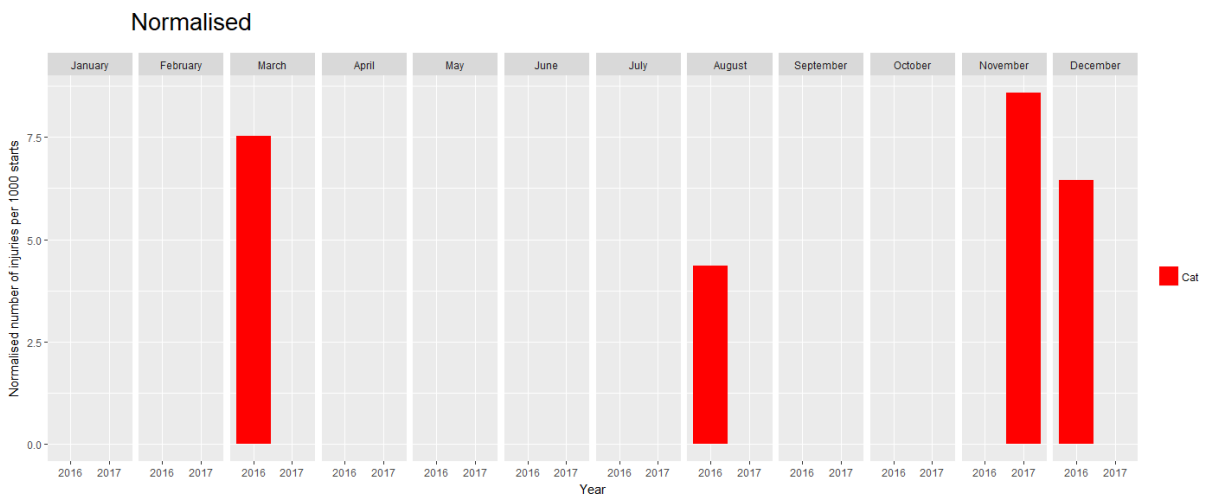

Figure 215: Wagga Wagga track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

GUNNEDAH

GUNNEDAH: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.100 Figures 216 to 223 contain Gunnedah Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

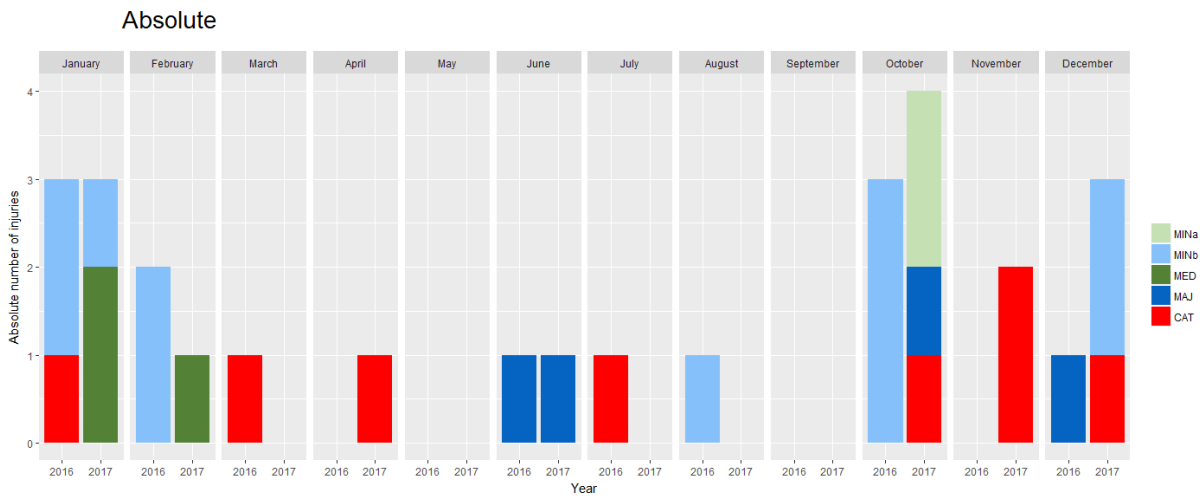

Figure 216: Gunnedah track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

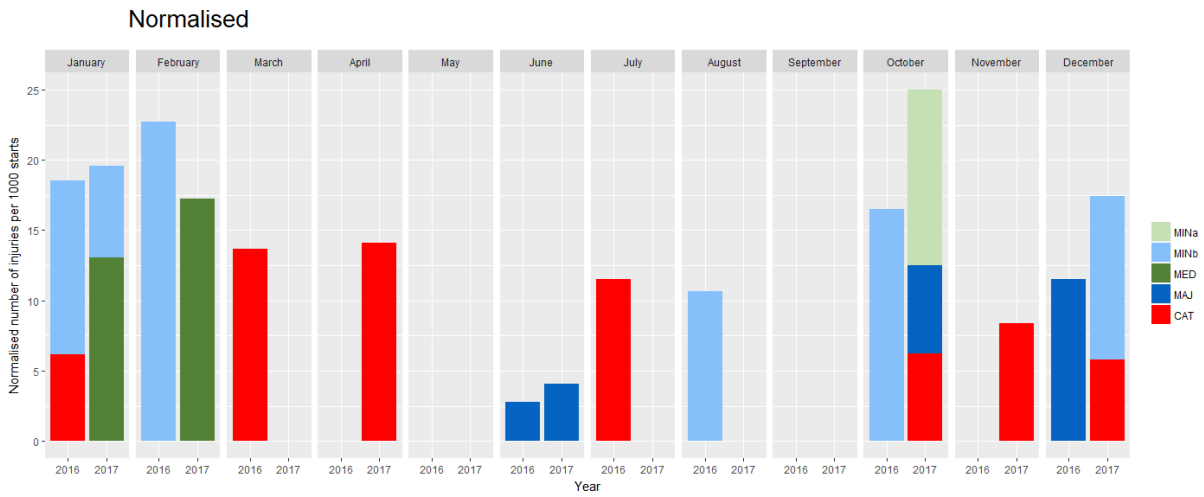

Figure 217: Gunnedah track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

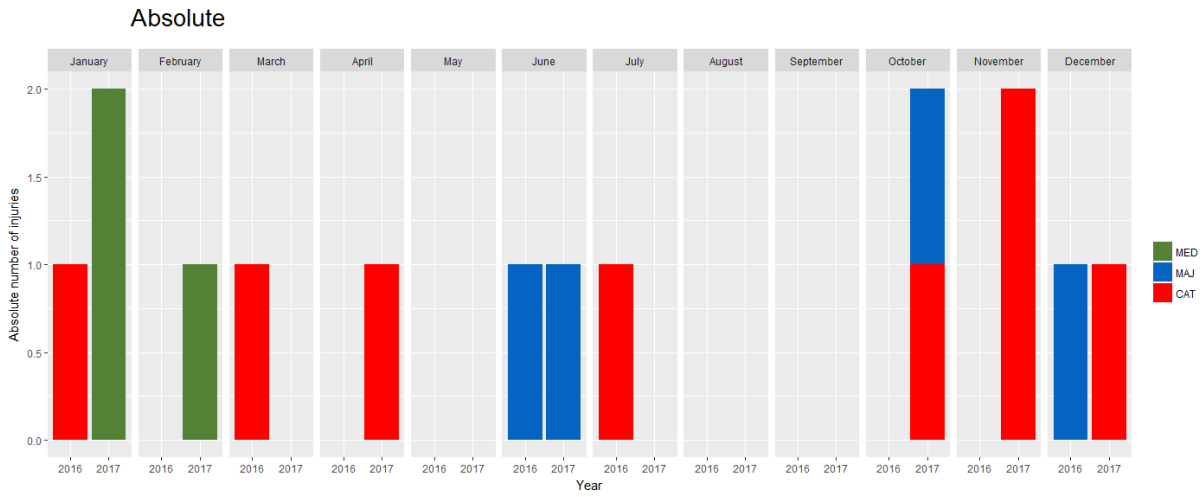

Figure 218: Gunnedah track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

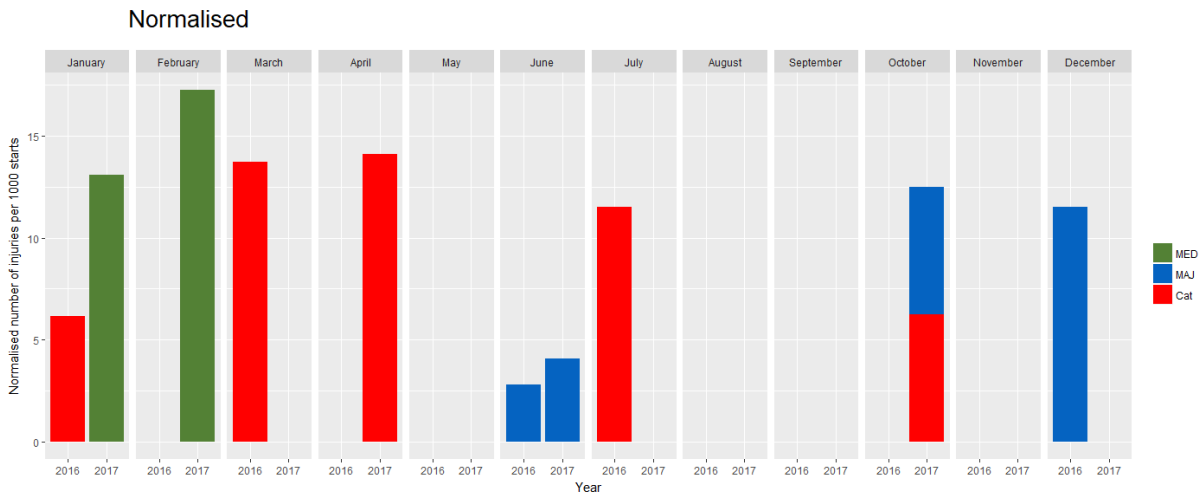

Figure 219: Gunnedah track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

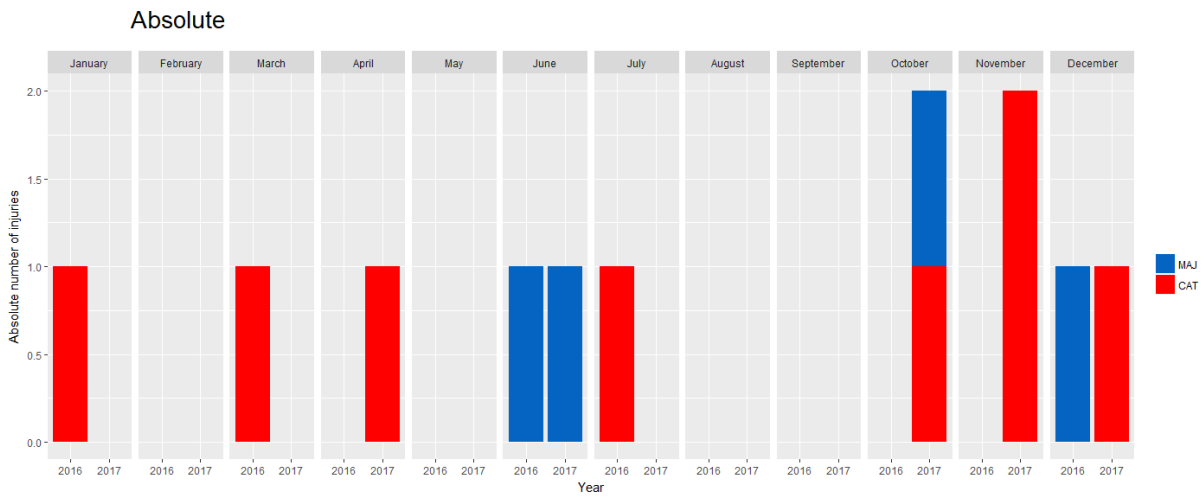

Figure 220: Gunnedah track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

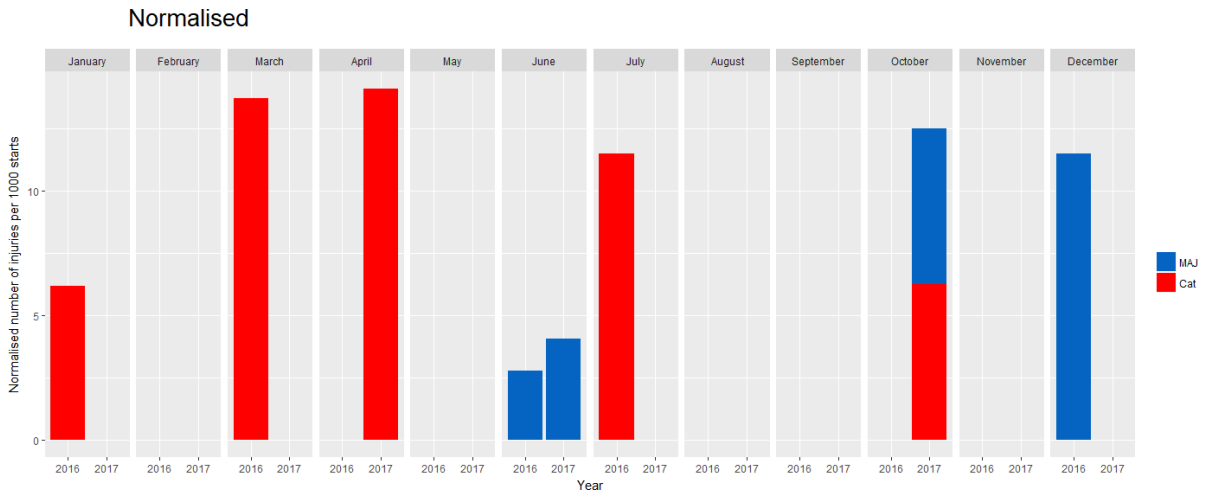

Figure 221: Gunnedah track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

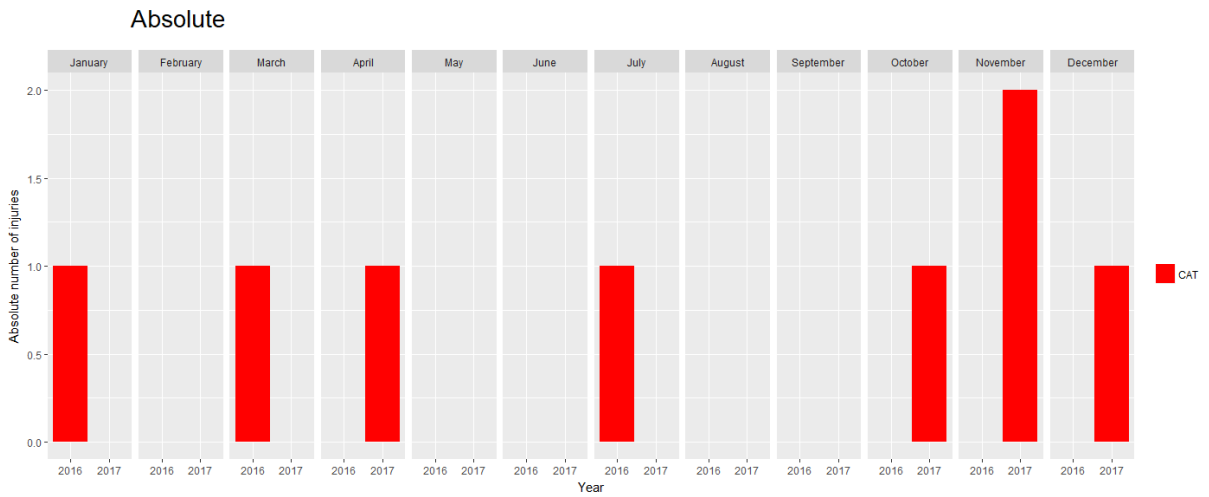

Figure 222: Gunnedah track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

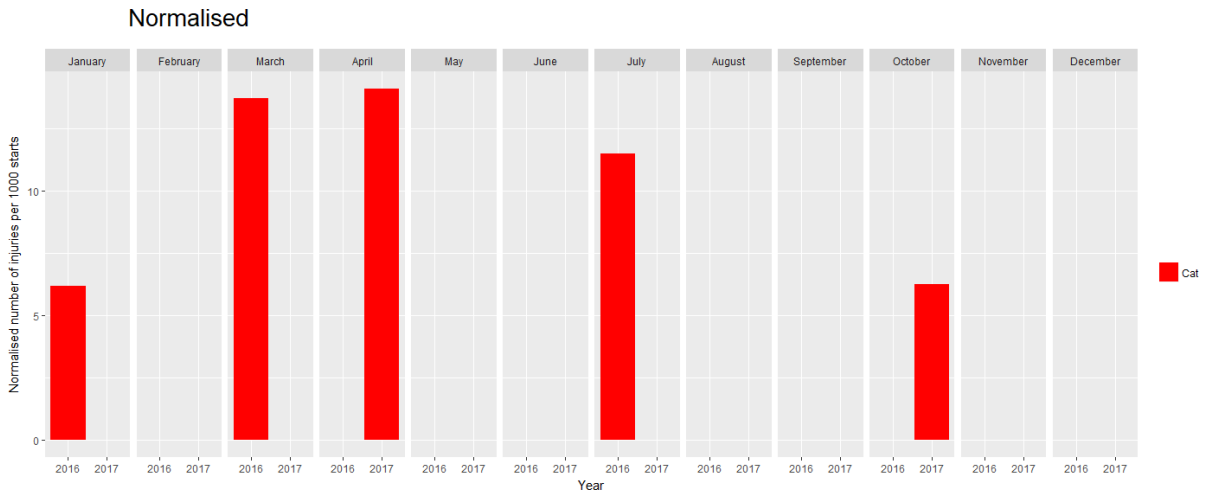

Figure 223: Gunnedah track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

LITHGOW

LITHGOW: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.101 Figures 224 to 231 contain Lithgow Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

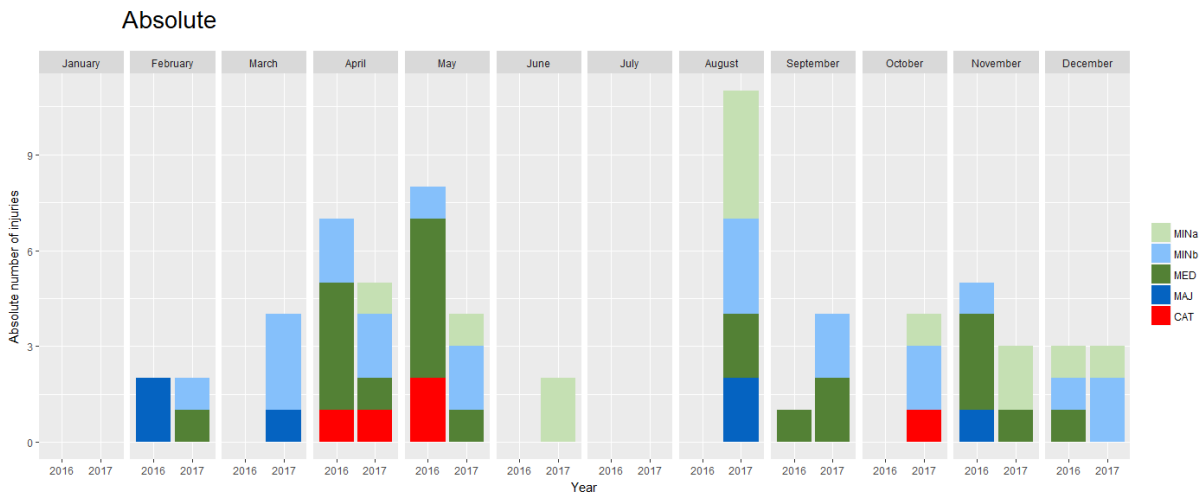

Figure 224: Lithgow track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

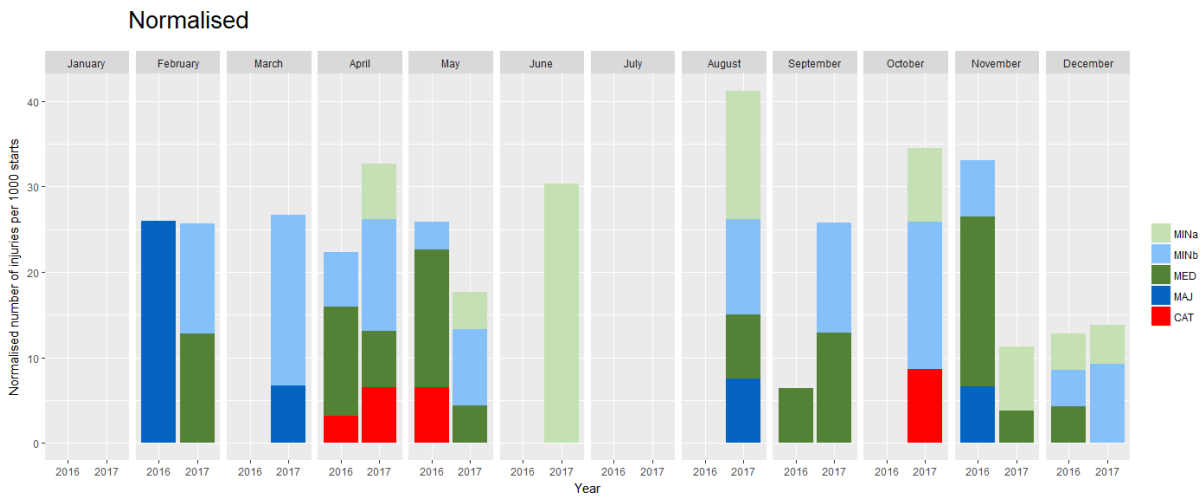

Figure 225: Lithgow track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

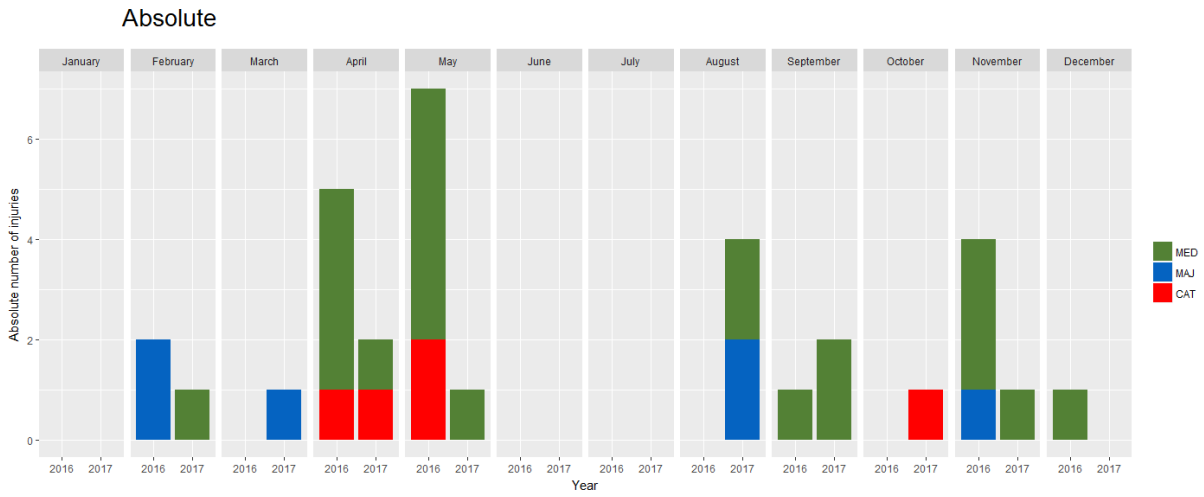

Figure 226: Lithgow track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

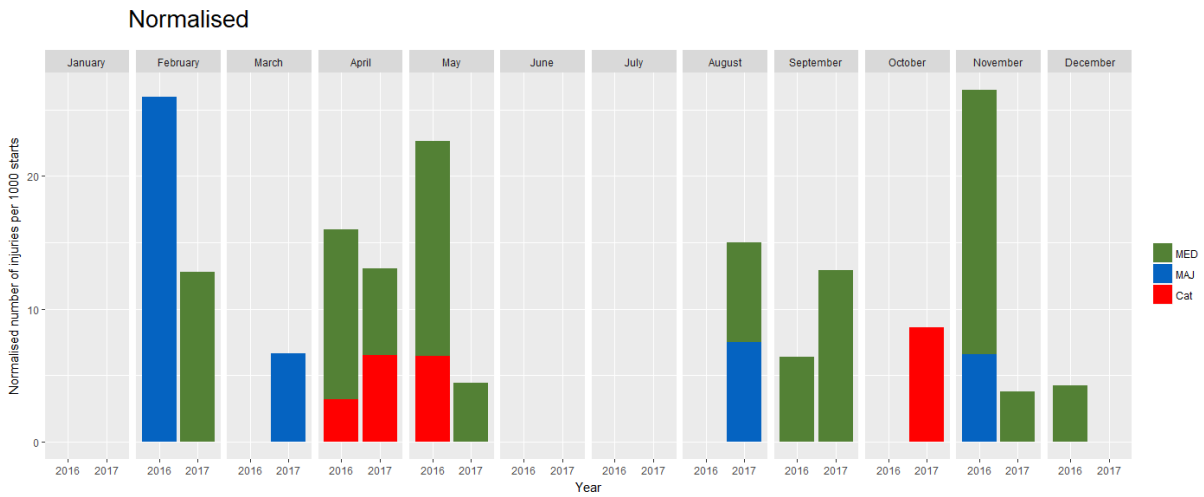

Figure 227: Lithgow track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

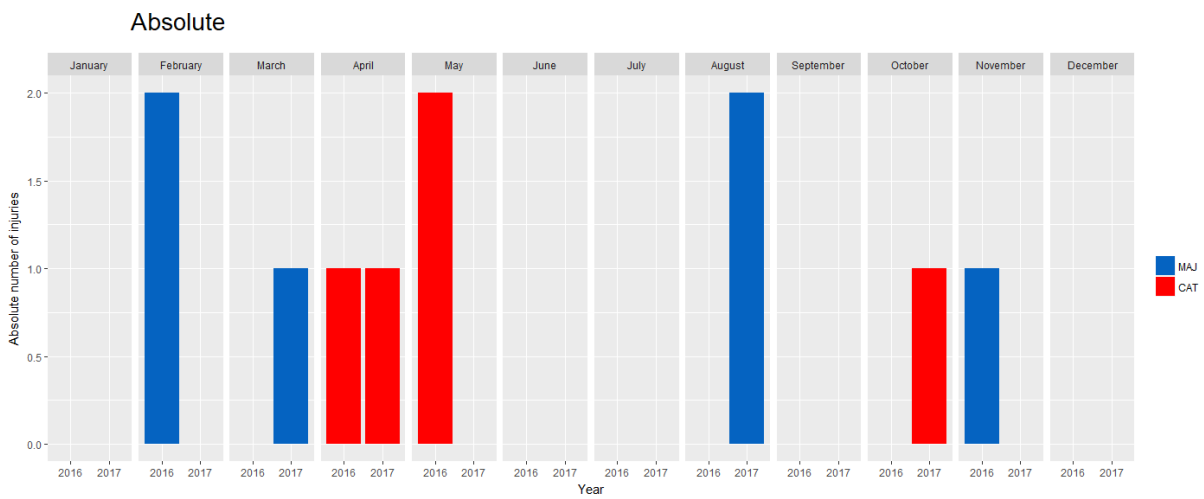

Figure 228: Lithgow track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

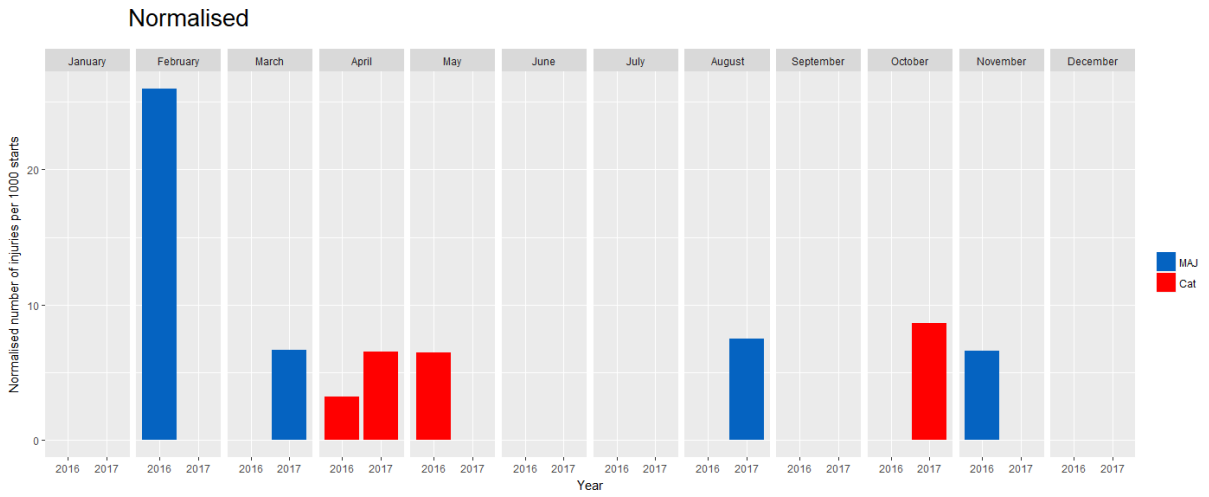

Figure 229: Lithgow track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

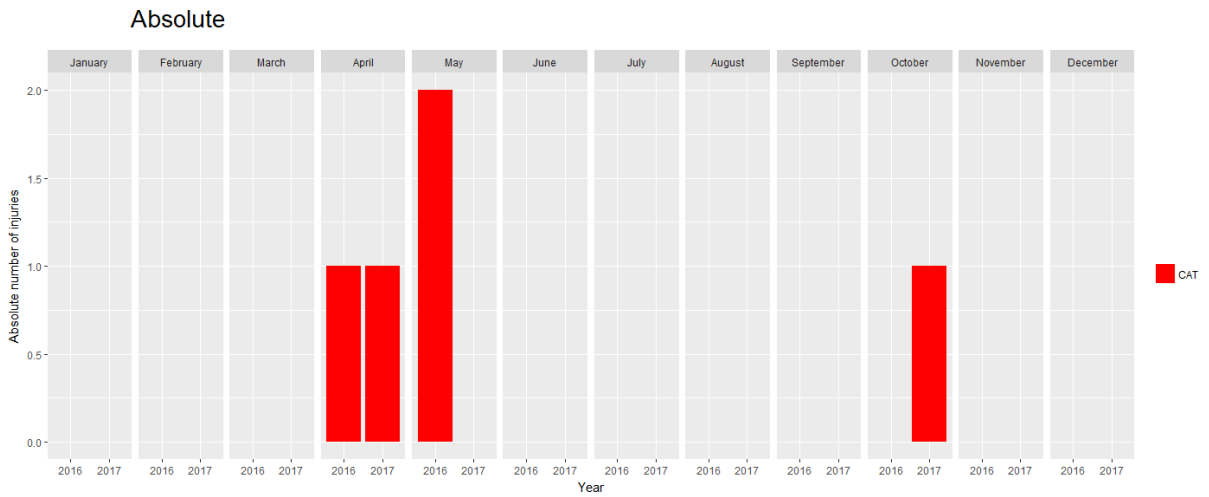

Figure 230: Lithgow track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

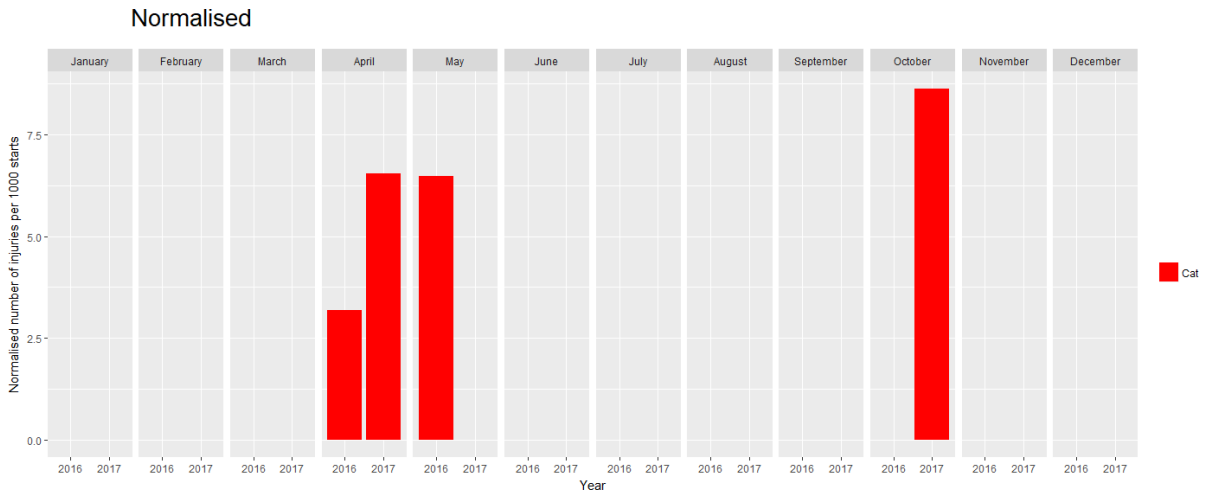

Figure 231: Lithgow track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

COONABARABRAN

COONABARABRAN: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.102 Figures 232 to 239 contain Coonabarabran Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

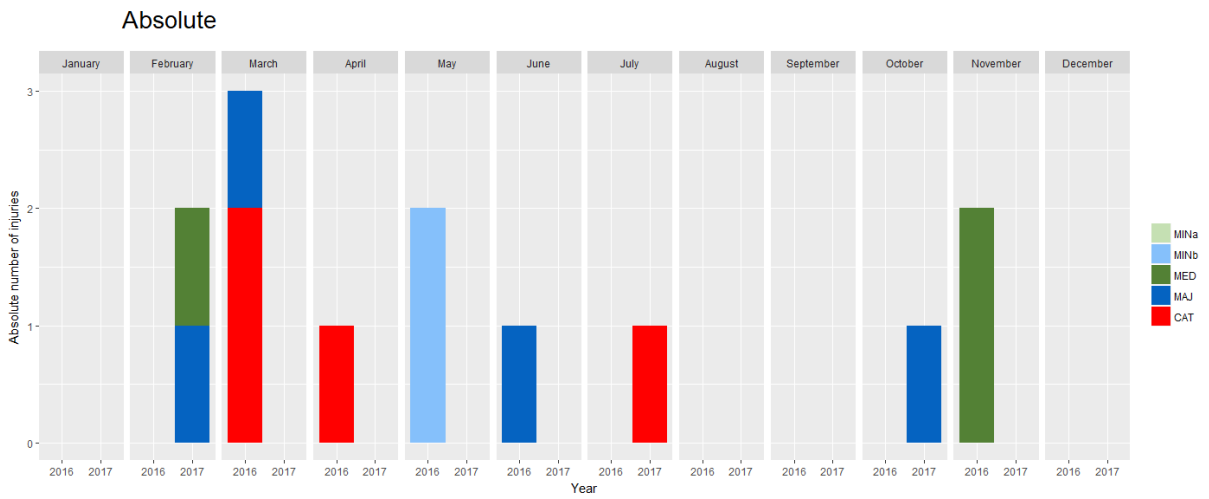

Figure 232: Coonabarabran track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

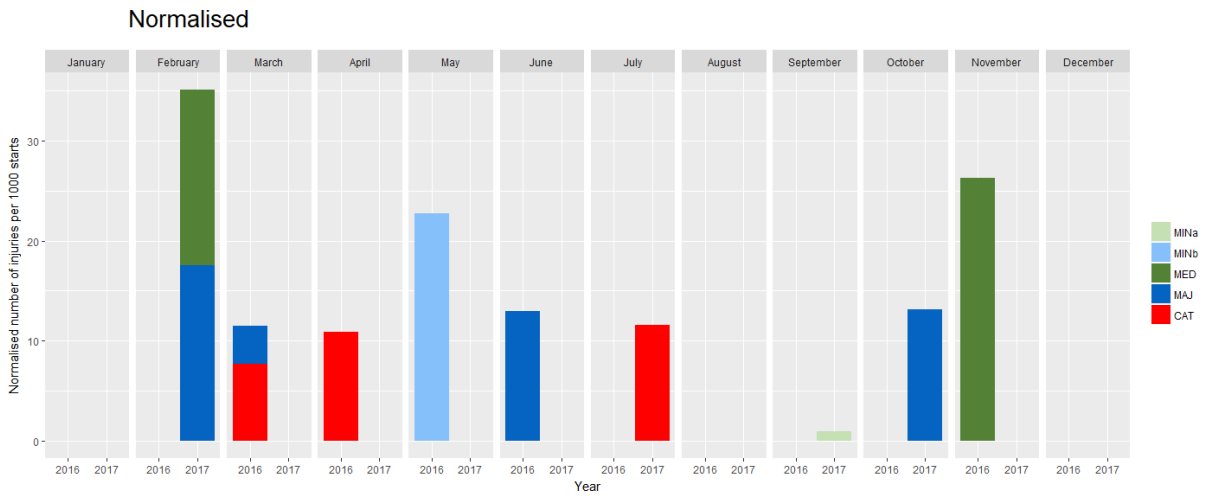

Figure 233: Coonabarabran track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

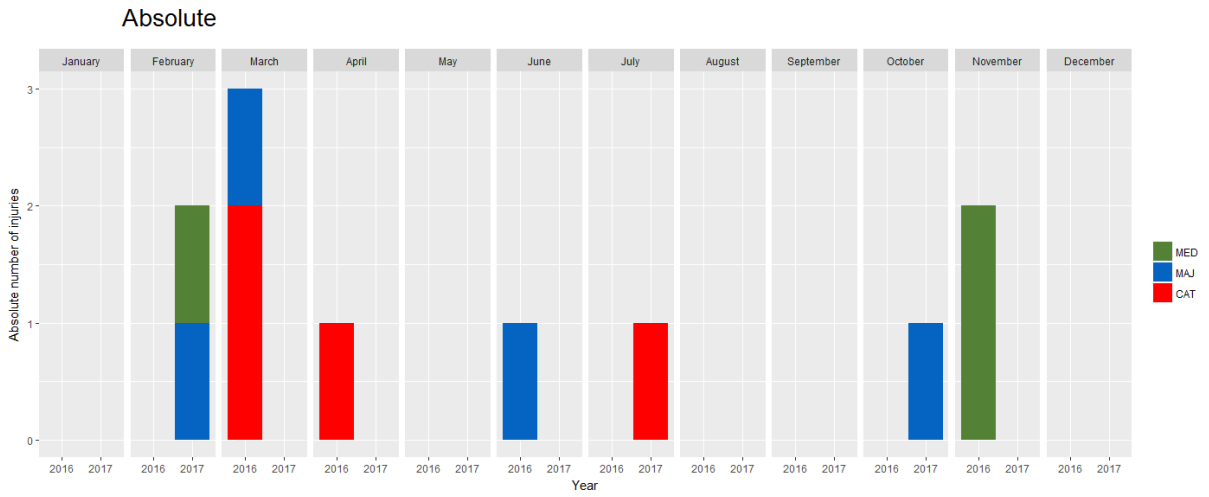

Figure 234: Coonabarabran track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

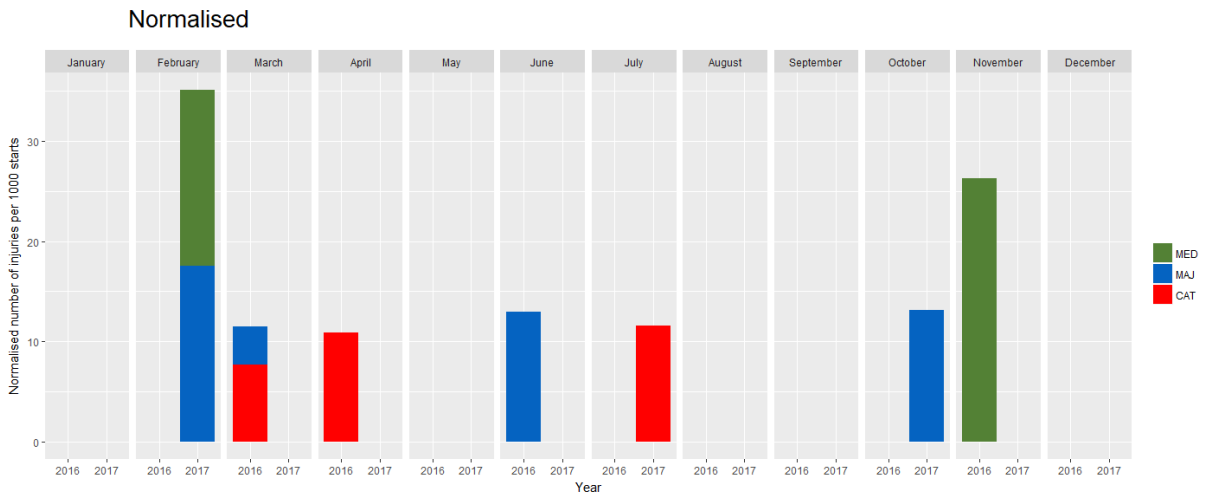

Figure 235: Coonabarabran track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

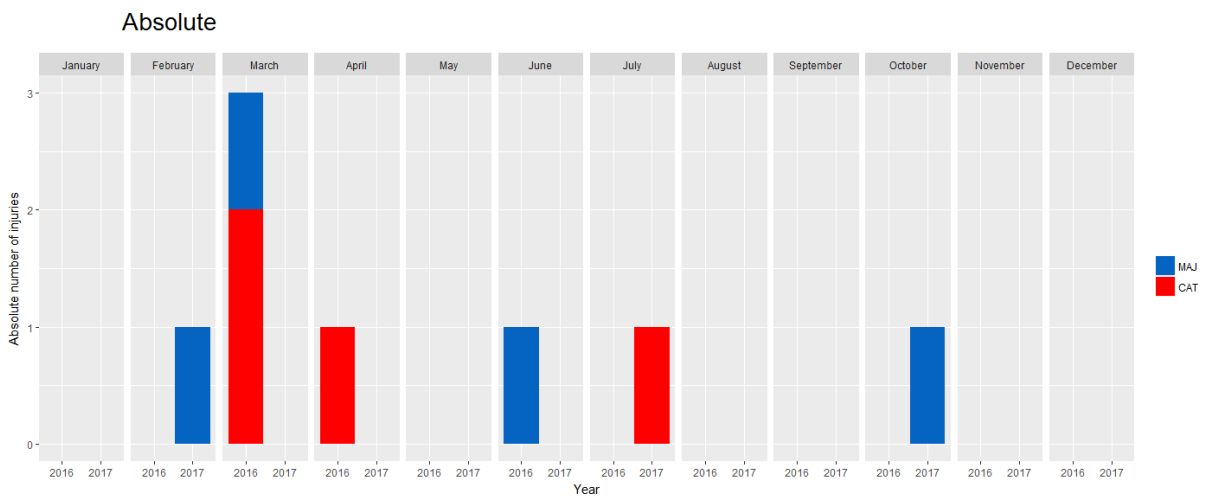

Figure 236: Coonabarabran track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

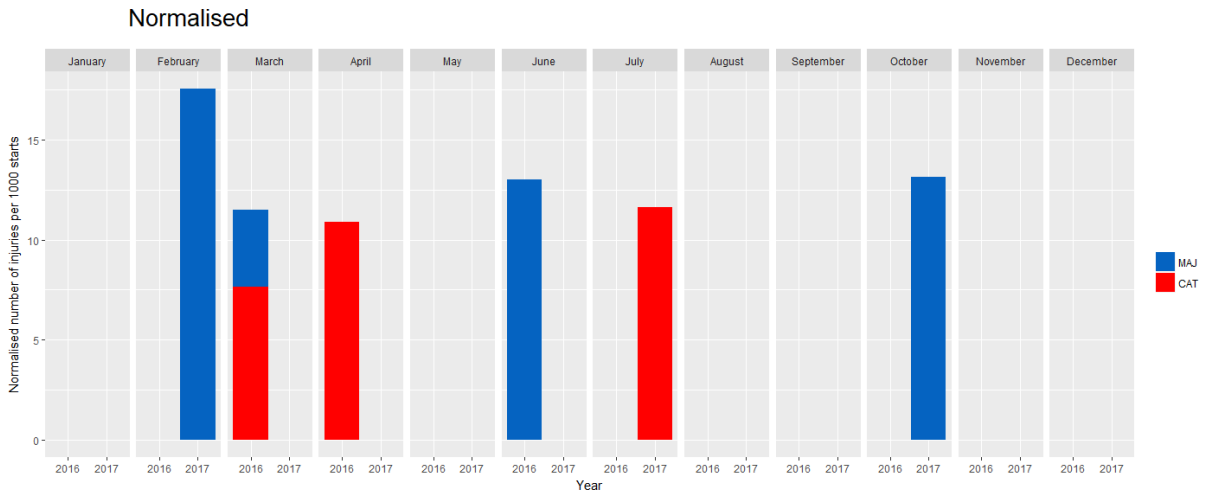

Figure 237: Coonabarabran track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

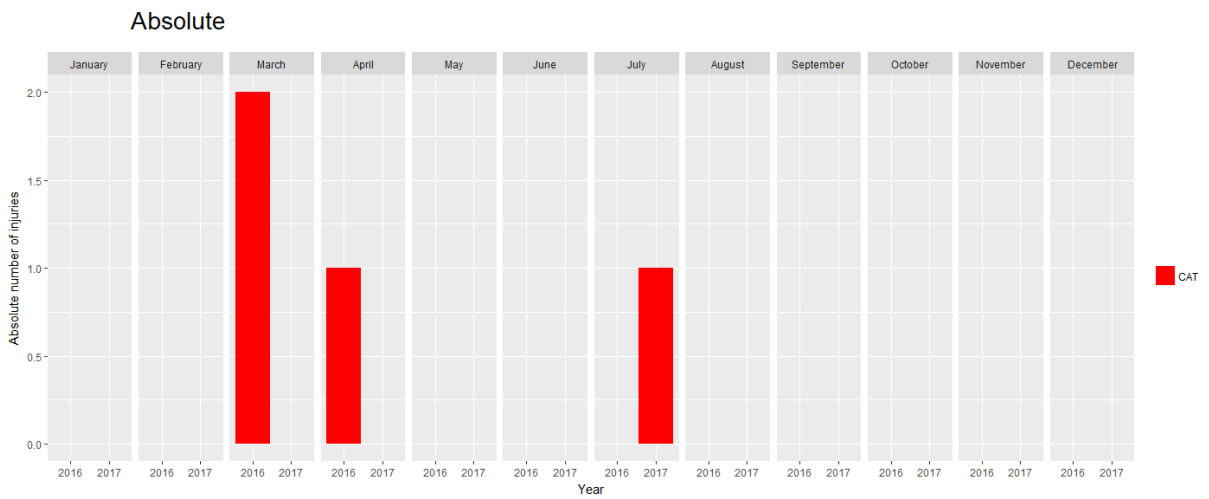

Figure 238: Coonabarabran track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

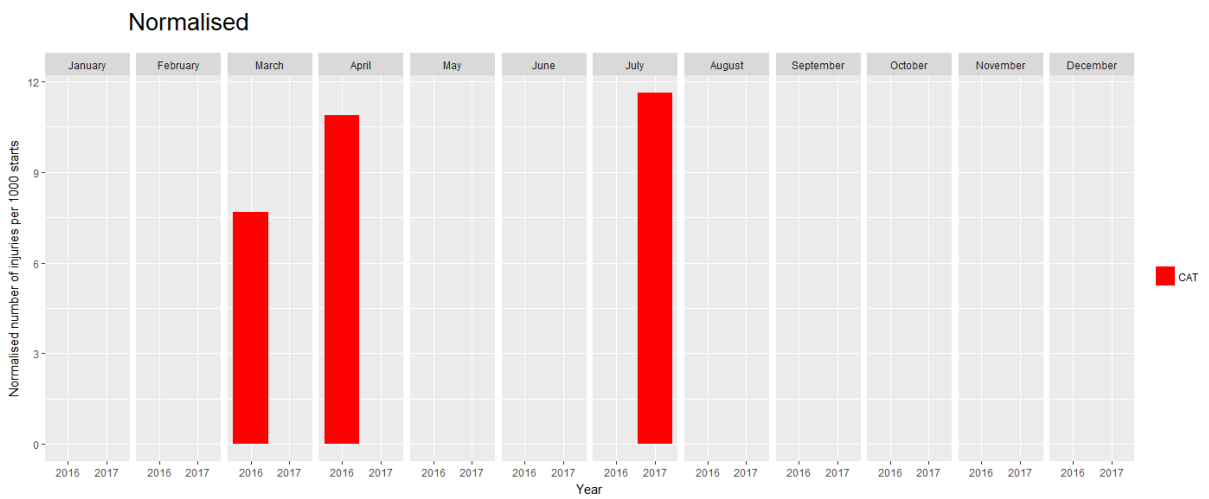

Figure 239: Coonabarabran track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

MUDGEE

MUDGEE: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.103 Figures 240 to 247 contain Mudgee Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

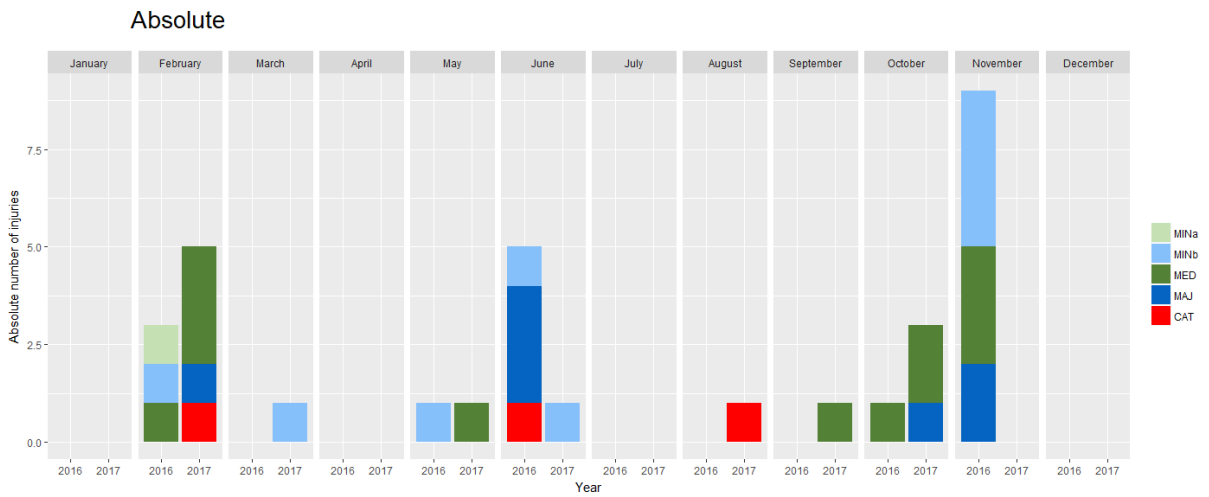

Figure 240: Mudgee track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

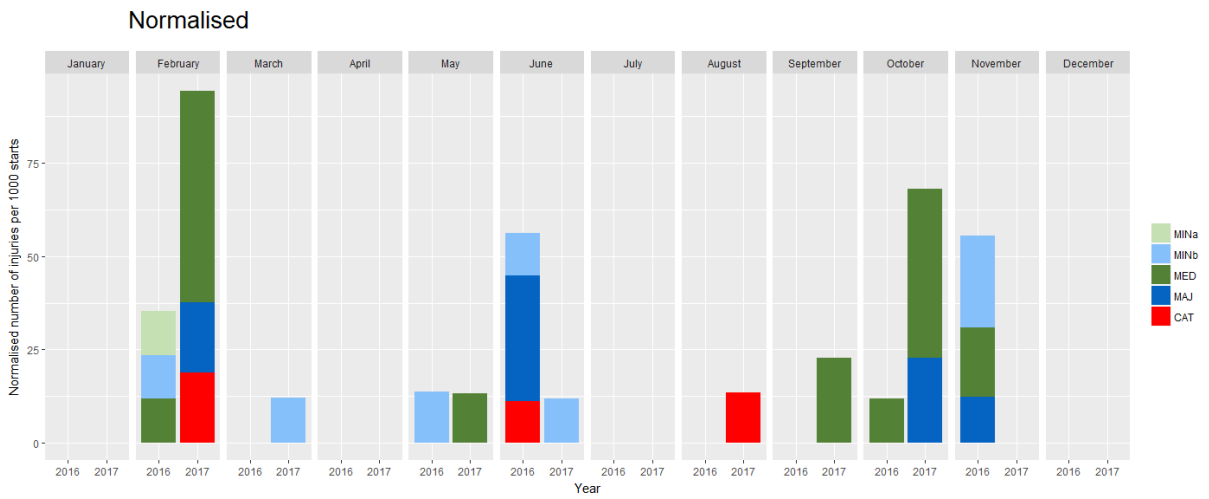

Figure 241: Mudgee track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

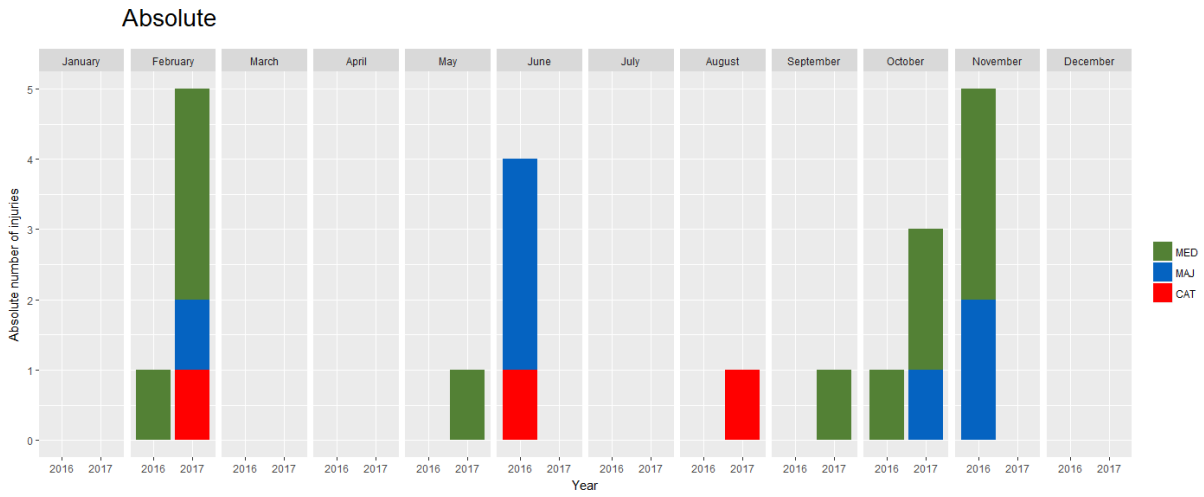

Figure 242: Mudgee track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

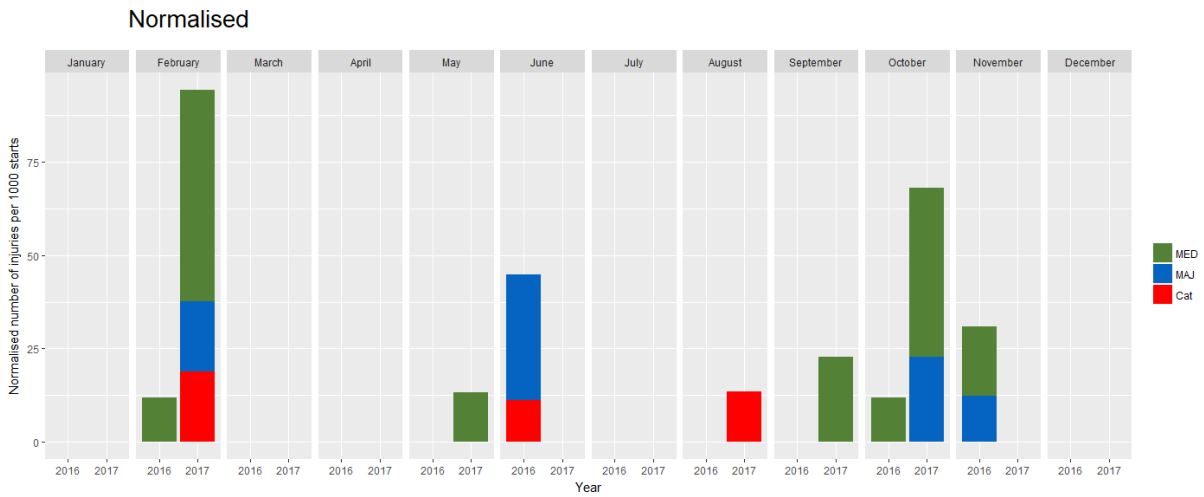

Figure 243: Mudgee track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

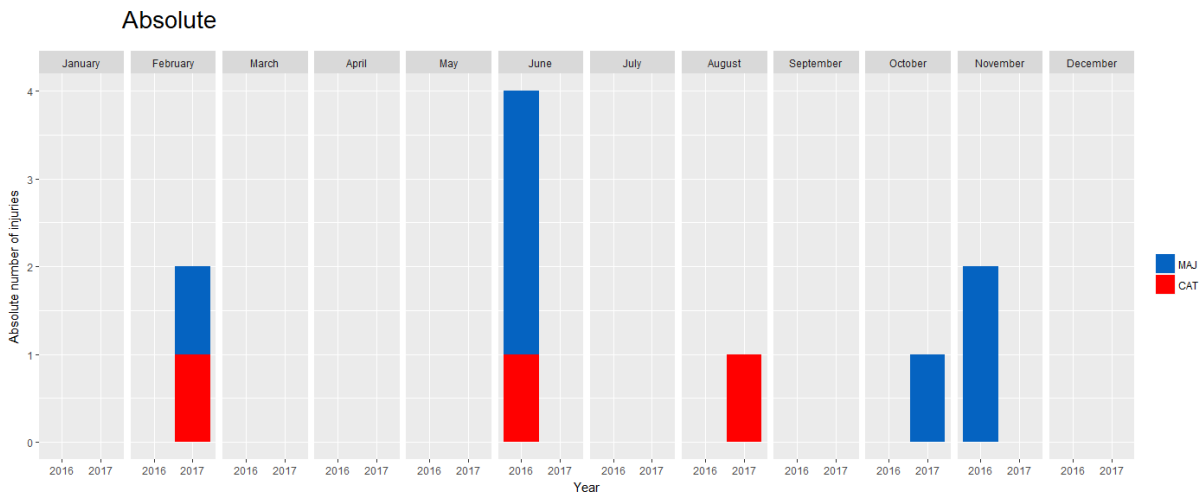

Figure 244: Mudgee track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

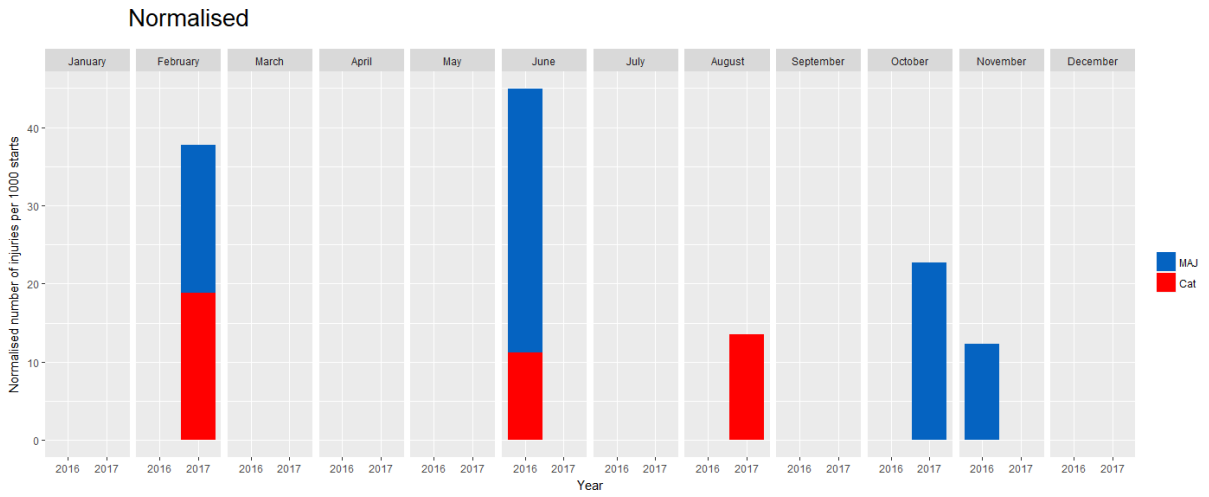

Figure 245: Mudgee track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

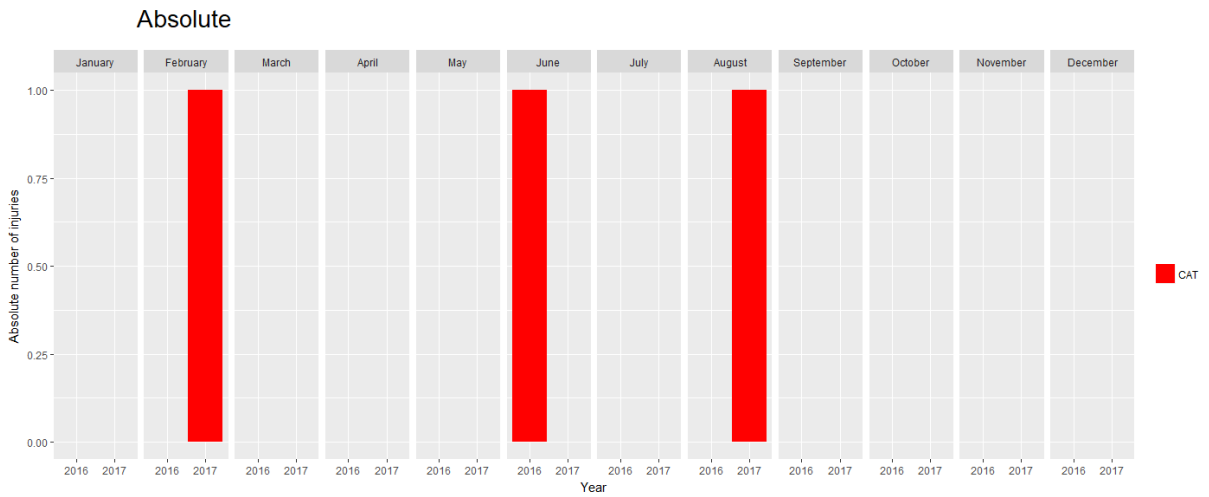

Figure 246: Mudgee track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

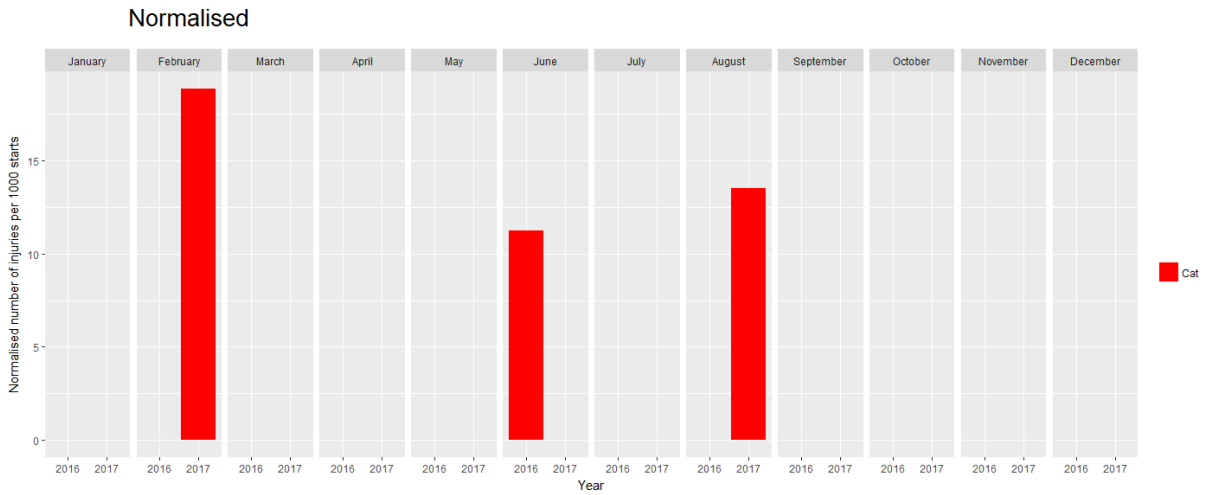

Figure 247: Mudgee track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

TEMORA

TEMORA: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.104 Figures 248 to 199 contain Temora Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

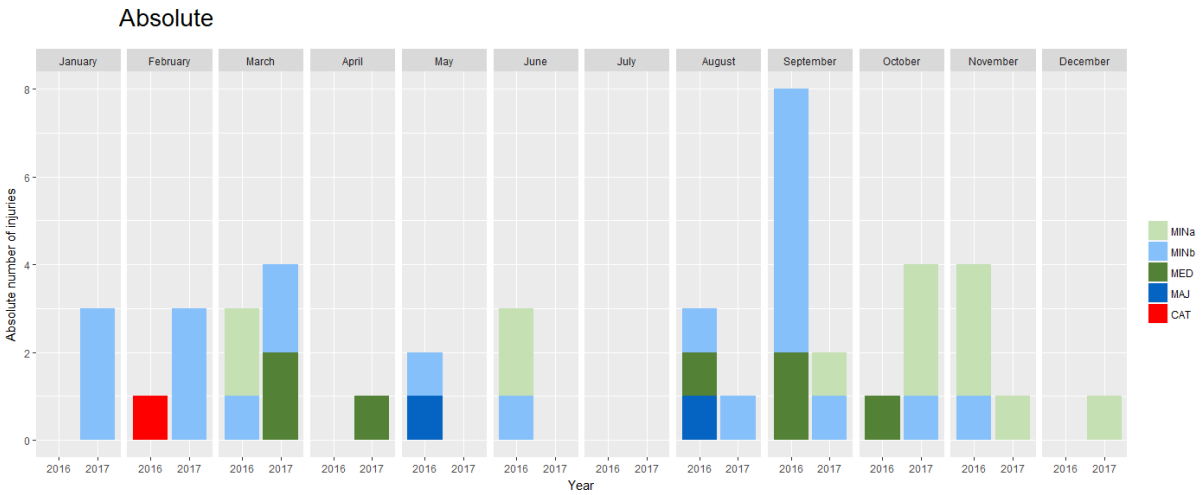

Figure 248: Temora track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

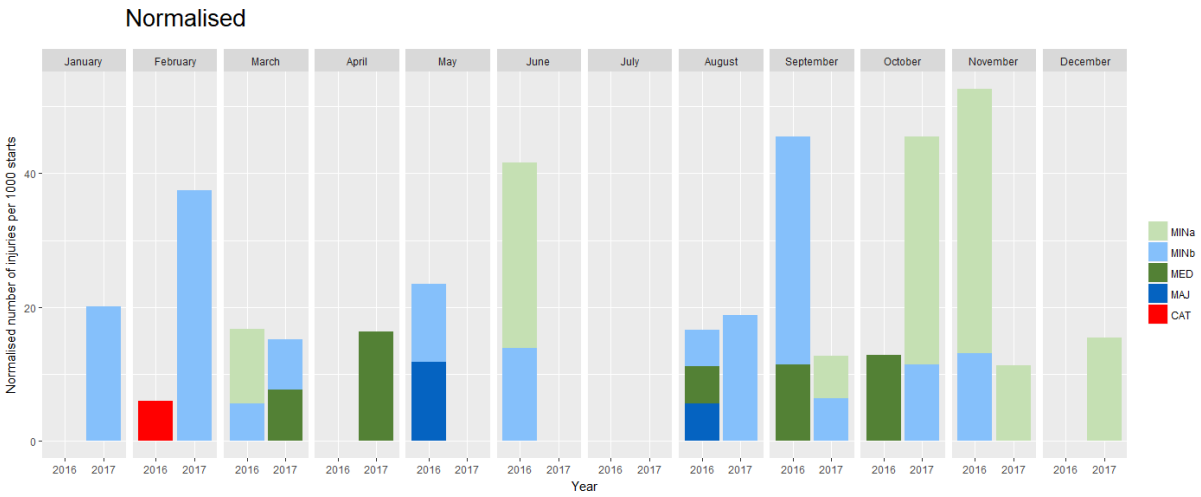

Figure 249: Temora track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

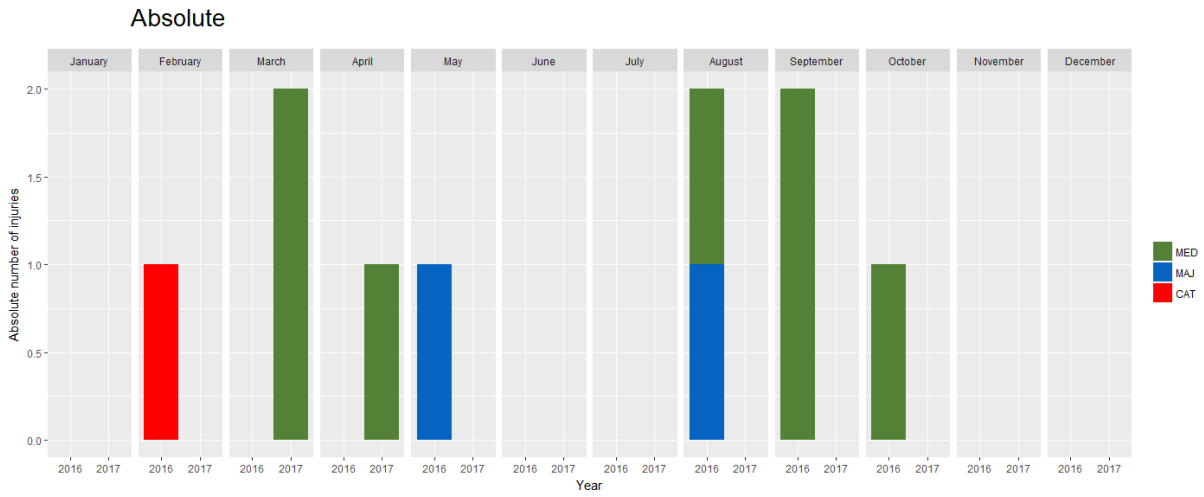

Figure 250: Temora track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

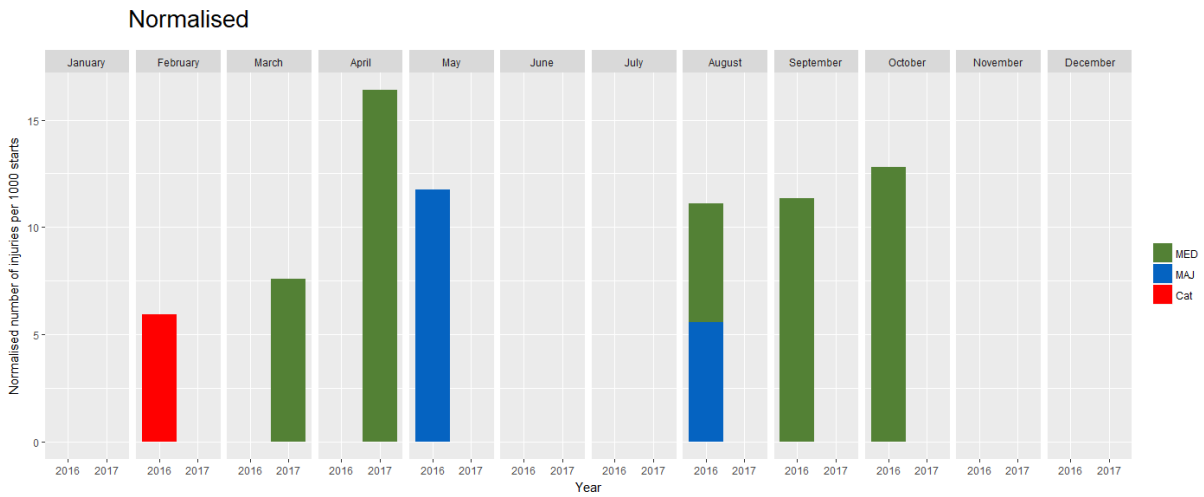

Figure 251: Temora track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

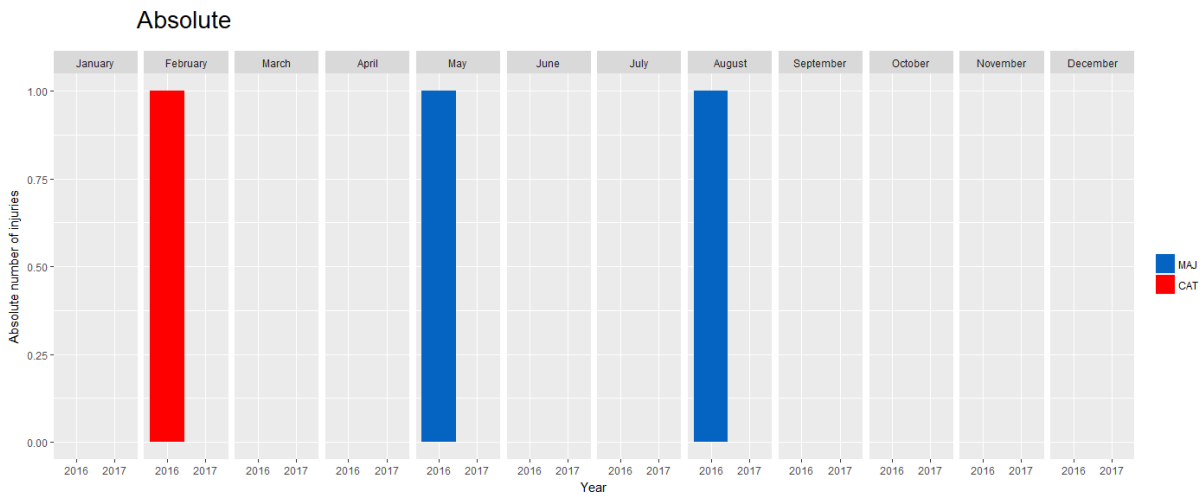

Figure 252: Temora track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

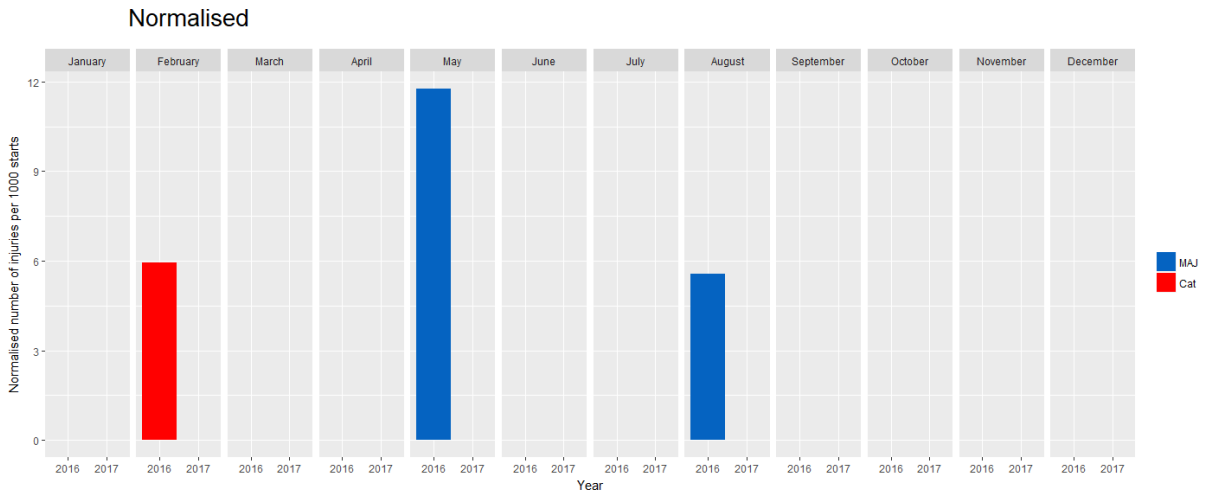

Figure 253: Temora track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

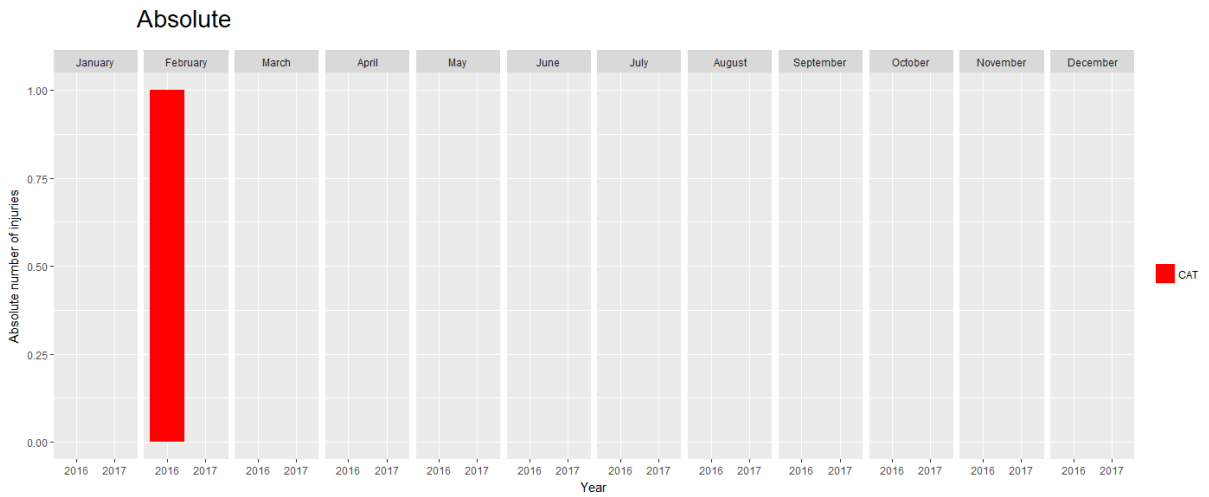

Figure 254: Temora track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

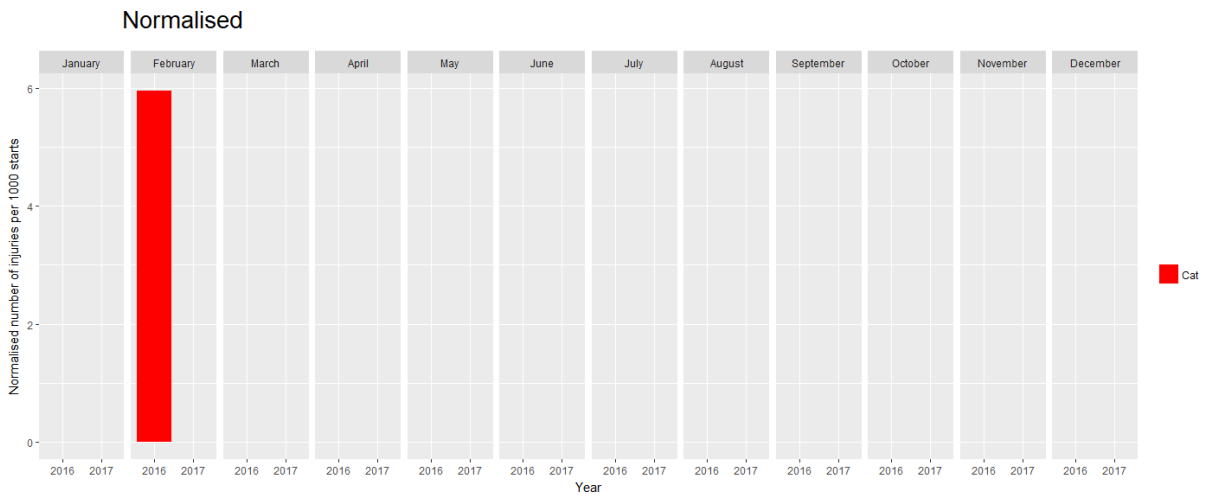

Figure 255: Temora track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

MOREE

MOREE: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.105 Figures 256 to 263 contain Moree Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

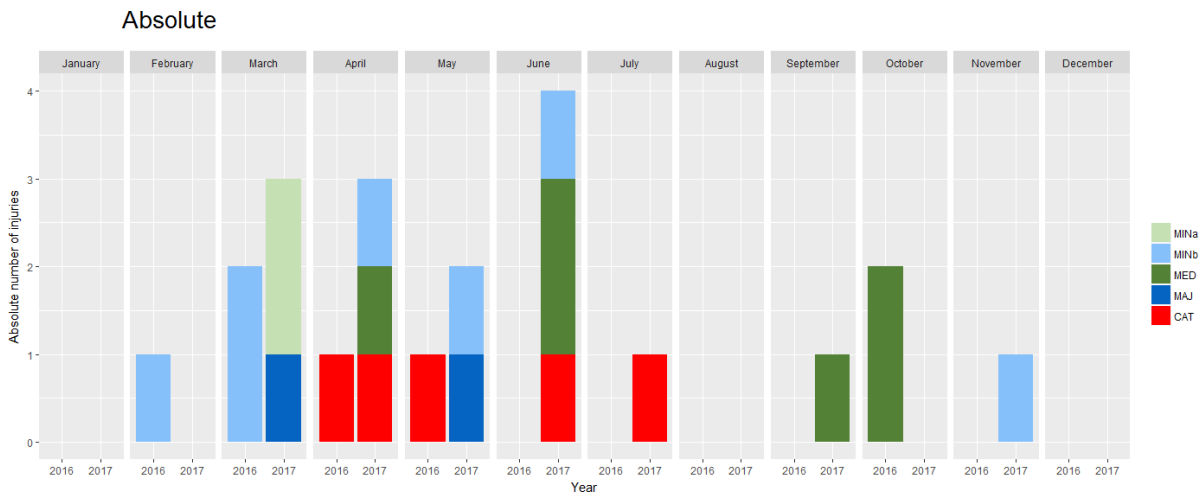

Figure 256: Moree track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

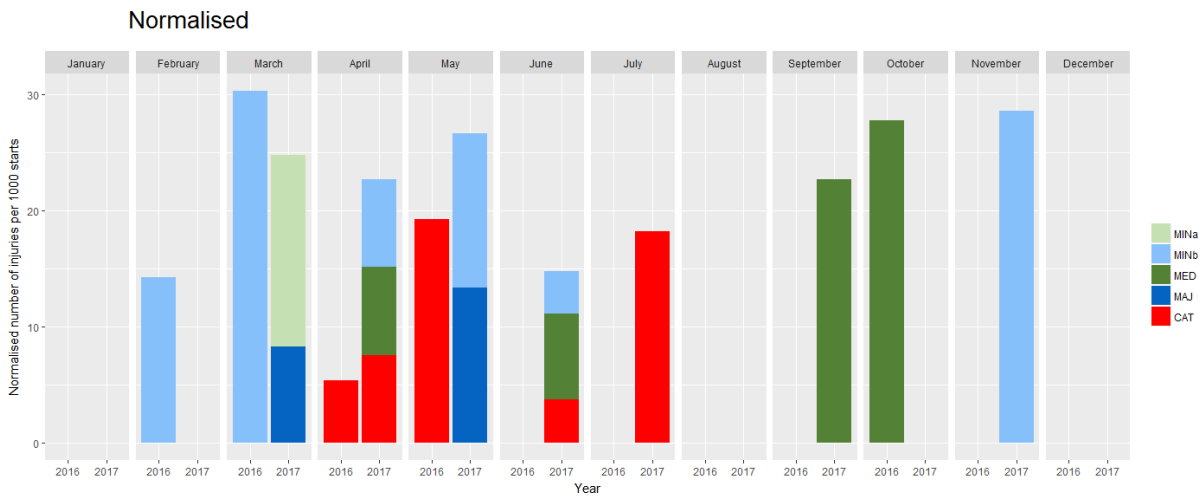

Figure 257: Moree track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

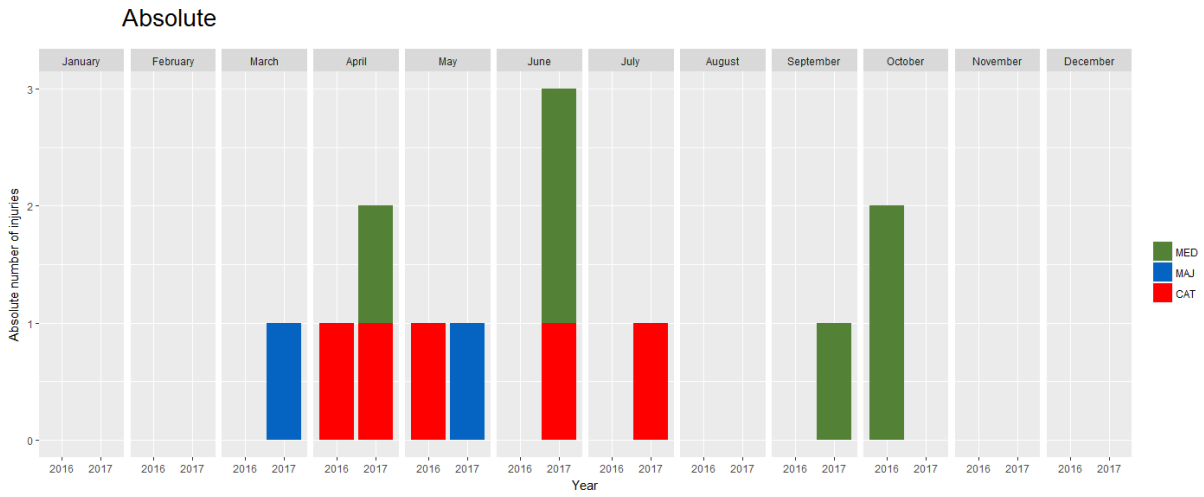

Figure 258: Moree track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

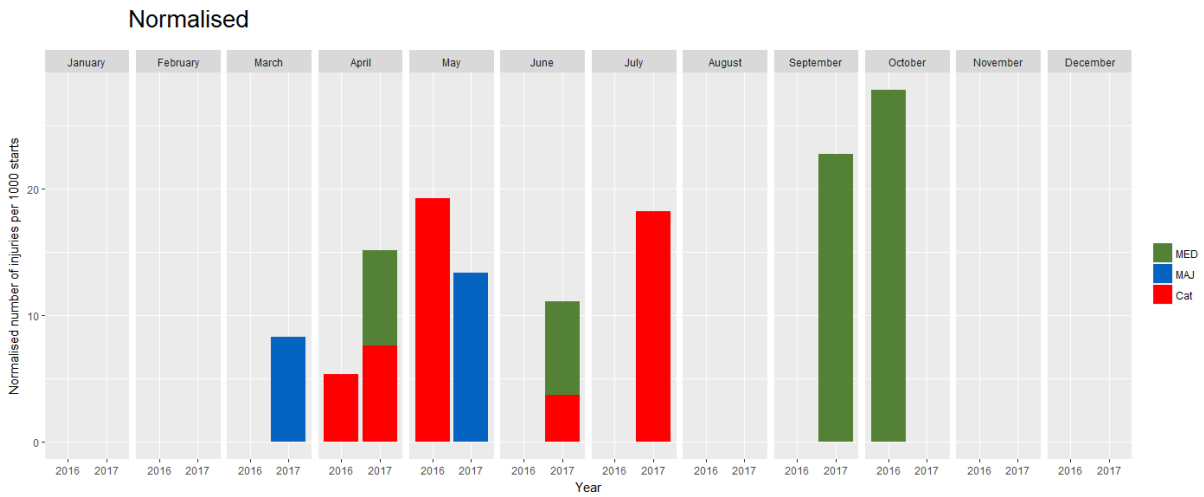

Figure 259: Moree track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

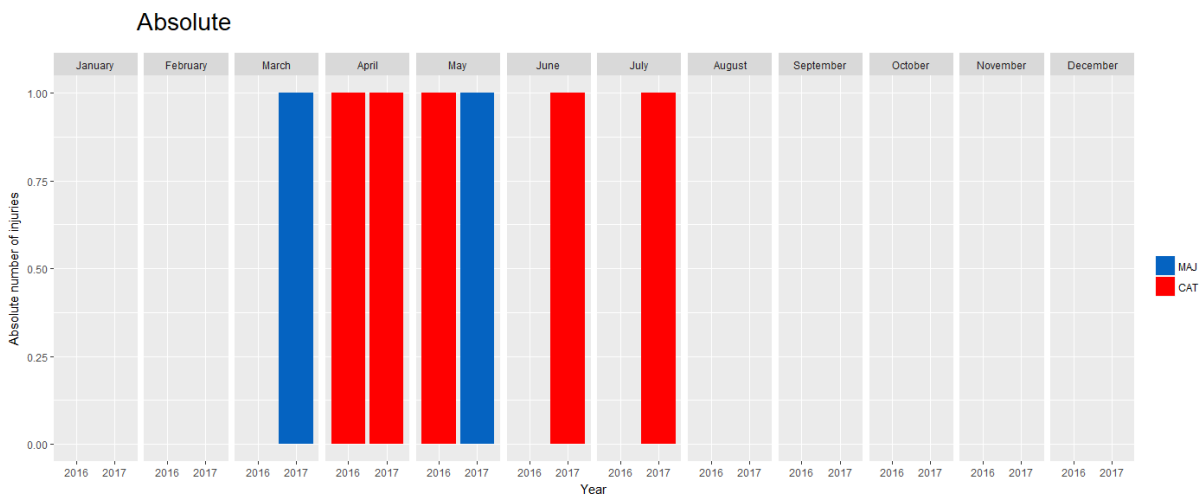

Figure 260: Moree track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

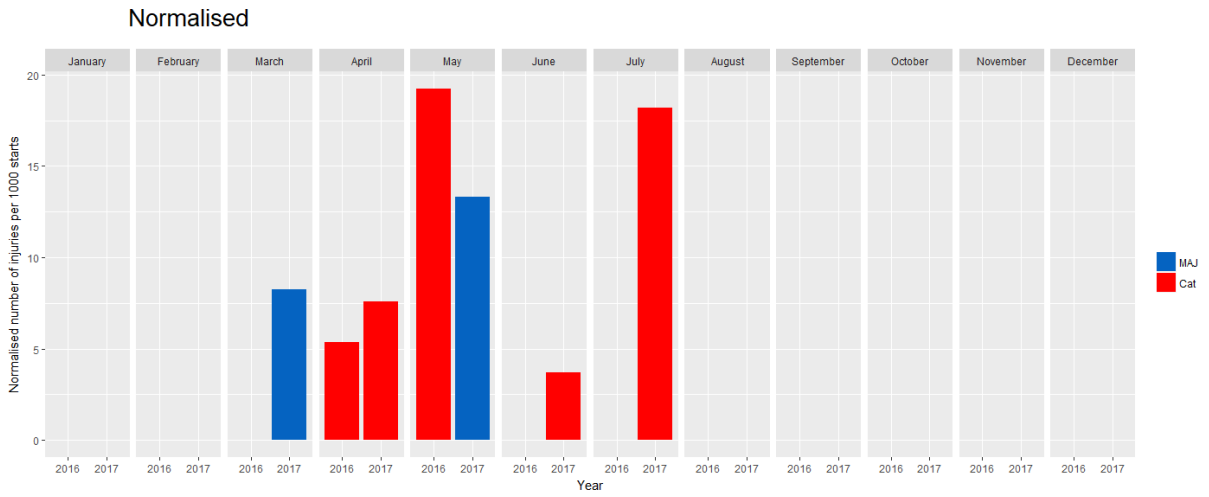

Figure 261: Moree track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

Figure 262: Moree track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

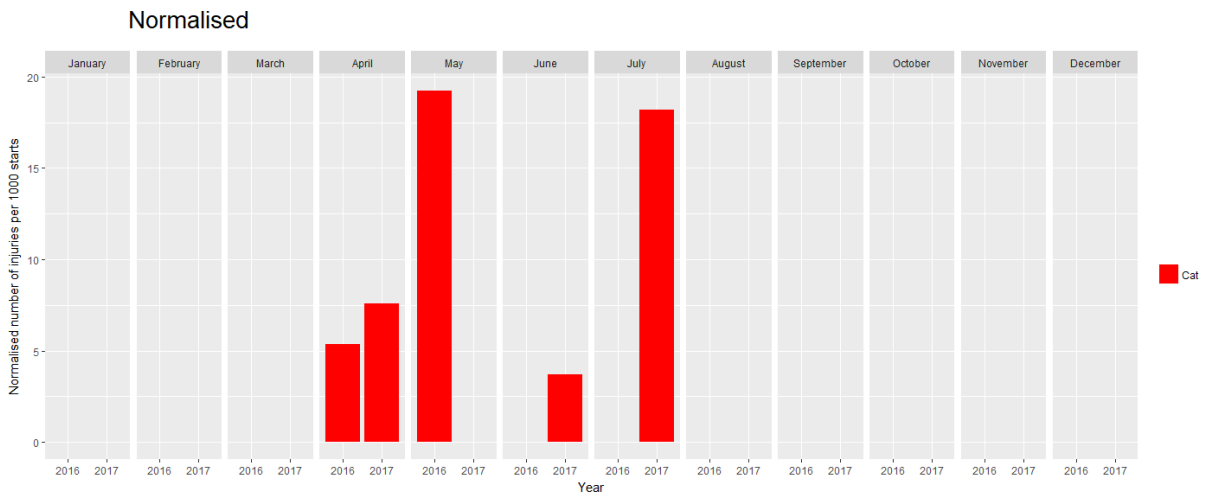

Figure 263: Moree track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

MUSWELLBROOK

MUSWELLBROOK: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.106 Figures 264 to 271 contain Muswellbrook Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

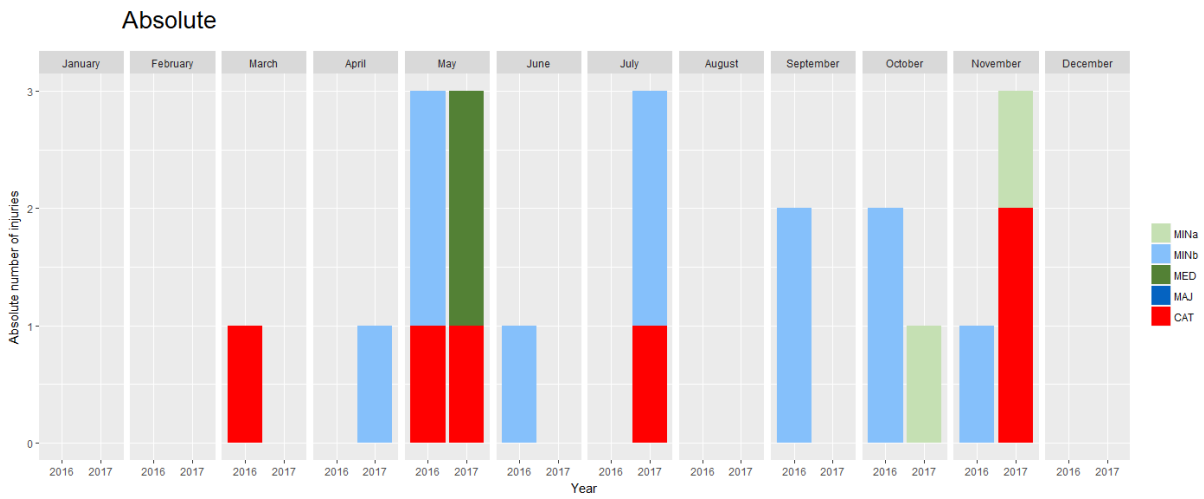

Figure 264: Muswellbrook track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

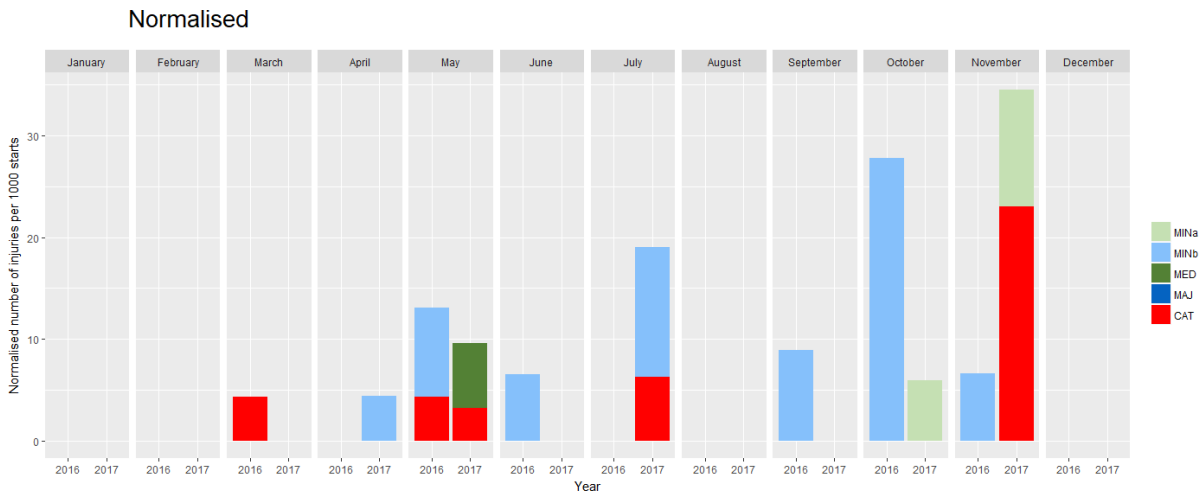

Figure 265: Muswellbrook track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

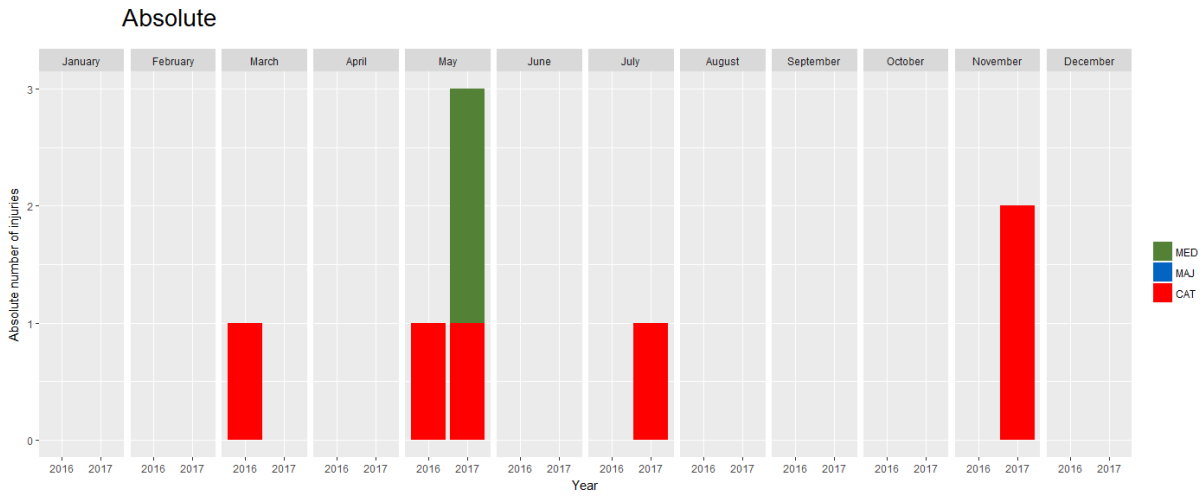

Figure 266: Muswellbrook track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

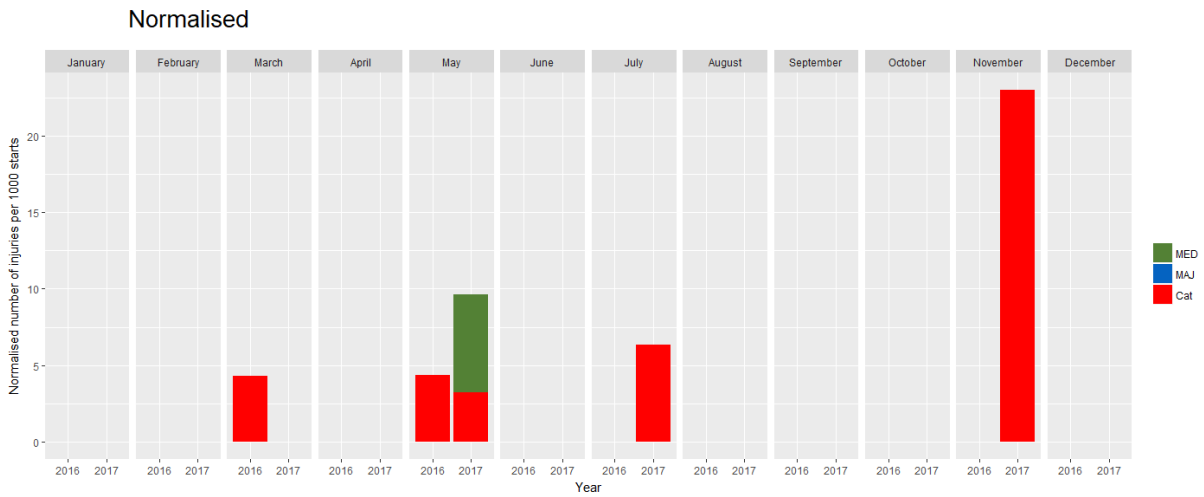

Figure 267: Muswellbrook track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

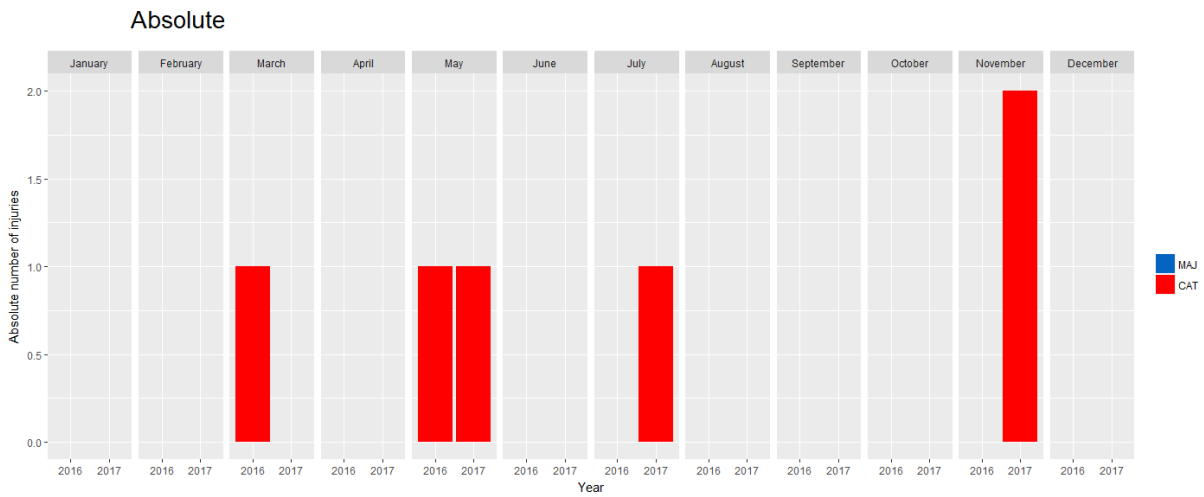

Figure 268: Muswellbrook track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

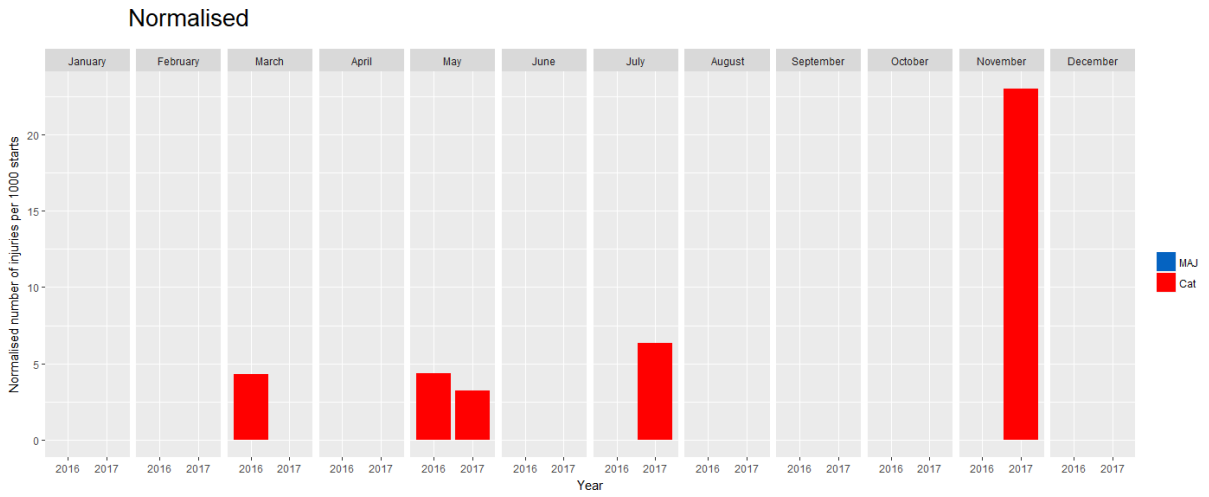

Figure 269: Muswellbrook track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

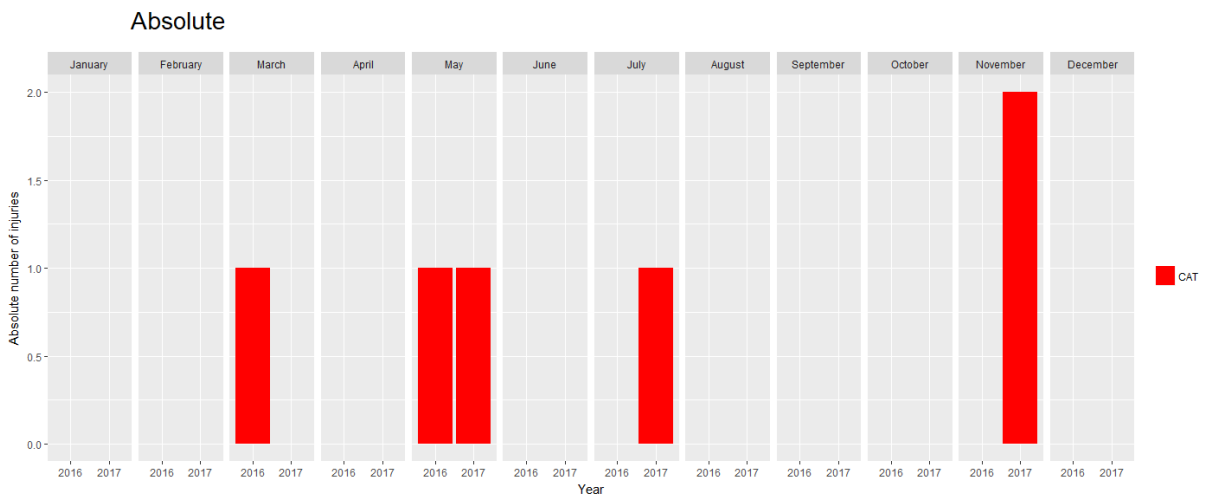

Figure 270: Muswellbrook track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

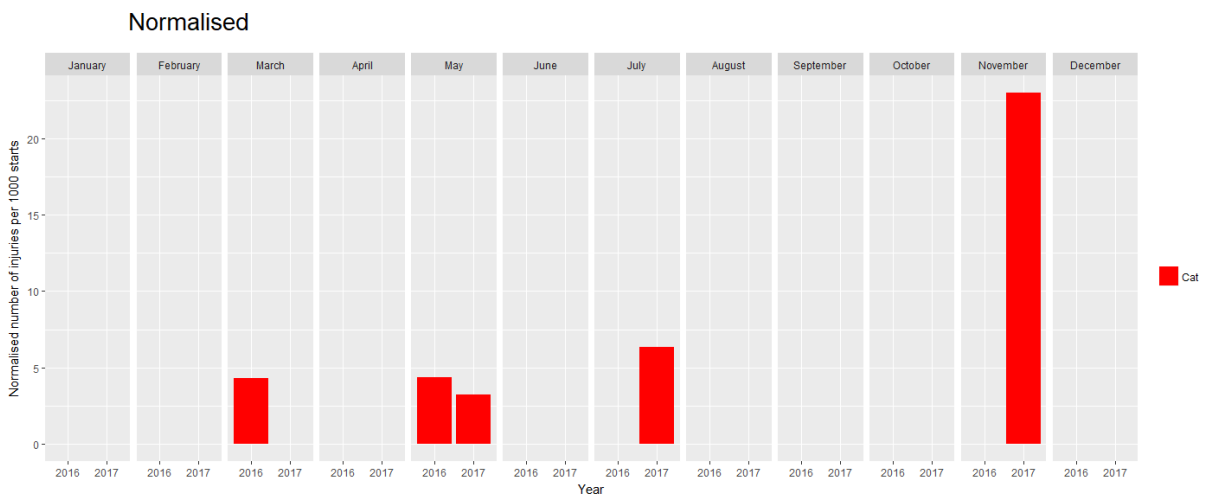

Figure 271: Muswellbrook track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

YOUNG

YOUNG: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.107 Figures 272 to 279 contain Young Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

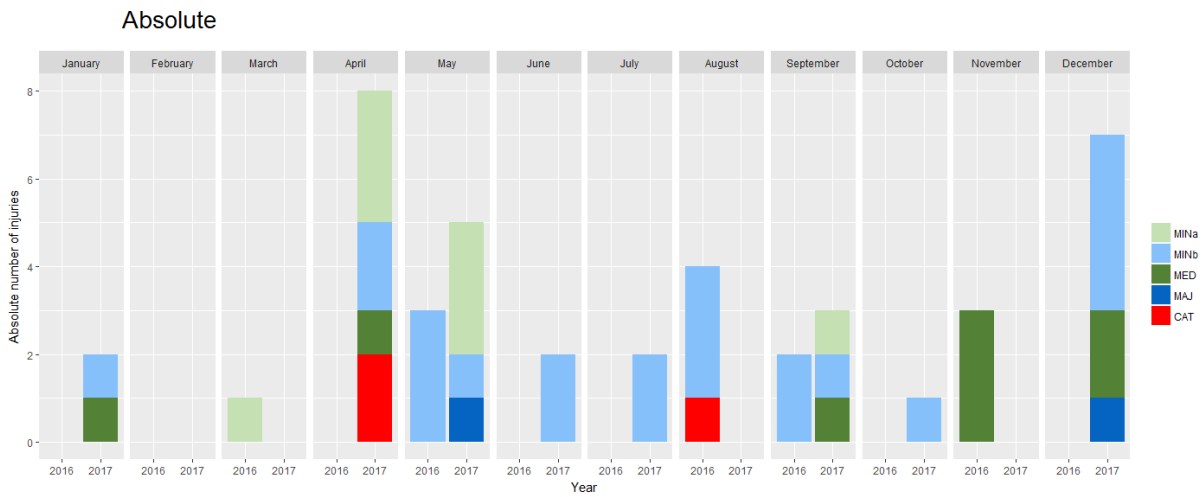

Figure 272: Young track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

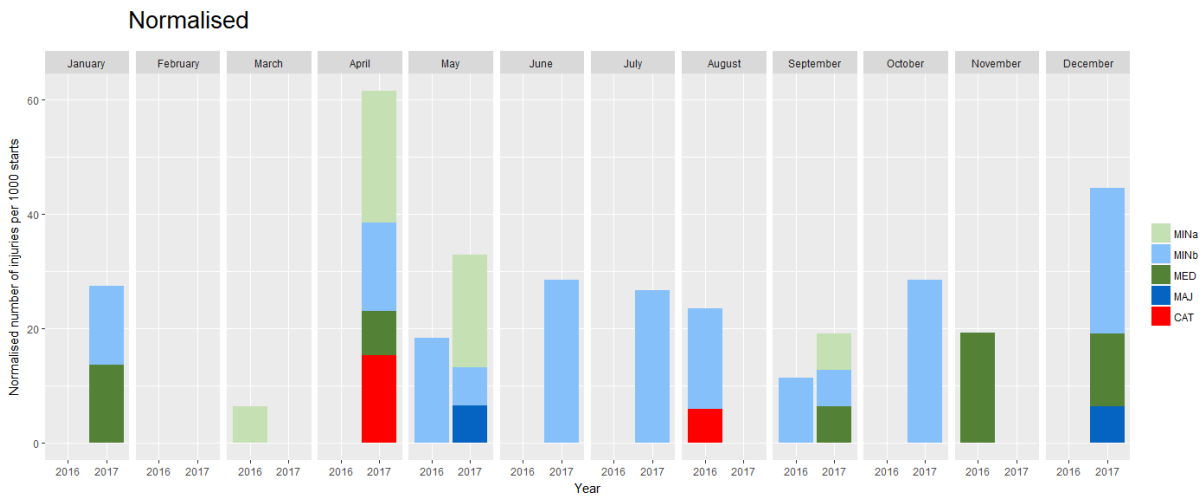

Figure 273: Young track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

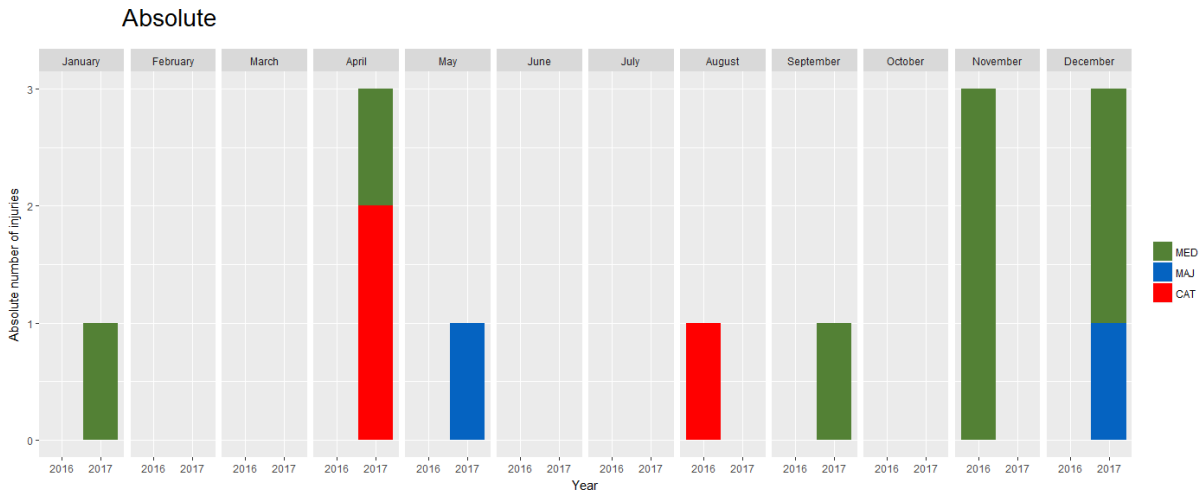

Figure 274: Young track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

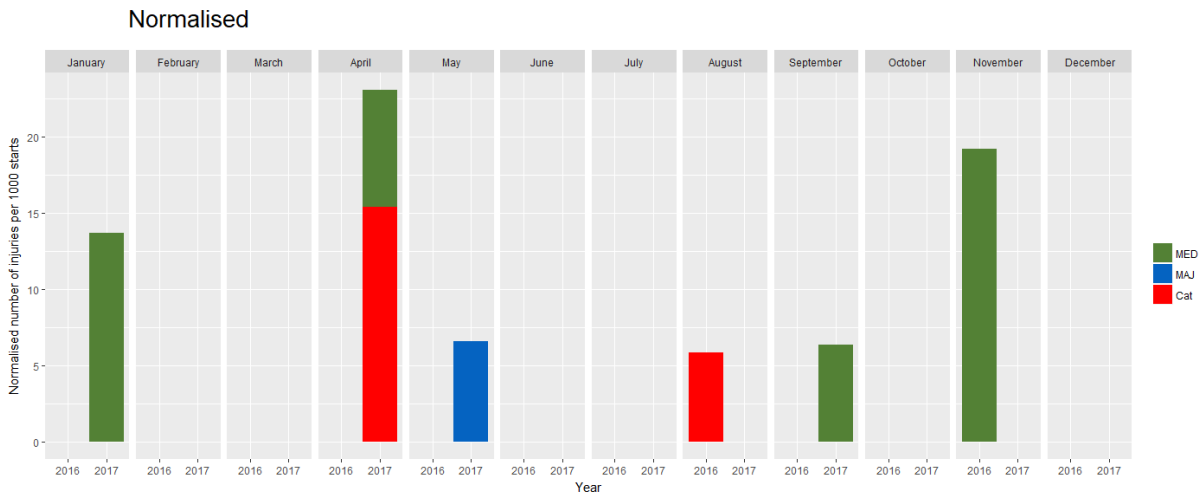

Figure 275: Young track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

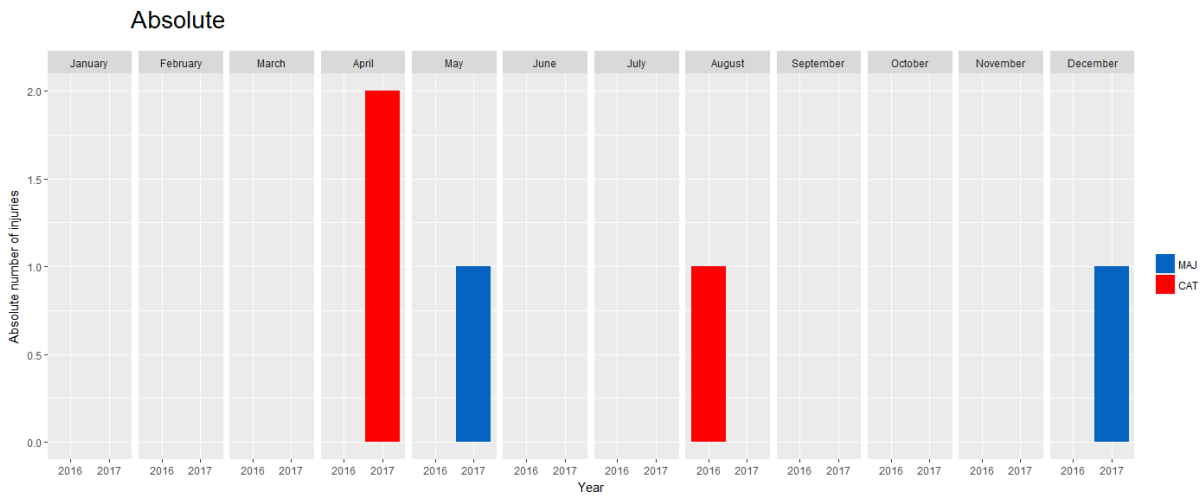

Figure 276: Young track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

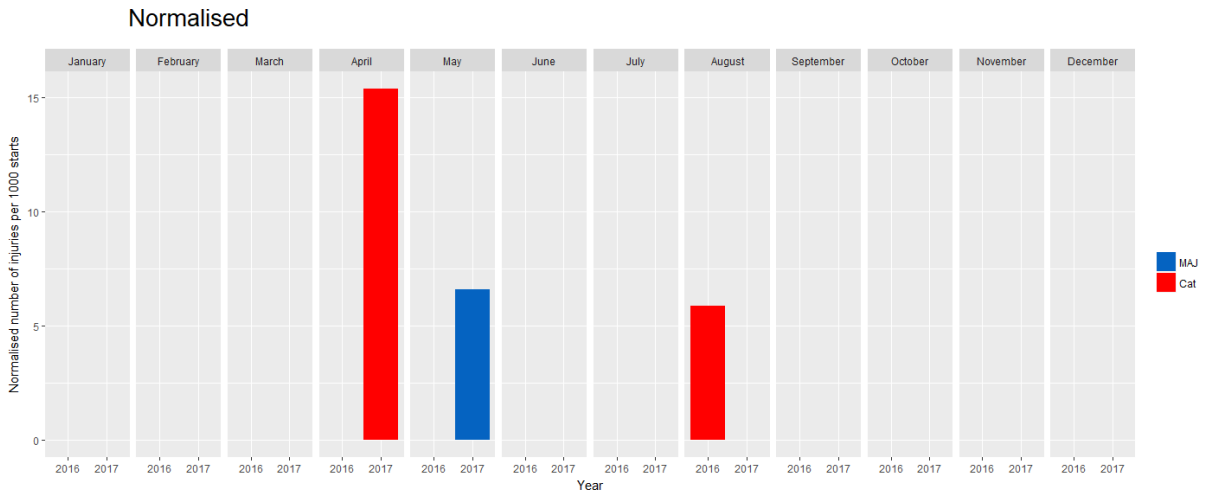

Figure 277: Young track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

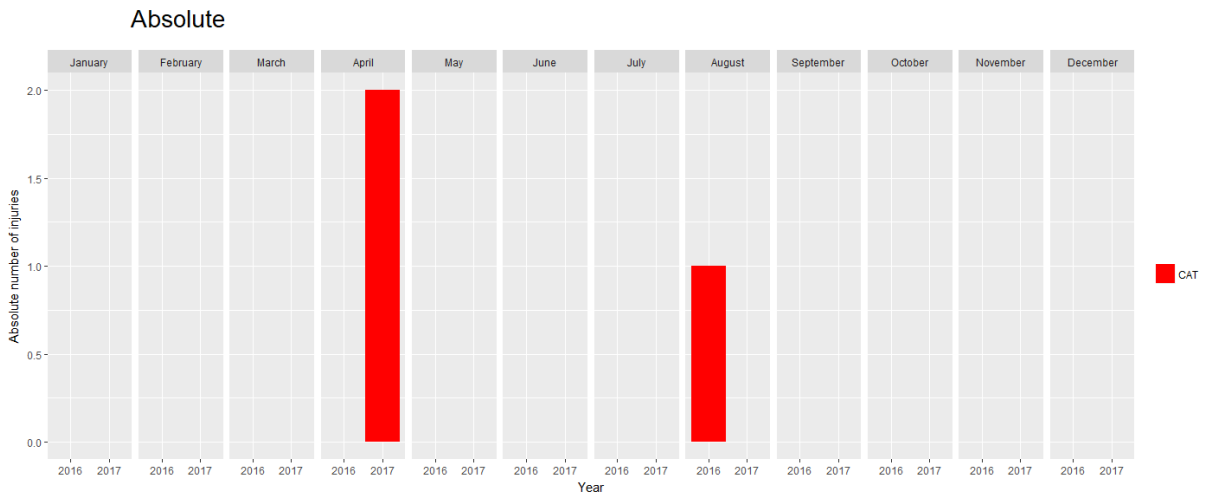

Figure 278: Young track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

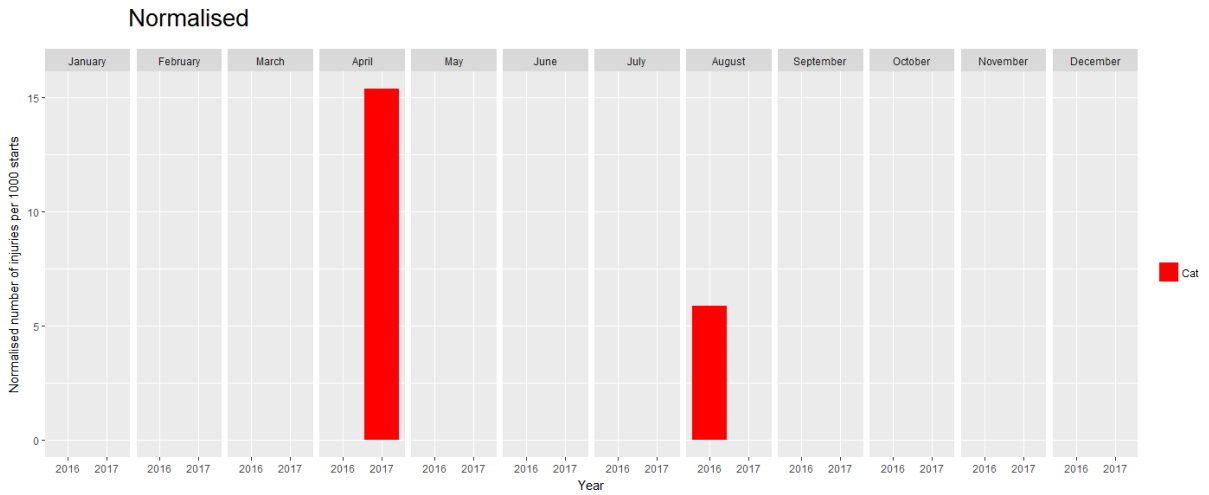

Figure 279: Young track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

COWRA

COWRA: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.108 Figures 280 to 287 contain Cowra Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

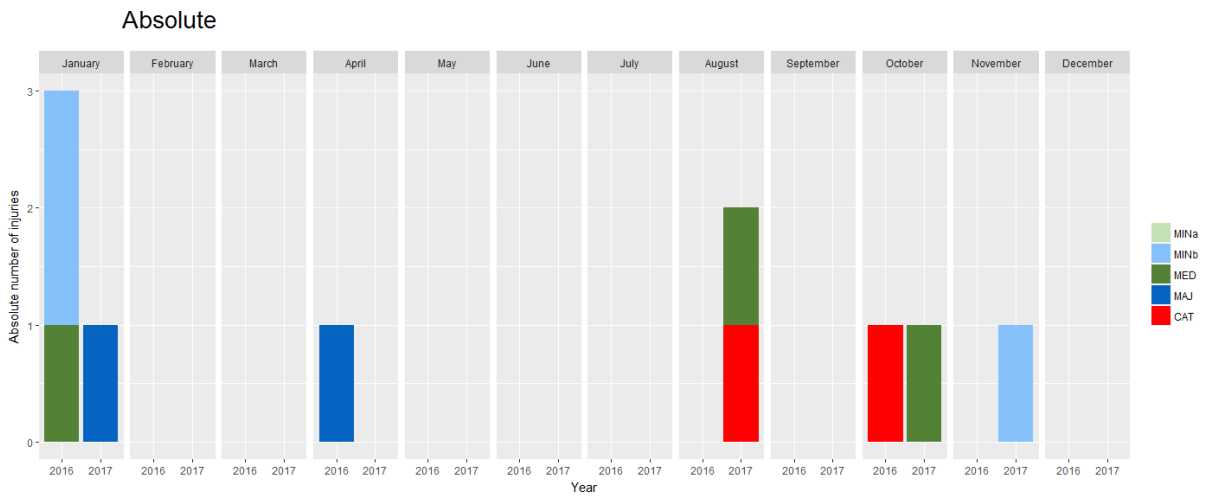

Figure 280: Cowra track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

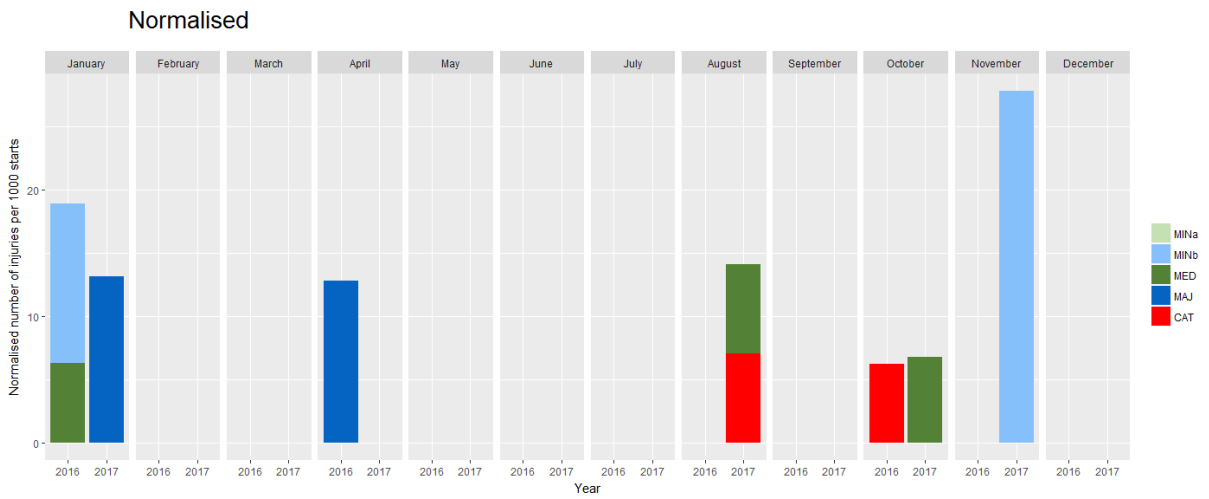

Figure 281: Cowra track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

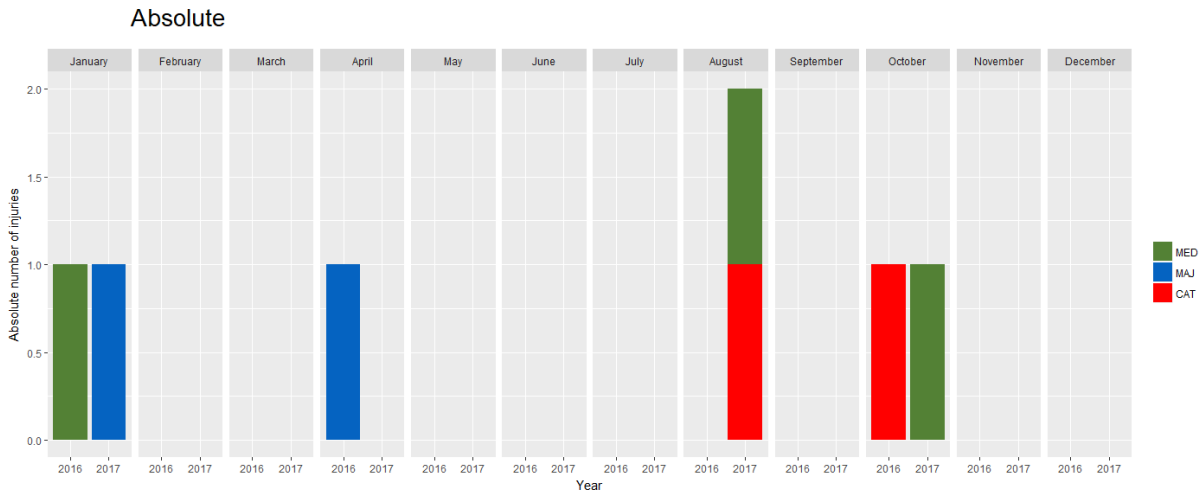

Figure 282: Cowra track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

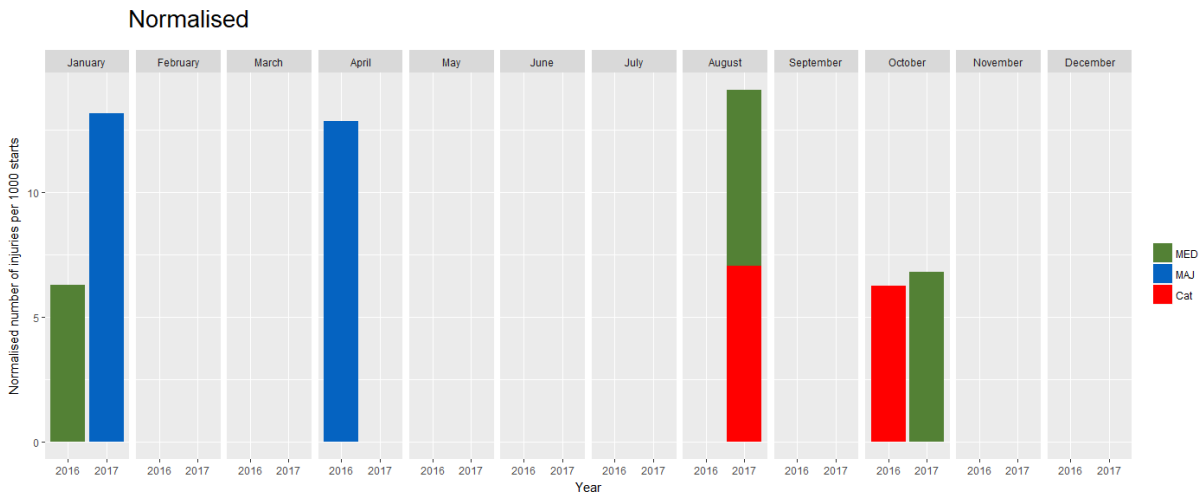

Figure 283: Cowra track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

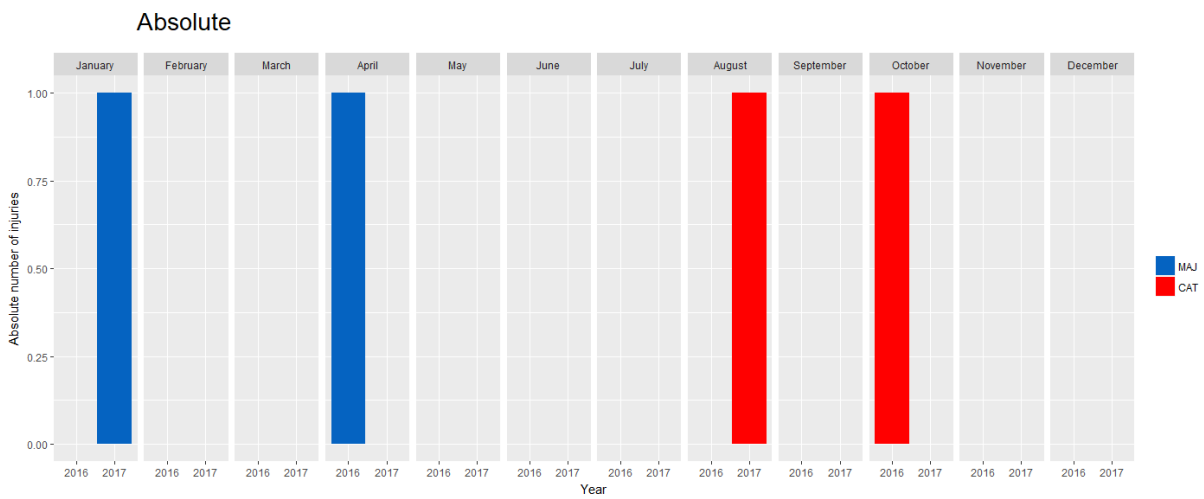

Figure 284: Cowra track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

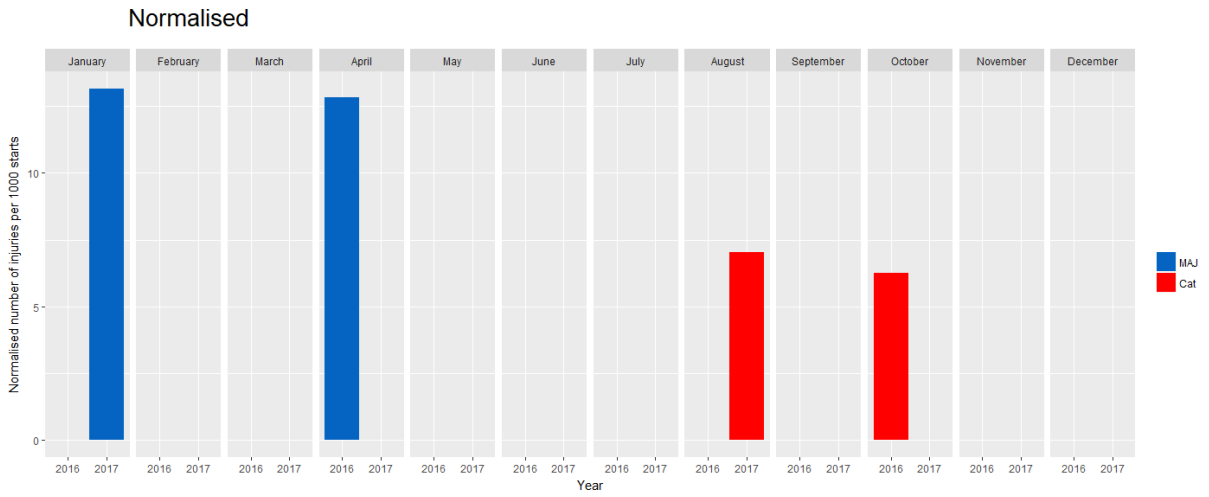

Figure 285: Cowra track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

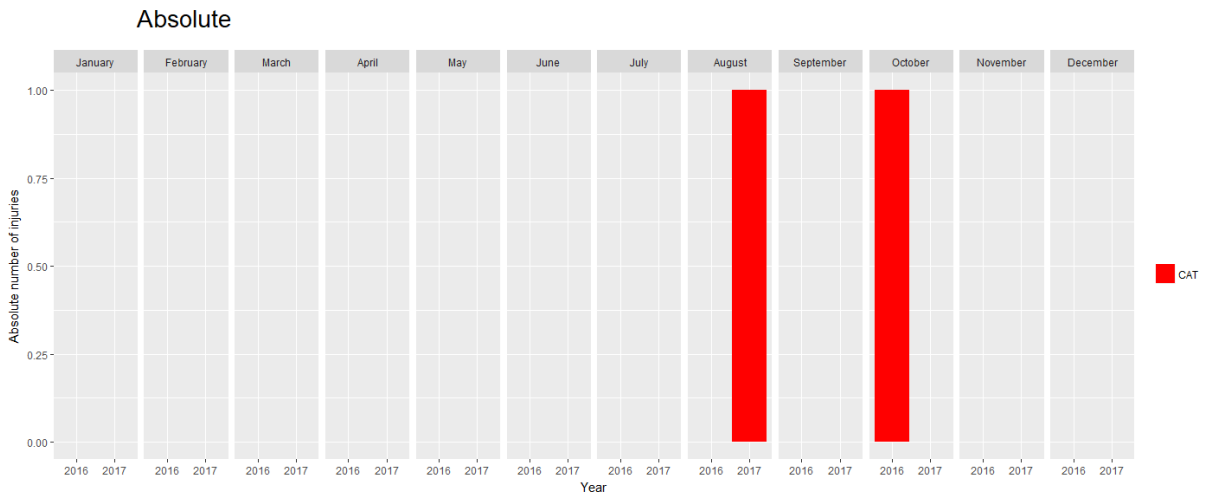

Figure 286: Cowra track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

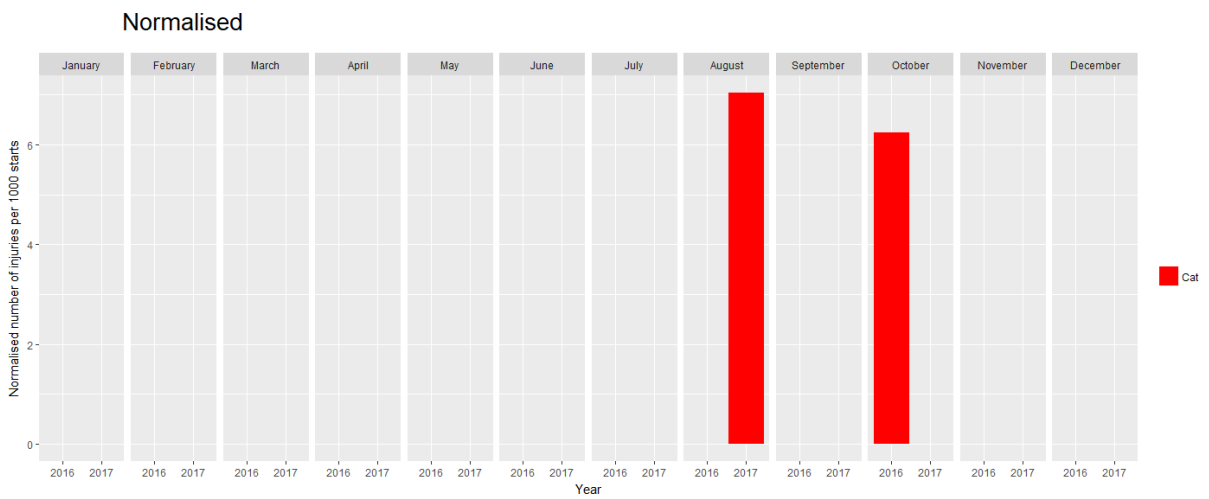

Figure 287: Cowra track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

ARMIDALE

ARMIDALE: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.109 Figures 288 to 295 contain Armidale Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

Figure 288: Armidale track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

Figure 289: Armidale track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

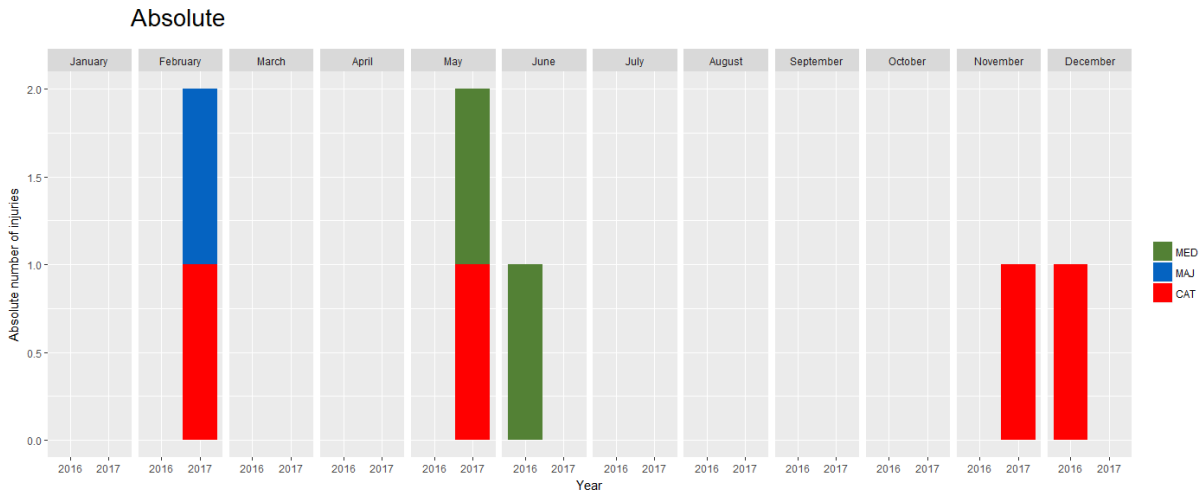

Figure 290: Armidale track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

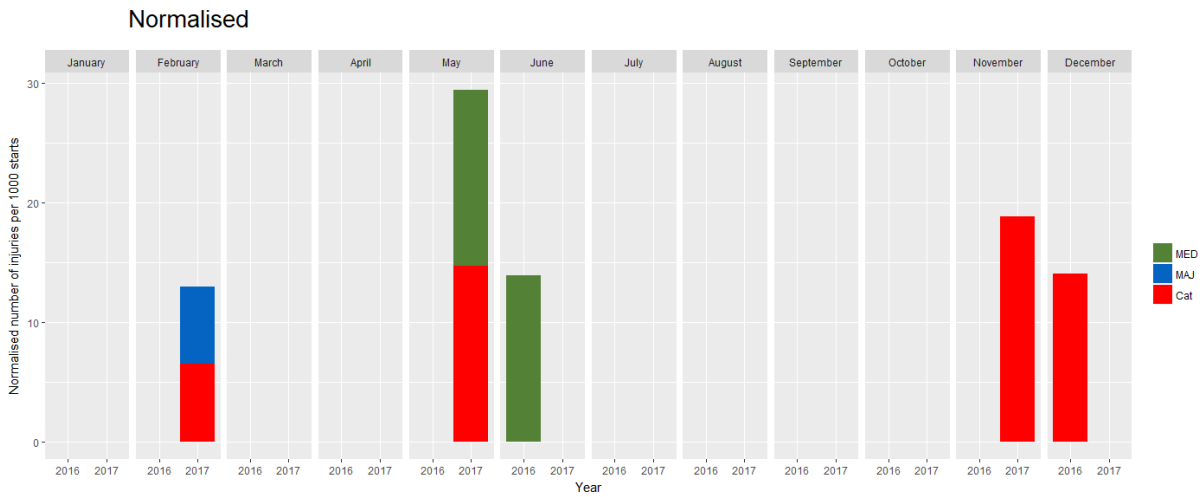

Figure 291: Armidale track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

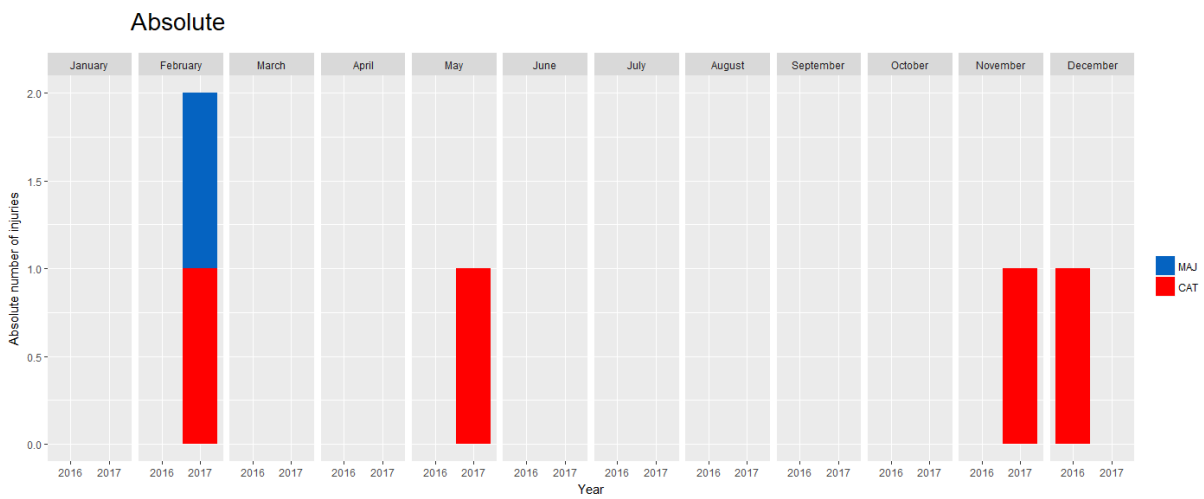

Figure 292: Armidale track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

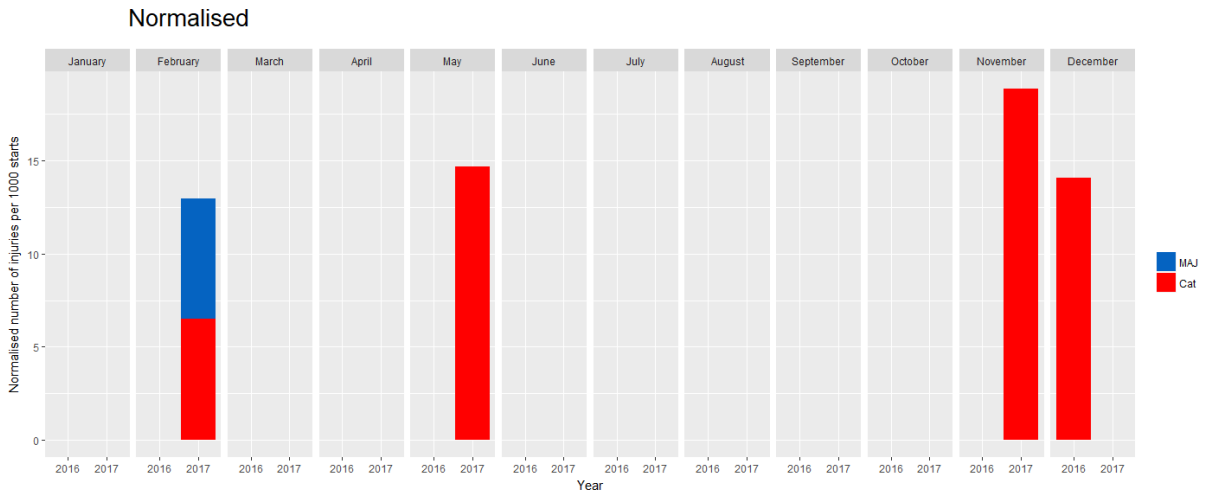

Figure 293: Armidale track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

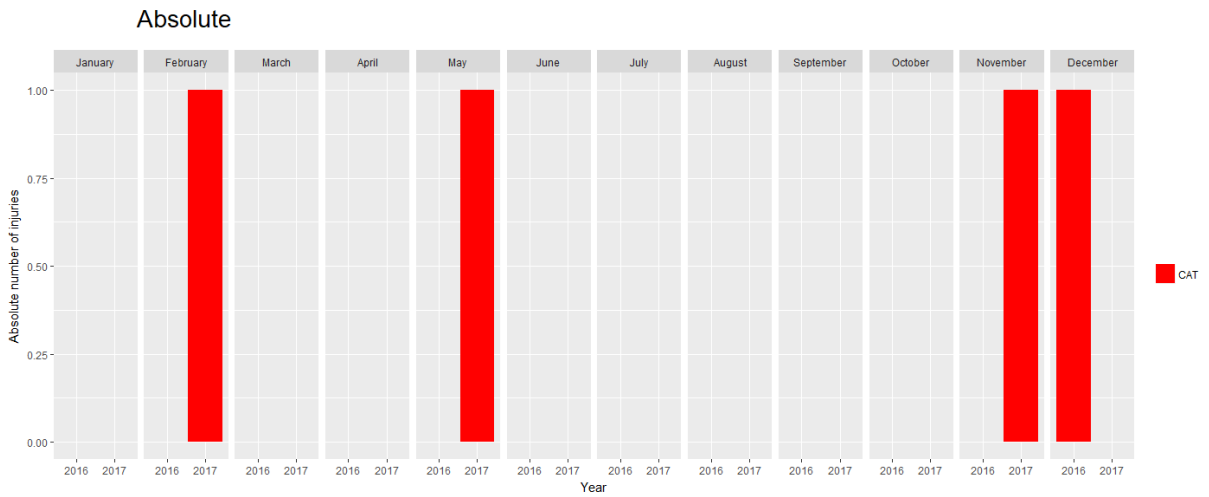

Figure 294: Armidale track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

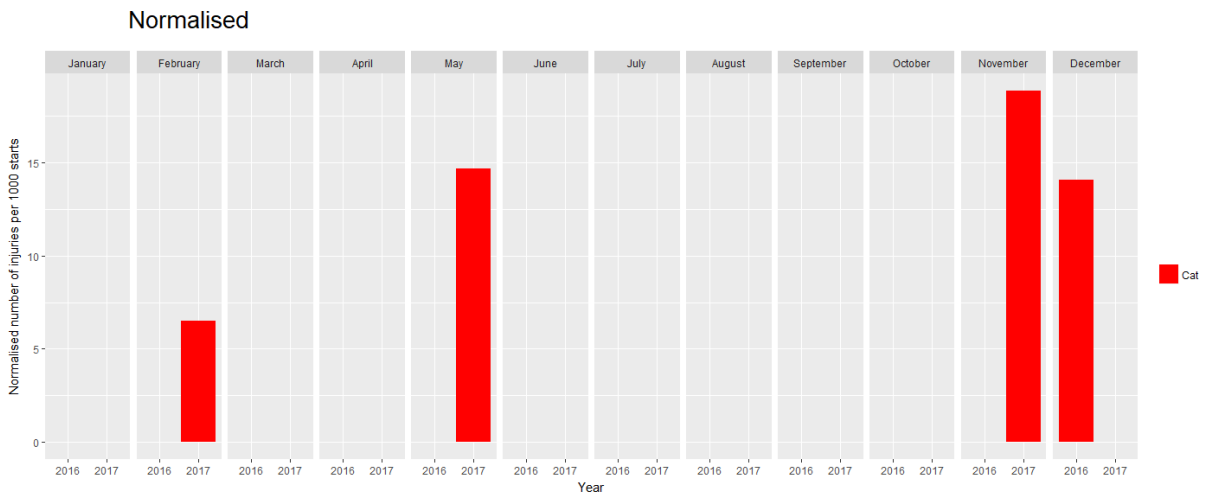

Figure 295: Armidale track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

BROKEN HILL

BROKEN HILL: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.110 Figures 296 to 303 contain Broken Hill Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

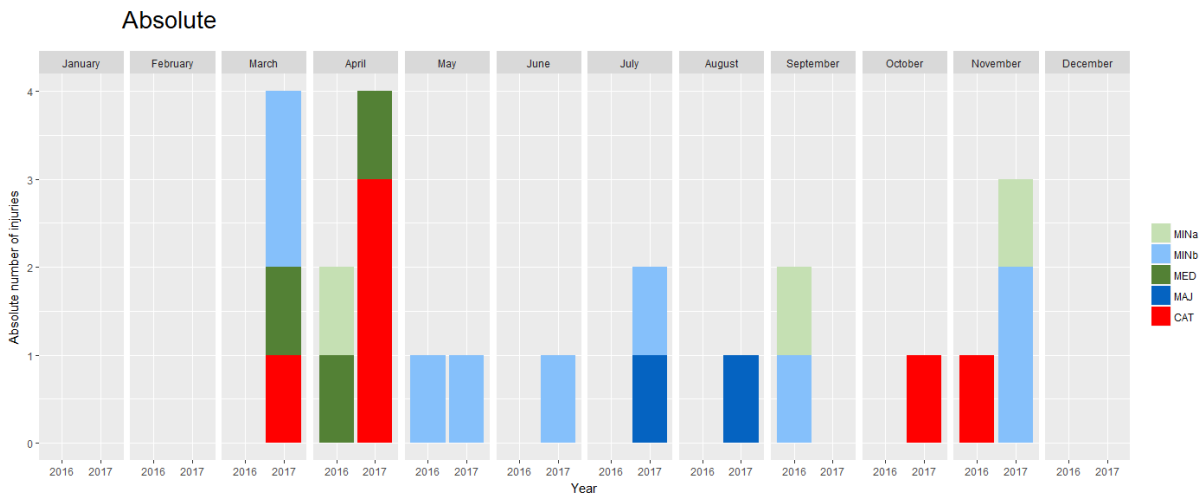

Figure 296: Broken Hill track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

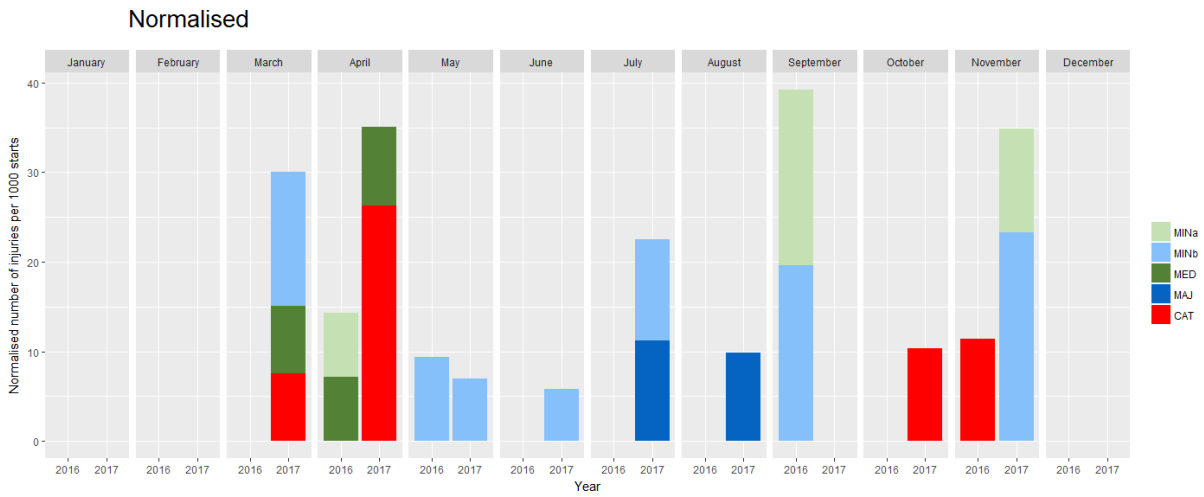

Figure 297: Broken Hill track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

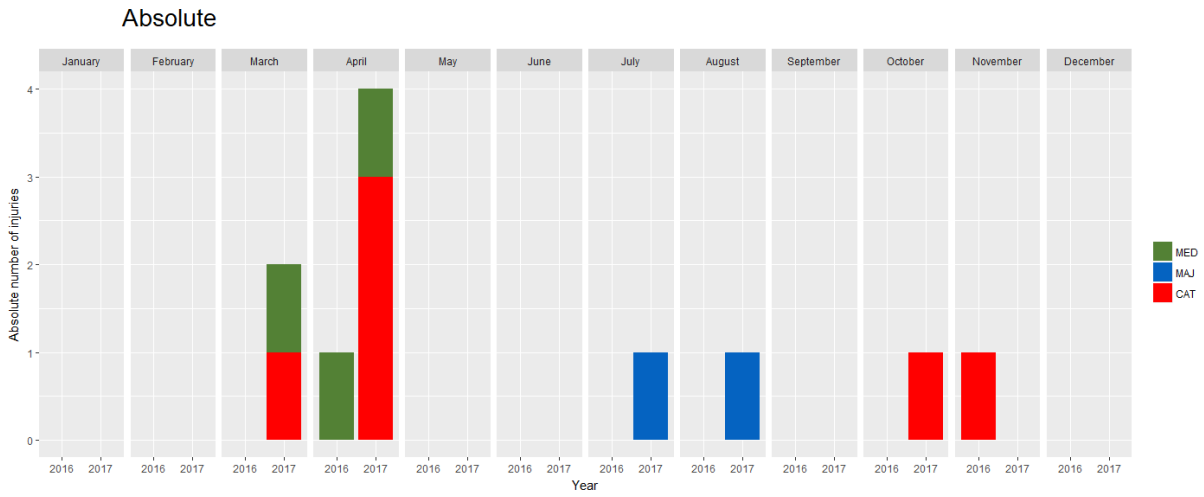

Figure 298: Broken Hill track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

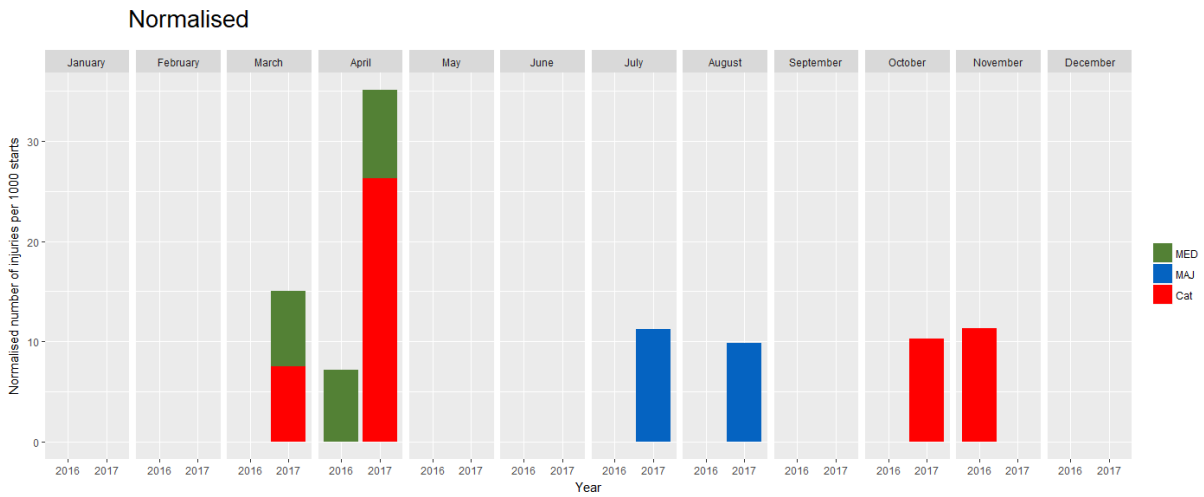

Figure 299: Broken Hill track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

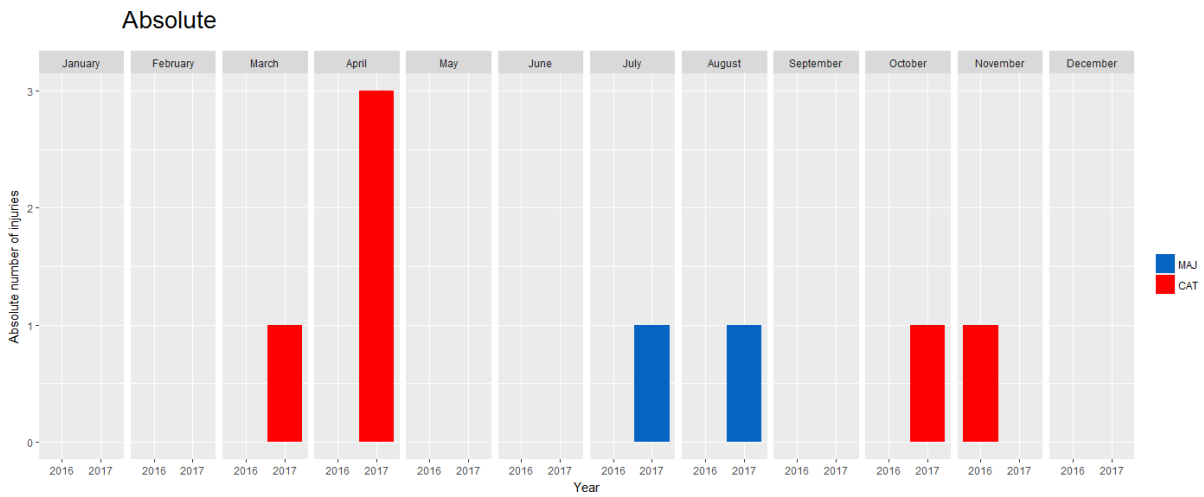

Figure 300: Broken Hill track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

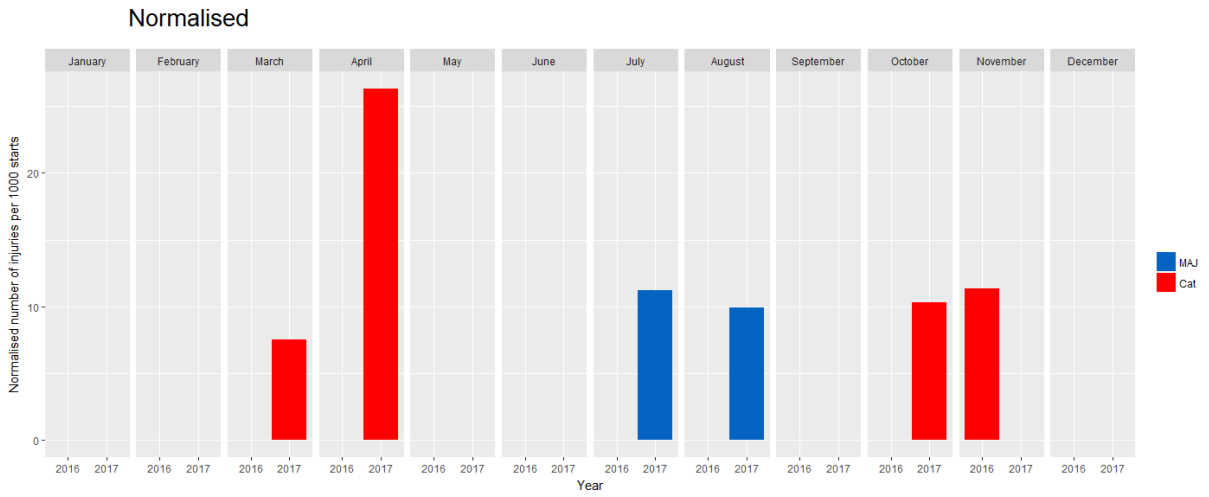

Figure 301: Broken Hill track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

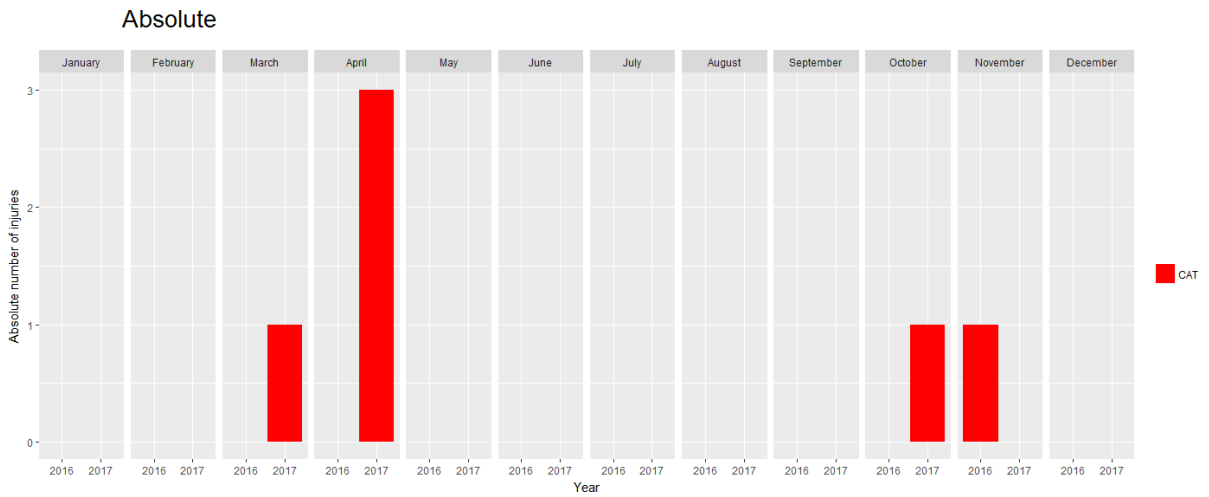

Figure 302: Broken Hill track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

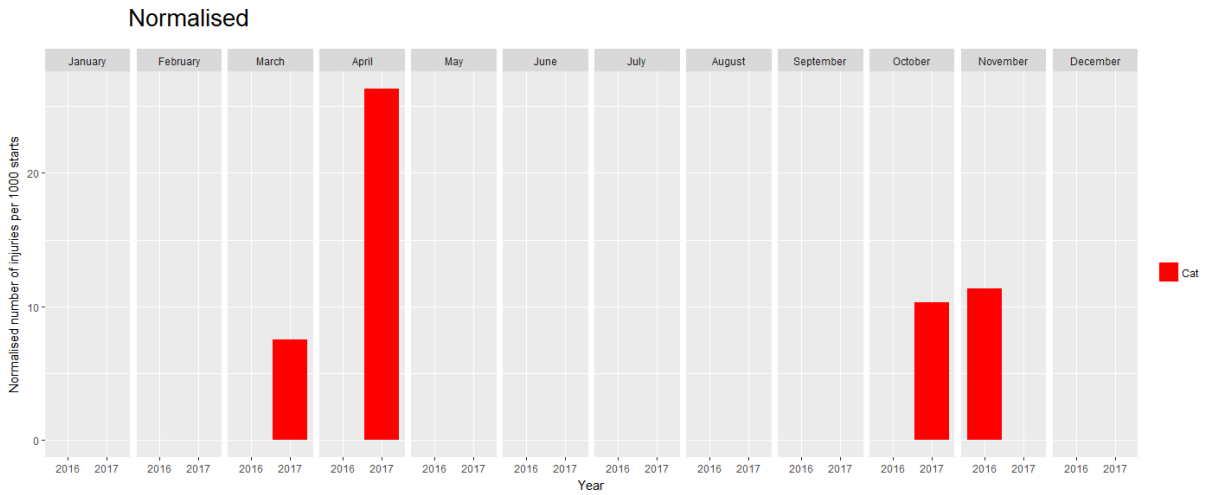

Figure 303: Broken Hill track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

WAUCHOPE

WAUCHOPE: ABSOLUTE AND NORMALISED INJURY RATE - 1 JAN 2016 TO 31 DEC 2017

3.111 Figures 304 to 311 contain Wauchope Level 1 to Level 4 injury data for each month in the period 1 Jan to 31 Dec 2017.

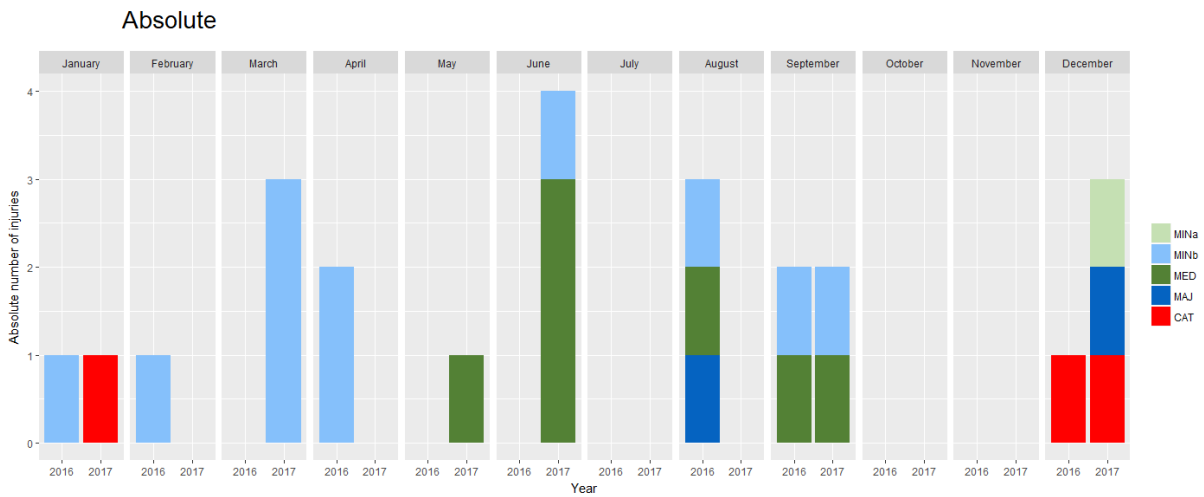

Figure 304: Wauchope track Level 4 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

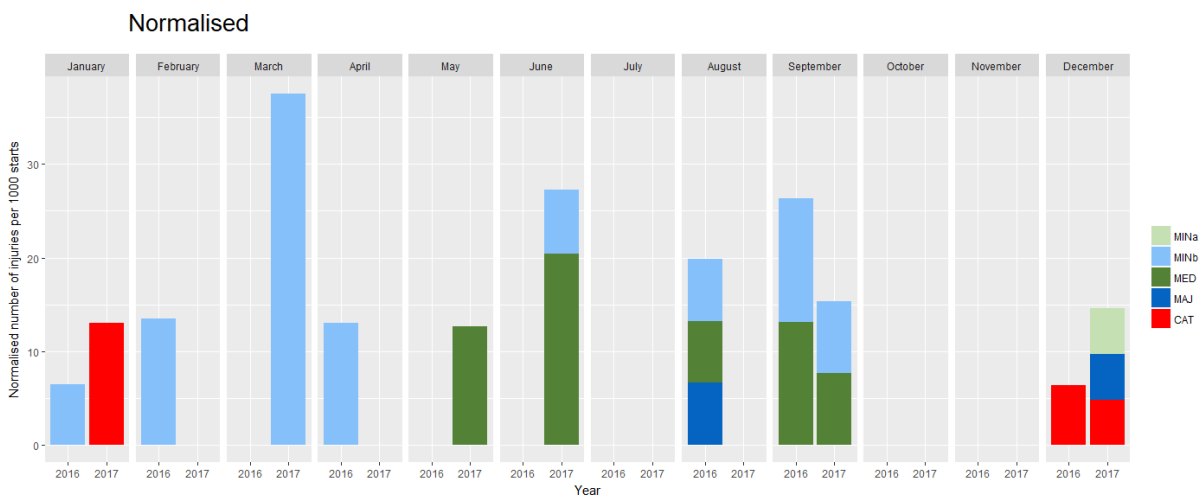

Figure 305: Wauchope track Level 4 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

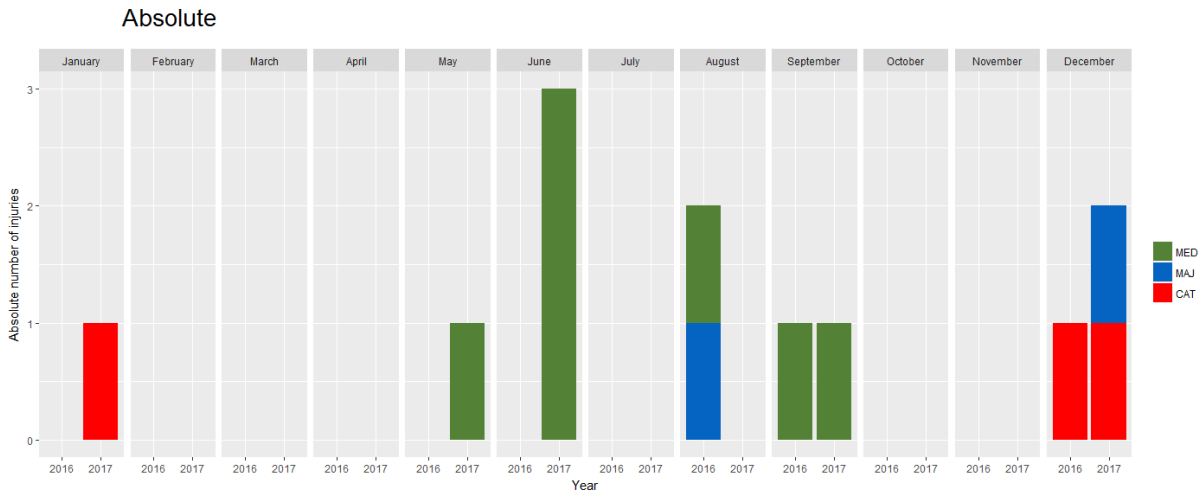

Figure 306: Wauchope track Level 3 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

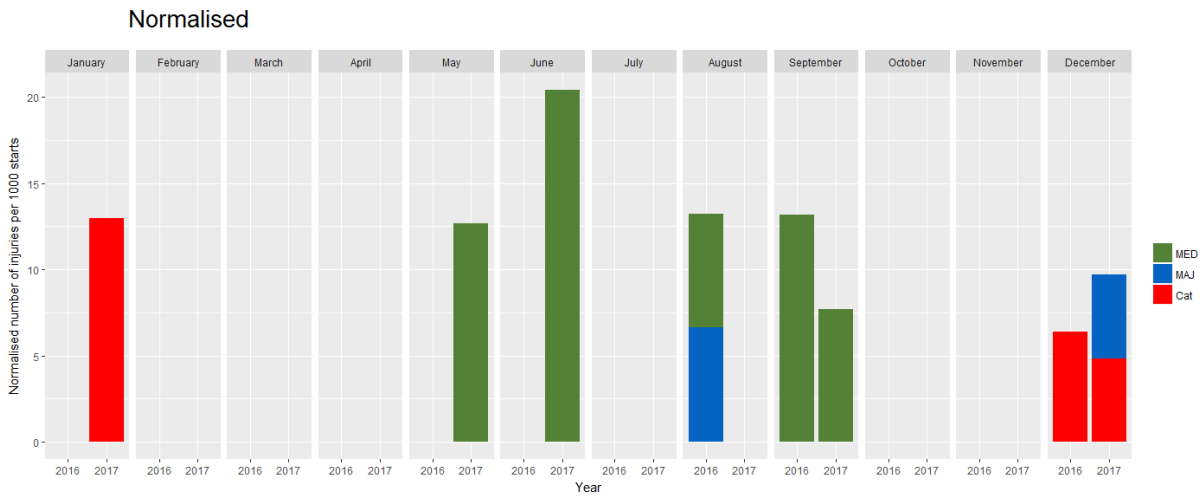

Figure 307: Wauchope track Level 3 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

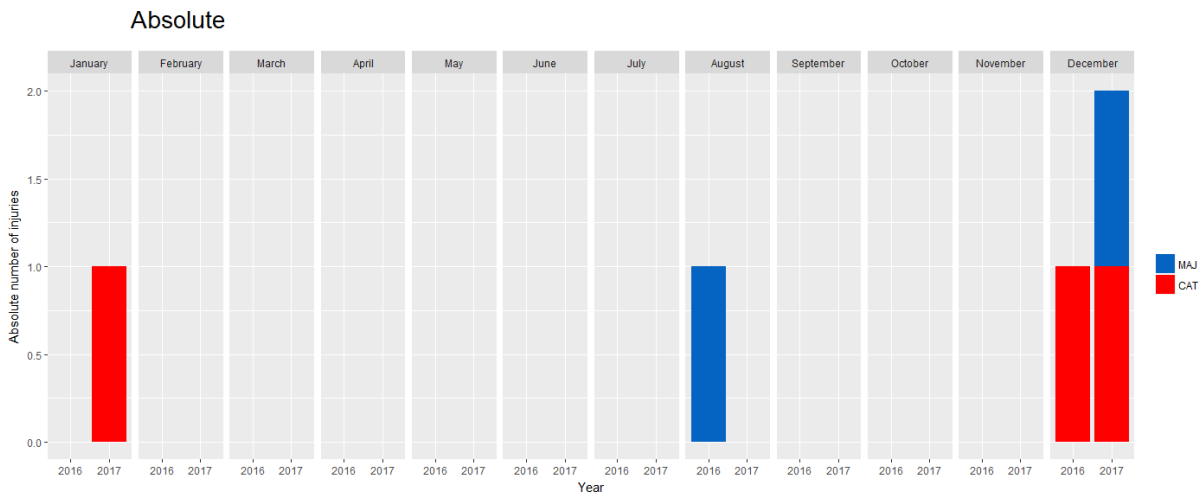

Figure 308: Wauchope track Level 2 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

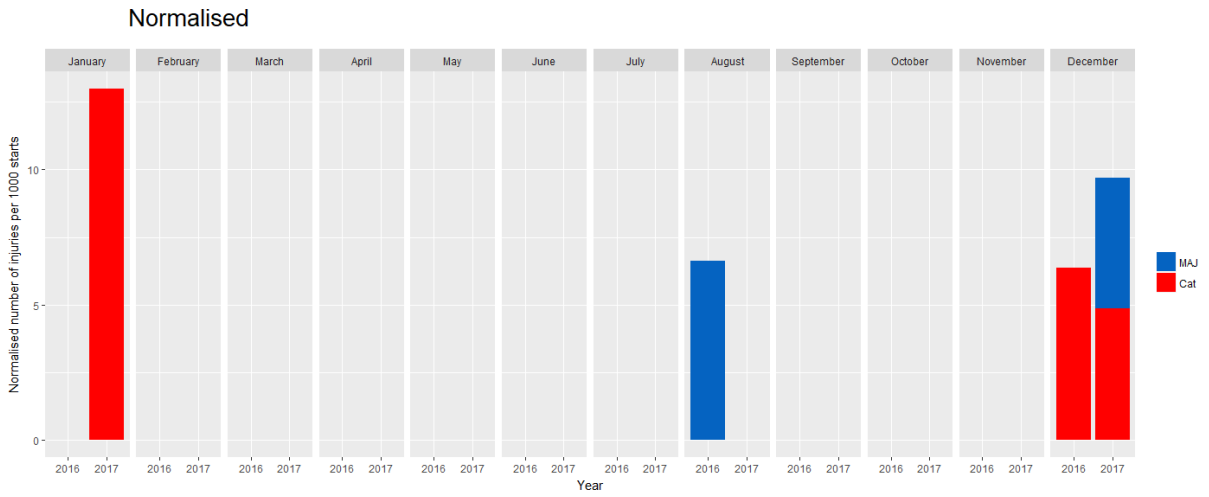

Figure 309: Wauchope track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

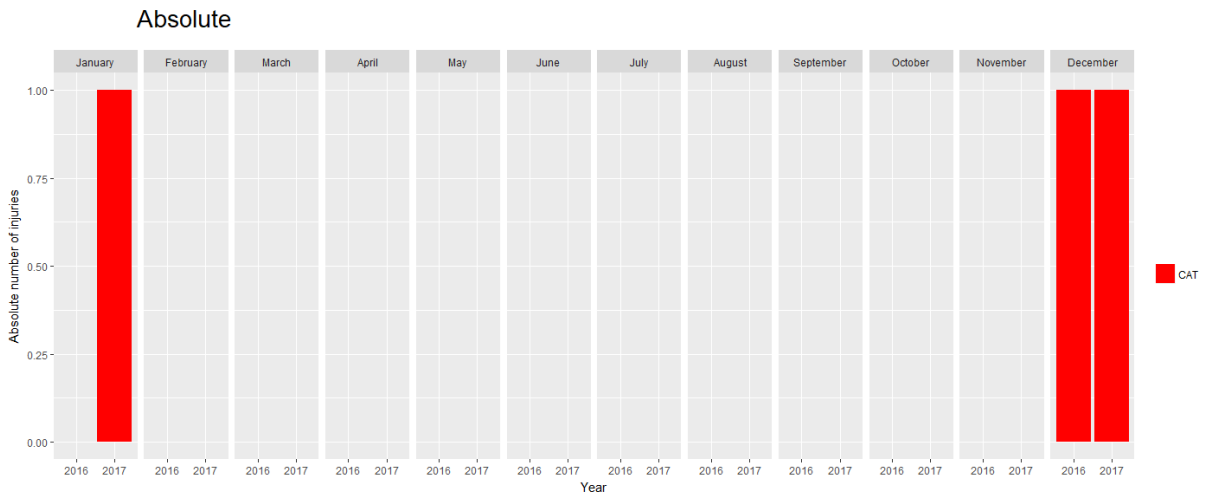

Figure 310: Wauchope track Level 1 absolute injury rate – 1 Jan 2016 to 31 Dec 2017

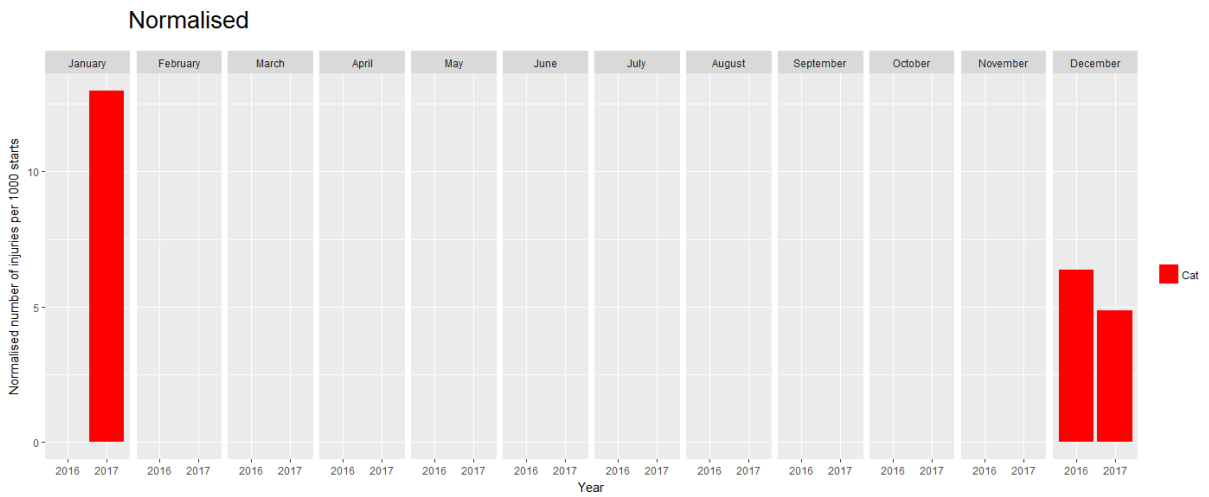

Figure 311: Wauchope track Level 2 normalised injury rate – 1 Jan 2016 to 31 Dec 2017

4 UTS DEVELOPED DATA ACQUISITION DEVICE

Variables of interest

4.1 UTS has determined a number of variables that may contribute to track related injuries. Some of these variables are inherent to greyhound physiology, performance and kinematics (i.e. the study of forces on moving objects) such as:

- Maximum Body Velocity

$$V_{max} = max(\frac{ds}{dt}), 0 < t < T \tag{1}$$

- Limb Contact Force

$$\vec{F_i} = m_i \vec{a_i} \tag{2}$$

- Limb Torsion

$$\tau = \vec{F_c} d_h \tag{3}$$

- Jerk

$$J = \frac{da}{dt}, 0 < t < T \tag{4}$$

- Centripetal Force

$$\vec{F_c} = \frac{mv^2}{r} \tag{5}$$

- Centripetal Acceleration

$$\vec{a_c} = \frac{v^2}{r} \tag{6}$$

- Kinetic Energy

$$E_k = \frac{1}{2} mv^2 \tag{7}$$

- Rotational Kinetic Energy

$$E_r = \frac{1}{2} I\omega^2 \tag{8}$$

...and others such as path of travel, line of sight, adjacent greyhound impacts (impulse $p = mv$) and quadruped stability on granular medium. Information that can be expected from these analyses can be used to investigate muscle trauma, joint trauma, internal force exposure and performance limitations on a per track and per greyhound basis. A kinematic analysis however requires baseline inertial information not readily accessible without specialised equipment. To understand the magnitudes and effects of the variables above, we must resolve the state of the greyhound for each instance of time.

4.2 The state of a greyhound can be defined as its translation (x, y, z) with reference to a global track coordinate origin, the respective rotations (θ, β, γ) about the track coordinate axis, the velocity vector $(\vec{v})$, the rotational velocity about the track coordinate axis $(\omega_x, \omega_y, \omega_z)$ and the acceleration vector $(\vec{a})$. We will define this as:

$$G = \left[X, Y, Z, \theta, \beta, \gamma, \omega_x, \omega_y, \omega_z, \vec{v}, \vec{a}\right] \tag{9}$$

Note: The state G assumes a single moving mass. For independent resolution of components in a high-dimensional multi-mass model, G grows to an $11n$-dimensional vector with n being equal to the number of independent moving components being modeled. If we assume a model consisting of a coupled body mass with upper and lower limb components then the system state can be defined within a maximum of 99 dimensions. We can reduce the number of dimensions by imposing mechanical constraints on the system. Ball and socket joints remove translation from all coupled components. We can therefore remove linear velocity and acceleration. To further simplify the model, we can assume no torsion in the longitudinal axis and no lateral rotation for each limb. What we are left with is:

$$G = \left[x, y, z, \theta, \beta, \gamma, \omega_x, \omega_y, \omega_z, \vec{v}, \vec{a}, \alpha_1, \omega_1, \ldots, \alpha_8, \omega_8\right] \tag{10}$$

…where the relative origins of each mass (x_{i0}, y_{i0}, z_{i0}) are known with respect to the reference body mass. Now that the variables have been defined encompassing the state of a greyhound in motion, a method is required to obtain the values for the state equation. UTS has developed a device to allow the acquisition of this required kinematic information.

Integrated kinematic measurement system

Figure 312: iKMS V1.1 central acquisition unit

4.3 The Integrated Kinematic Measurement System (iKMS) allows tracking of on-track position, tri-axial body rotation, tri-axial linear body acceleration and tri-axial magnetic heading and with rotational velocities of limb segments through

additional sub-units (as of version 2.0). The device is capable of acquiring up

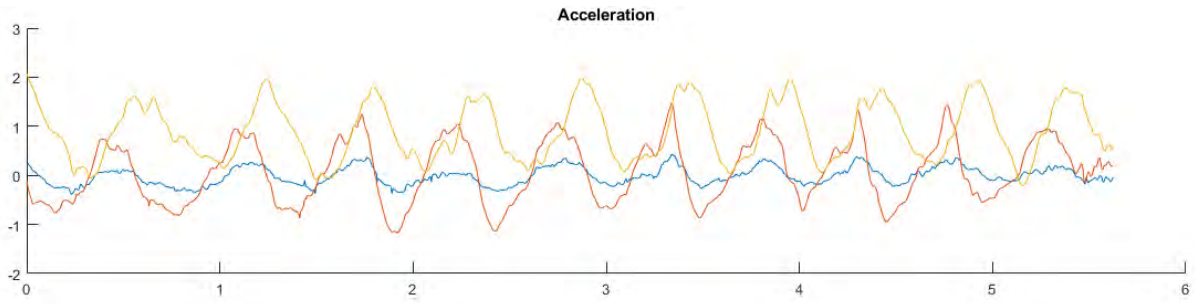

Figure 313: A readout sample of tri-axial acceleration over time

to 9 degrees of freedom for the integrated version and 63 degrees of freedom for the modular version in addition to real-time GPS location. Intelligent data fusion algorithms allow practicable and informative data readouts for use in the evaluation of greyhound performance and welfare on the track.

Planned verification and test schedule

4.4 The iKMS has been through a number of engineering phases throughout 2017 with additional functionality increasingly integrated over several board revisions. Verification runs are planned for the most current revision at several tracks throughout NSW in 2018. Additional functionality and peripherals are in the planning stages. A data set of sufficient size is required for statistically significant conclusions to be formed around greyhound performance and welfare, hence UTS requires the deployment of these modules to as many greyhounds as possible over a minimum 12 month period.

5 TRACK MODELLING AND RACING SIMULATION

INTRODUCTION

5.1 This chapter outlines some of the findings as a result of racing simulation and modelling of tracks during the year 2017. The chapter also briefly looks into work limitations imposed by data availability, suitability of the results, and future work related to designing optimum greyhound racing tracks.

SIMULATION AND MODELLING NEED

5.2 The modelling of greyhound racing tracks helps identify finer details of tracks which may be a contributing factor for non-optimum racing conditions. Furthermore, modelling aims at looking into individual track factors which are otherwise complex to comprehend and fine tuning them to derive a reasonably practical solution which copes well with every other racing variable. The simulation of greyhound racing on the other hand helps produce theoretical results for greyhound dynamic conditions and predict racing variables which would require optimisations. In the broader sense, both simulation and modelling aim at verifying and fine tuning of greyhound racing conditions for optimum track design.

GREYHOUND ATTACK ANGLE RELATIVE TO BOX ALIGNMENT

5.3 A greyhound's attack angle measures how quickly a greyhound can turn or change direction during a race. Simulation data shows that within the first few hundred milliseconds into the race the greyhounds reach their maximum attack angle.

5.4 The maximum attack angle is produced as a result of the starting box's alignment and orientation towards the track. The attack angle is an important factor because it contributes to injuries that may occur while greyhounds are leaving the starting boxes. As such the higher the attack angle the higher the risk of injury.

5.5 The result of this becomes visible as the data show that most of the injuries occur on the first corner due to the tracks hazardous conditions and the musculoskeletal strain applied to the greyhounds due to the high attack angle from leaving the starting boxes.

5.6 The greyhounds attack angle varies depending on the size of the lure, the design of the track and the box alignment and orientation. This means that there is no one size fits all solution as they will all be track specific.

5.7 The following simulation videos show straight and bend start boxes to track greyhound transition for Grafton and Casino tracks for 610 m and 620 m starts respectively. From the videos it can be seen that bend starts such as the Casino 620 m start provide a more streamlined box to track navigation path for greyhound.

Grafton 610 m start simulation videos:

https://drive.google.com/open?id=1-XtMIdEctAYhIPbCvLjFMNVK3uyOKdxu

https://drive.google.com/open?id=15zMpc_pFvZTdJKOOTX2xCrnMx9pl33yj

https://drive.google.com/open?id=1JOdzJK_-UEqi7DyXjdhMHcohisCRJ7oB

Casino 620 m start simulation videos:

https://drive.google.com/open?id=1G2wre2BWvwiWnf8s78tXjmHtn_NbU-IJ

https://drive.google.com/open?id=1dOxNOqcKTE7FWpQ09E5DoUCs1wEJk1DV

5.8 Heading attack angle of a greyhound on the track can be used as a parameter for measuring the greyhound's lateral dynamics stability. Fluctuations or dramatic change in the attack angle of a greyhound result in substantial lateral dynamics jerks.

5.9 The following graphs were selected from simulated data which show the attack angle of a greyhound closest to the rail as simulated against surveyed data for different distances race starts for the Gosford and Murray Bridge tracks. The heading attack angle burst within 900 milliseconds is due to box alignments on the track. The graphs show the typical effect of different box alignments.

5.10 Gosford 515 m start created a maximum attack angle of approximately 3.4 rad/s (Figure 314).

5.11 Gosford 400 m and 600 m starts generated similar attack angles of approximately 1.8 rad/s and 2 rad/s respectively (Figures 315 and 316).

5.12 Murray Bridge 530 m start produced the smallest attack angle of approximately 0.69 rad/s (Figure 317).

5.13 Murray Bridge 455 m start produced a higher attack angle than Murray Bridge 530 m start of about 1.86 rad/s (Figure 318).

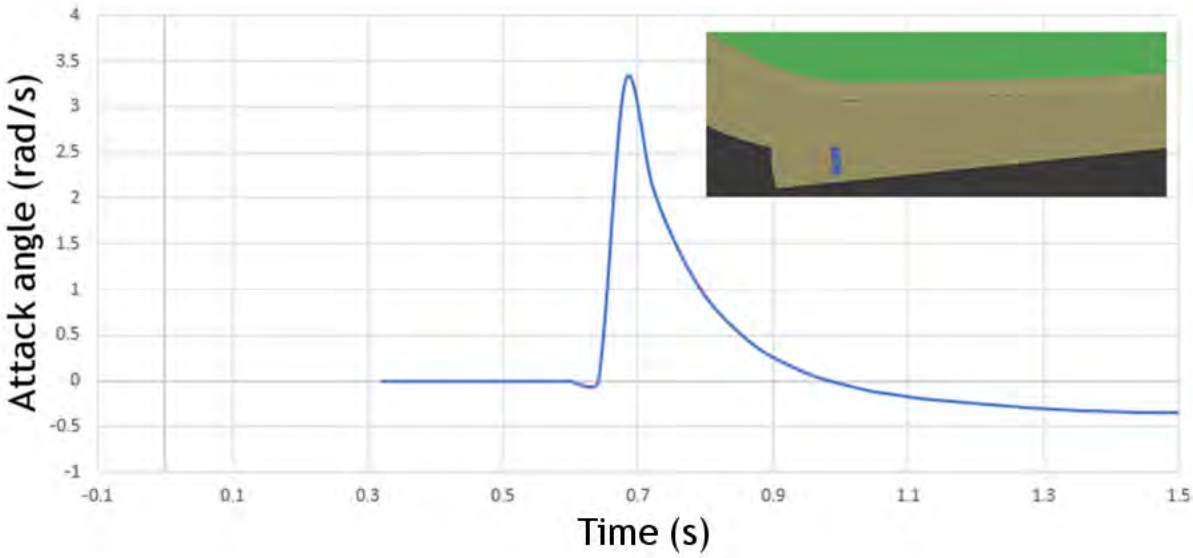

Figure 314: Gosford track 515 m start greyhound attack angle

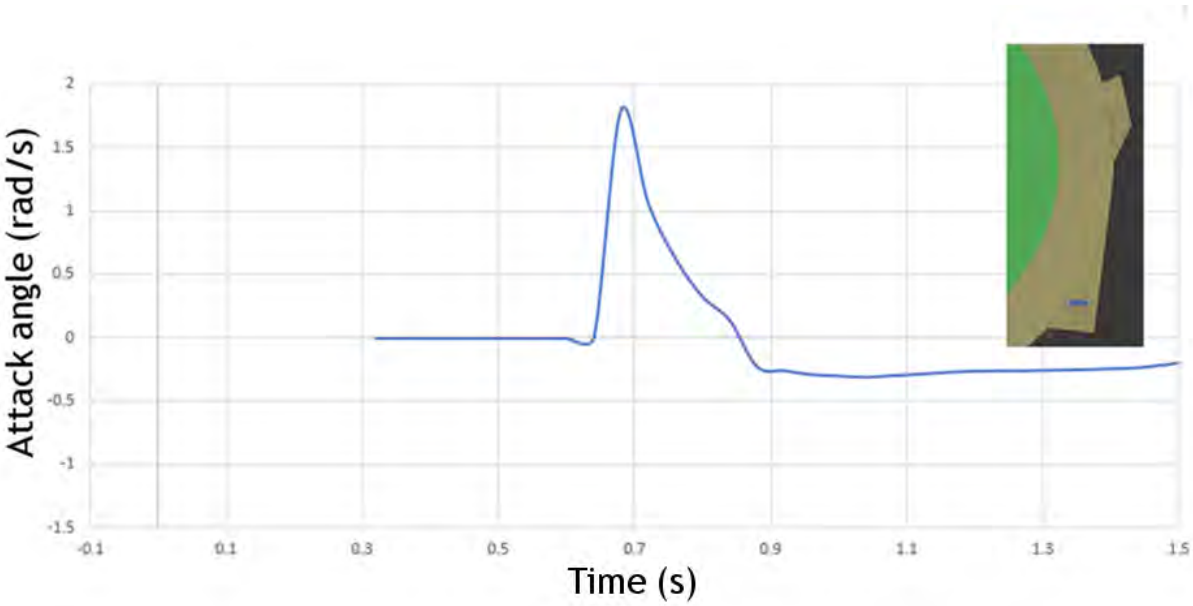

Figure 315: Gosford track 400 m start greyhound attack angle

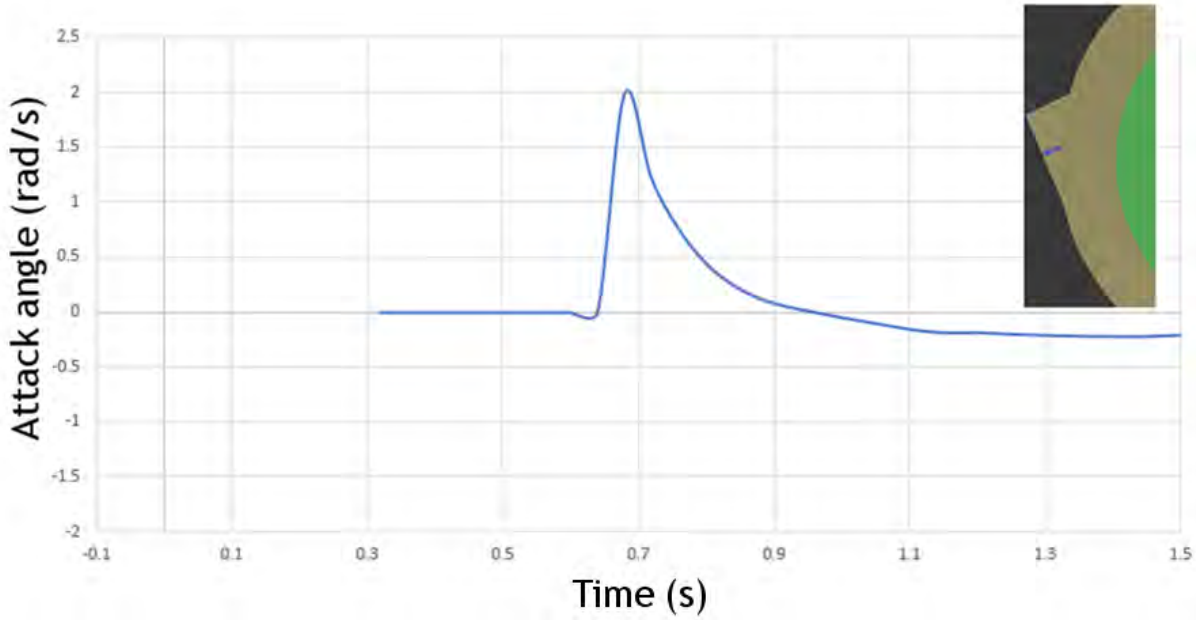

Figure 316: Gosford track 600 m start greyhound attack angle

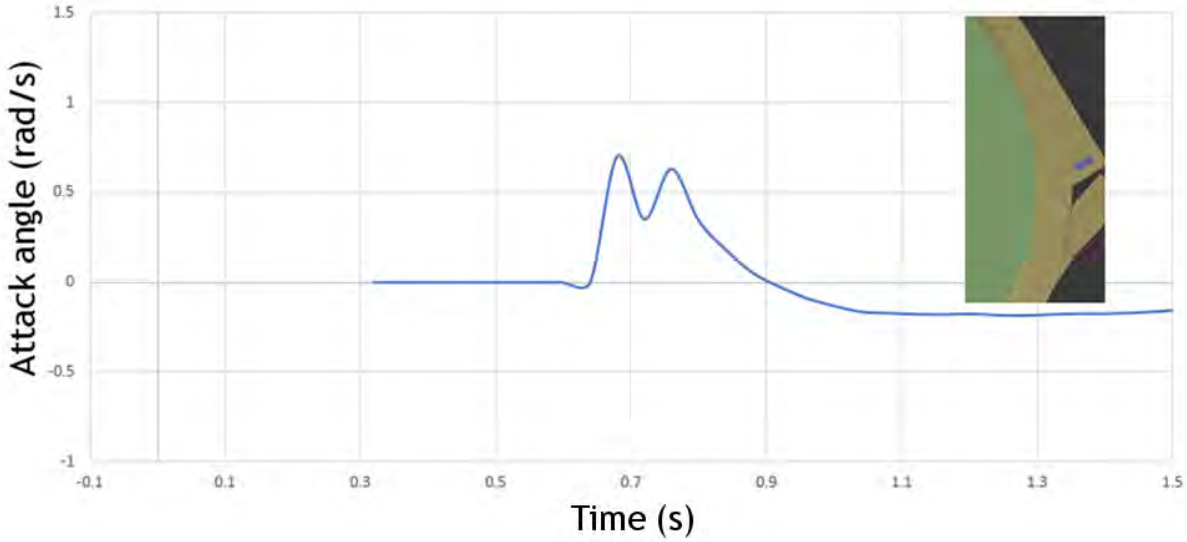

Figure 317: Murray Bridge track 530 m start greyhound attack angle

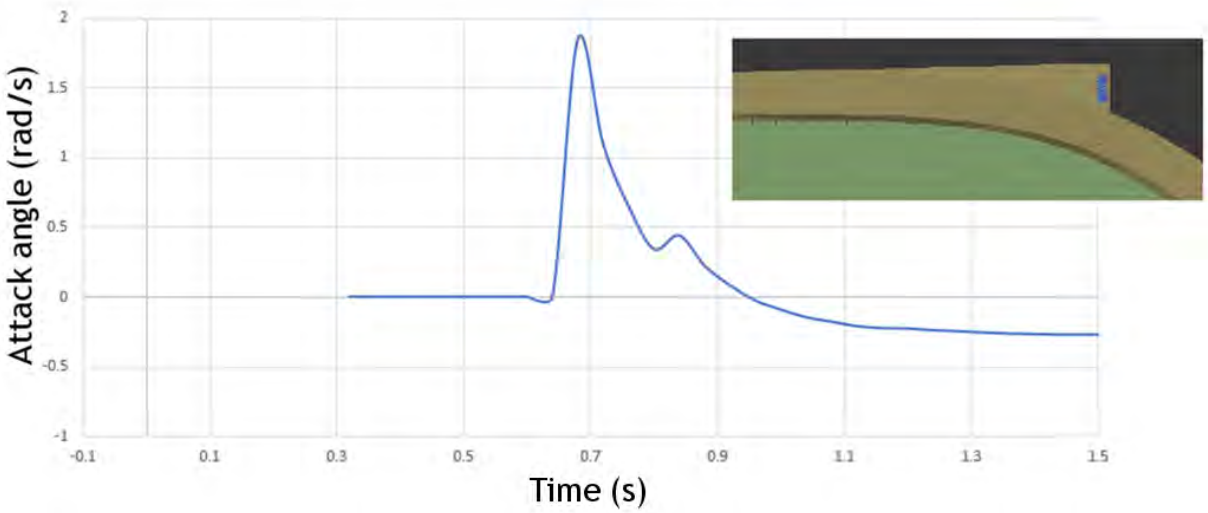

Figure 318: Murray Bridge track 455 m start greyhound attack angle

5.14 Preliminary simulation analysis showed greyhounds' higher attack angles while navigating from starting boxes to the tracks can be minimised to some extent by changing the box alignment to a head clearance of approximately 40 m when the box opening was tripped as the lure passed a line perpendicular to the box as depicted in Figure 319 where the box alignment is 6.4 deg offset for 512 m distance starts at the Mount Gambier track. This roughly 40 m head clearance box alignment creates adequate space for greyhound formations as well as optimising box alignment with the track circuit.

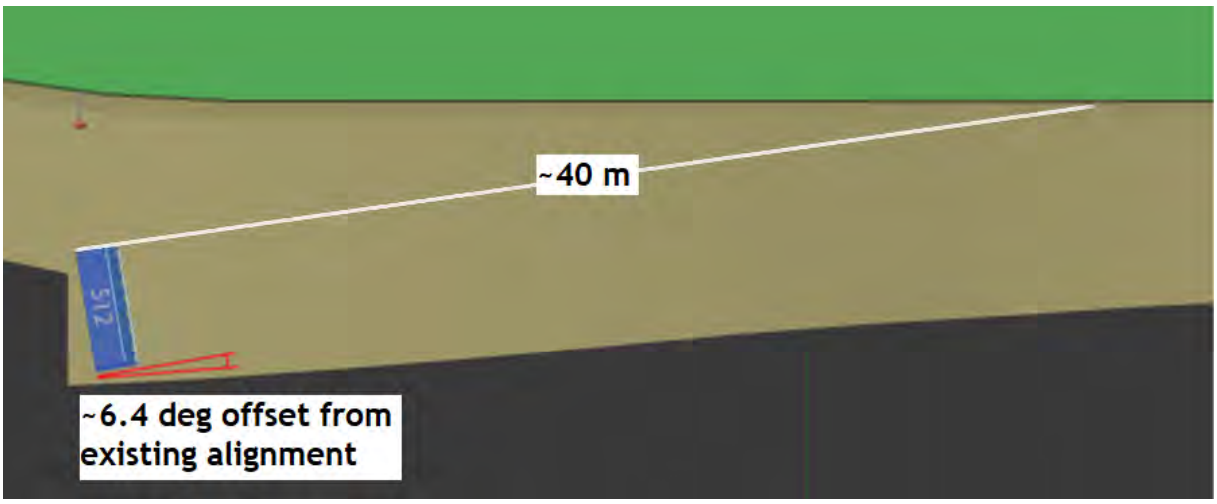

Figure 319: Mt Gambier track 512 m improved starting box alignment

LURE POSITIONING IN THE TRACK

5.15 As the lure travels around the track it creates a follow path for greyhounds which depends on the horizontal location of the lure in the track as depicted in the Figure 320. This follow path of the lure defines greyhound heading attack angles where the optimum attack angle is a function of box alignments in the track.

Horizontal positioning of the lure closer to the boxes improves the greyhound attack angle. Figure 321 shows that when the lure arm length is 3.75 m the defining horizontal location of the lure was optimum for Richmond track box alignments as simulated from surveyed data.

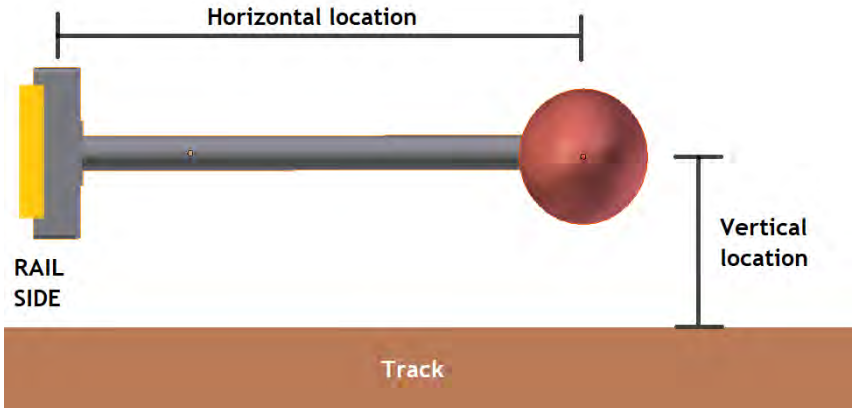

Figure 320: Lure positioning in the track

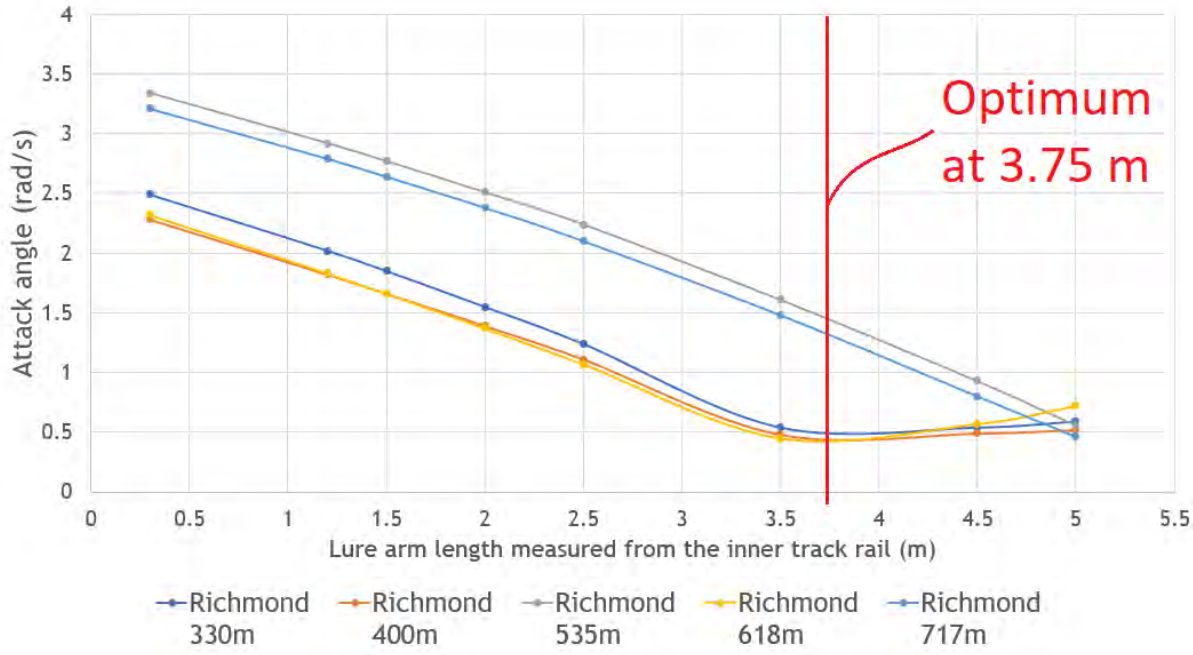

Figure 321: Richmond track optimum lure arm length defining lure horizontal location in the track

5.16 Currently, the positioning along the rail because of the placement of the starting box opening gate sensor as shown in Figure 322 for Richmond track 535 m distance promotes congestions and sharp turning of greyhounds as they exit the boxes. This also creates a distance bias for greyhounds as shown in Figure 323 where the greyhound and the lure distance difference between the greyhounds closest to the rail and farthest to the rail is 2.84 m for Richmond track 535 m distance as per the simulation approximation. Positioning the lure adequately

ahead of the starting box by placing the starting box opening gate sensor roughly 10 m along the rail (Figure 324) would give the greyhounds clearer vision of the lure as well as providing them with a clearer navigation path as depicted in Figure 325 for Richmond track 535 m start as per the simulation approximation. This also removes some greyhound and lure distance bias as shown in the Figure 325.

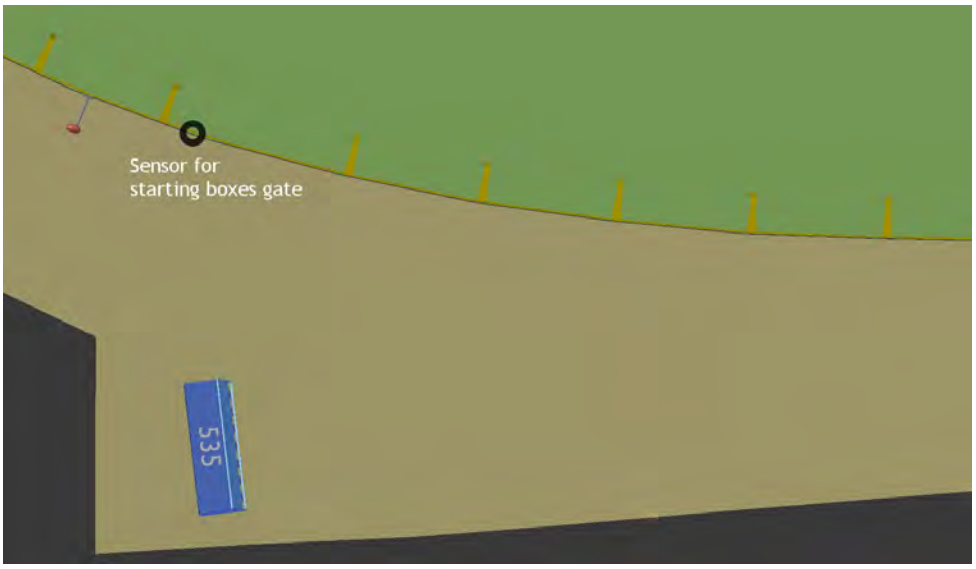

Figure 322: Richmond track starting box opening gate sensor location for 535 m distance race

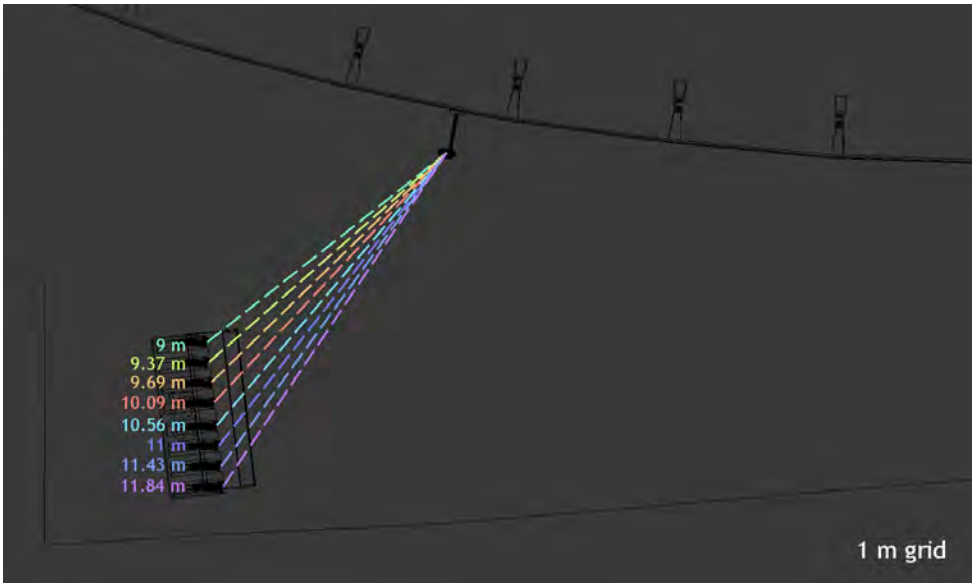

Figure 323: Richmond track greyhound distances to the lure for 535 m distance race

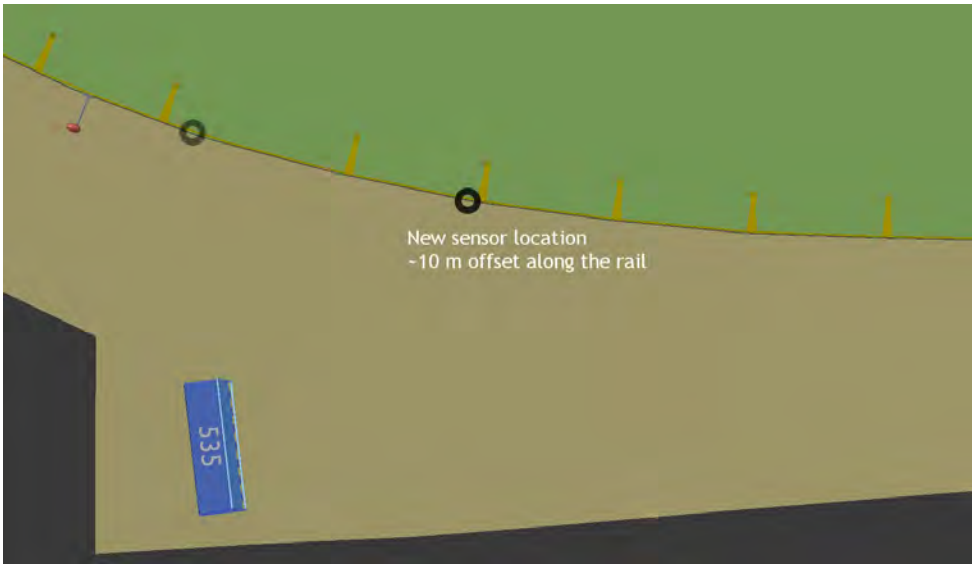

Figure 324: Richmond track starting box opening gate new sensor location for 535 m distance race

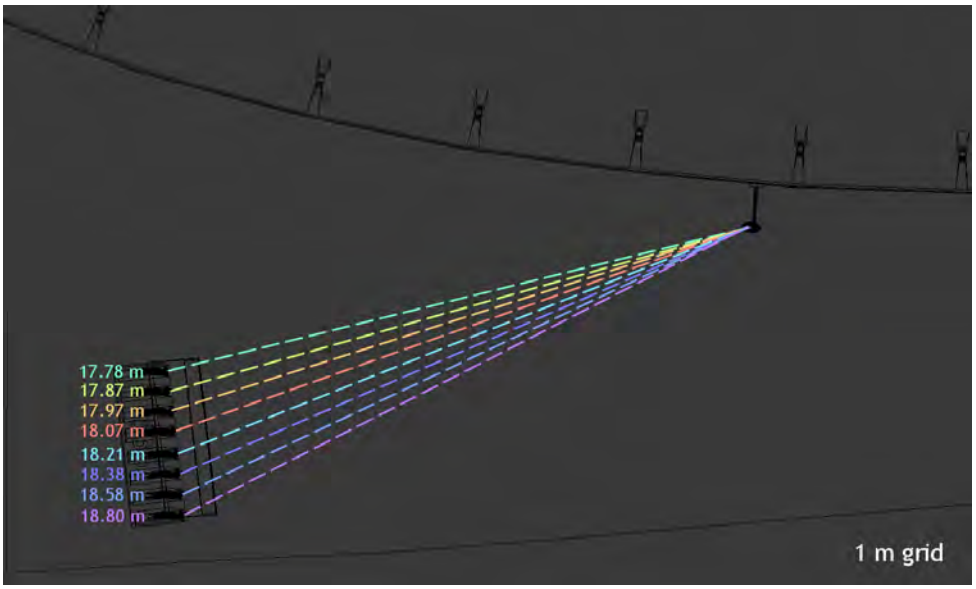

Figure 325: Richmond track greyhound distances to the lure for 535 m distance race with new sensor location.

GREYHOUNDS CLUSTERING ON THE TRACK

5.17 It can be seen from the race videos that clustering of greyhounds is a major contributing factor for injuries. The simulations showed that clustering cannot be minimised effectively by box alignment and lure positioning in the tracks alone due to the convergence of greyhounds to a single lure. Furthermore, variability of lure speed and acceleration of lure is a contributing factor for the momentary and corner clustering.

5.18 Clustering in the track can be measured by the pack density of the greyhounds. Pack density is measured by taking averages of the distances of each greyhound

to the centroid (Figure 326) of the pack where a lower value means the greyhounds are tightly packed and a higher value means the greyhounds are loosely packed. Simulated data showed that greyhound pack density remains significant until greyhounds pass the first corner of the track bend and that the two spots susceptible to clustering are near the starting boxes after the race starts and upon entering the first bend.

5.19 The following race simulation of Wentworth Park track for 520 m starts show that clustering was formed from the starting boxes as greyhounds converged and was maintained throughout until the first bend was approached where clustering could not be maintained as the running distances varied from greyhound to greyhound. The simulation also shows the number of greyhounds for the 520 m race distance does not change the clustering pattern significantly.

Wentworth Park 520 m race with 6 greyhounds:

`https://drive.google.com/open?id=1HQ3PDFG_JLfLZCmL70NUa3cHRMQo_onf`

Wentworth Park 520 m race with 8 greyhounds:

`https://drive.google.com/open?id=1QrJHNdG0zqOqgUyD_g8QzMbgWT3NI0ss`

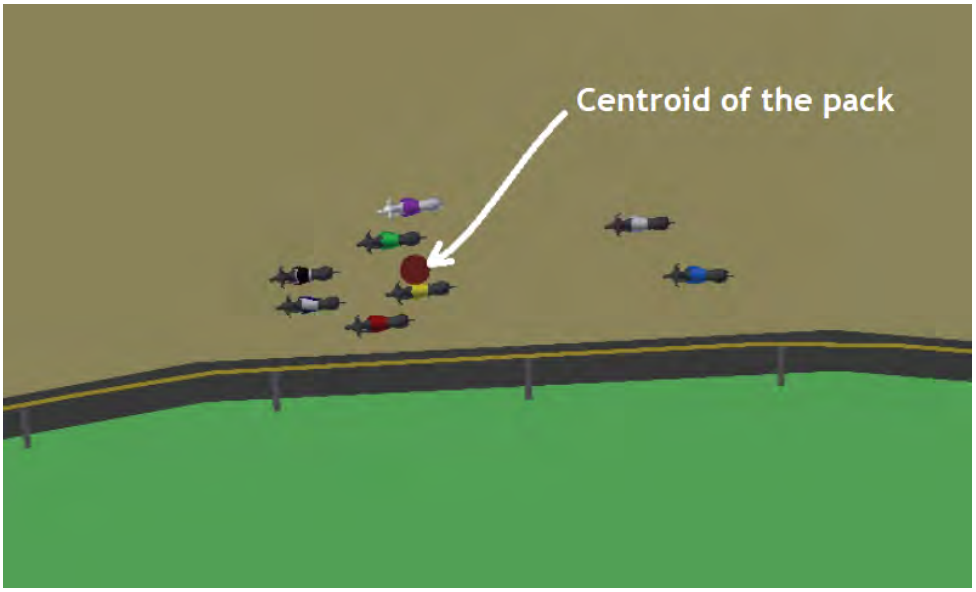

Figure 326: Greyhounds pack centroid

5.20 The following graph (Figure 327) shows average pack density for simulated Richmond 535 m race as a distance between greyhounds from the pack centroid where a lower value indicates higher pack density. As can be seen from the graph the greyhound pack is significantly denser between 2 and 6 seconds into the race denoting a racing period where the probability of clustering is high.

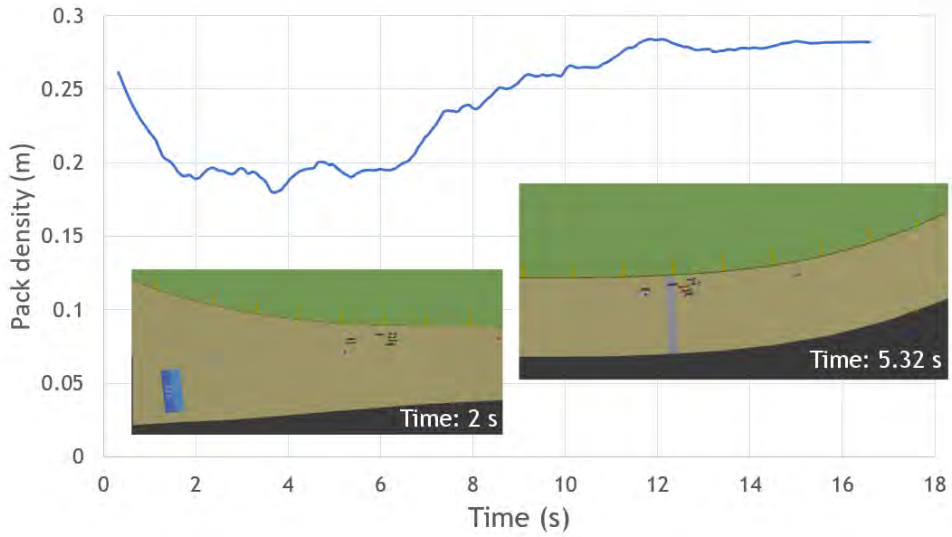

Figure 327: Richmond track 535 m simulated race average pack density

5.21 As greyhound pack density is a precursor to clustering, reducing pack density can also reduce the probability of clustering in the track thus resulting in fewer injuries. In the simulated race it was found that when the greyhounds were positioned with a heading offset in the starting boxes as shown in Figure 328 the overall pack density was reduced.

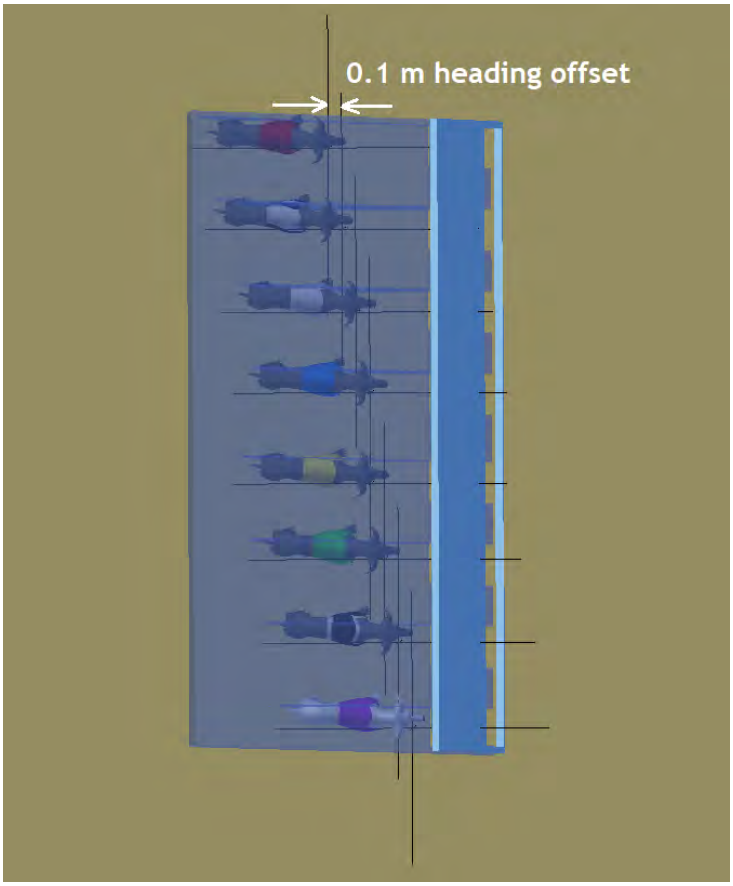

Figure 328: Greyhounds heading offset in the starting boxes

5.22 The following graph (Figure 329) shows 3.5 seconds average pack density data of Richmond 535 m simulated race for race with and without heading offsets for greyhounds as shown in Figure 328. As can be seen from the graph with greyhound heading offsets as in Figure 328, the overall pack density was reduced denoted by the higher value of the pack density.

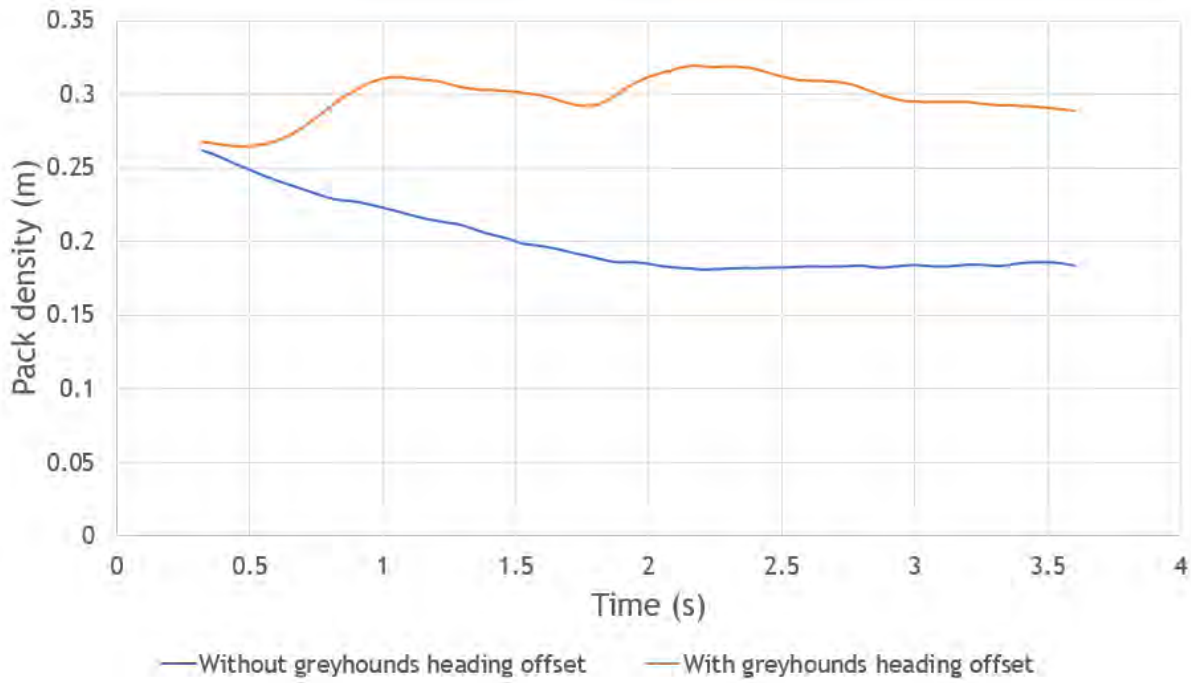

Figure 329: Richmond 535 m simulated race average pack density with and without greyhound heading offset

5.23 Lure visibility in the track could be an indirect influence for injuries. Figure 330 shows typical greyhound formation around the corner when the lure and greyhound separation distance is 5 m and lure arm length is 1.2 m. Figures 331 and 332 show greyhound sight when viewed from the very back of the pack and viewed from behind the leading cluster. From both figures it can be seen that the lure was obscured which may cause confusion among non-leading greyhounds and may motivate greyhounds to change heading direction in the hazardous corner.

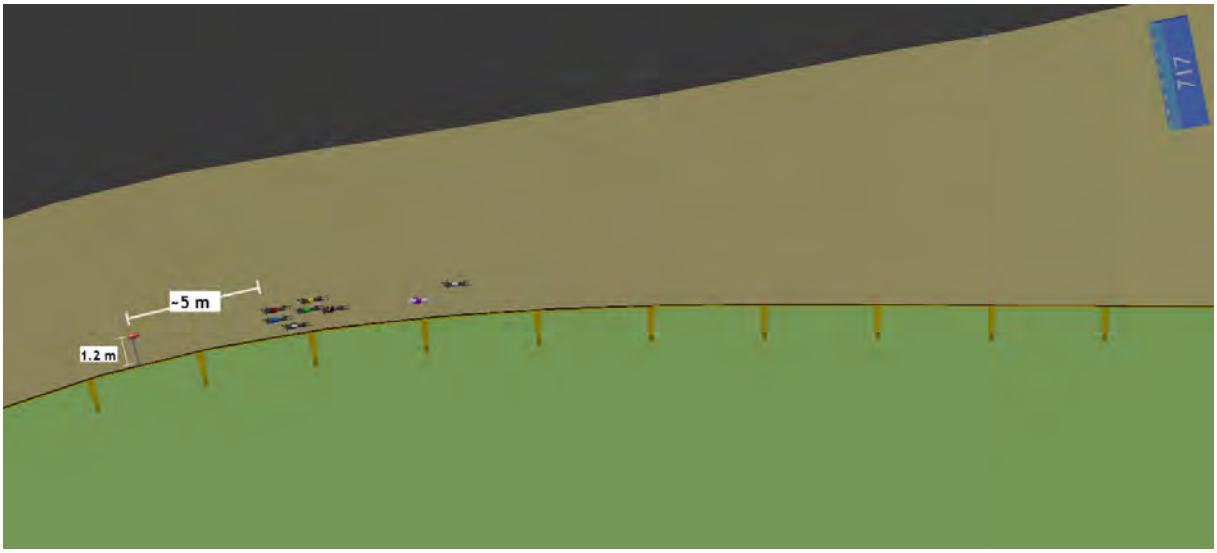

Figure 330: Richmond track 717 m simulated race bend greyhound formation

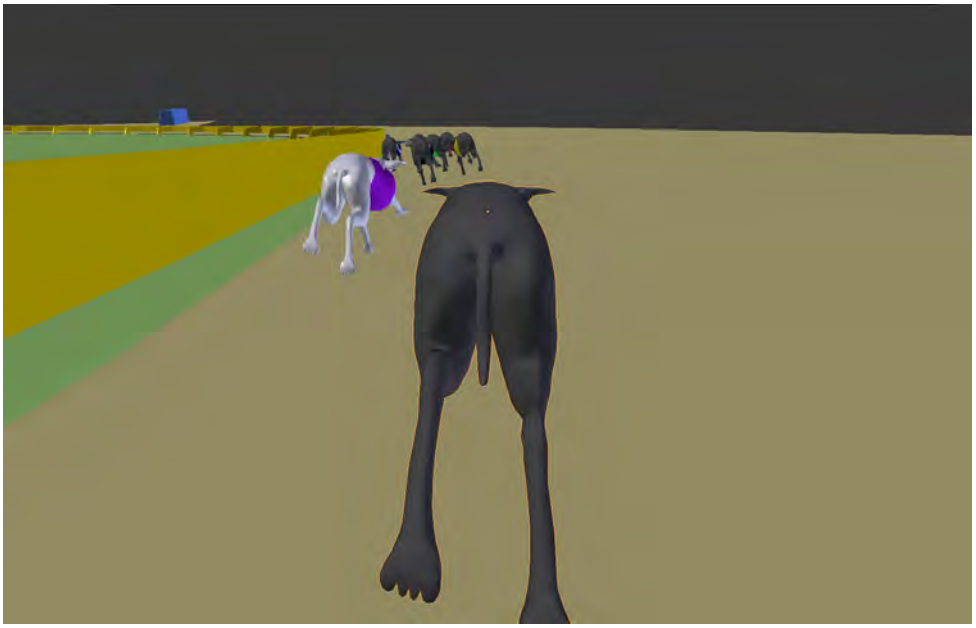

Figure 331: Richmond track 717 m simulated race greyhound sight from the very back of the pack

Figure 332: Richmond track 717 m simulated race greyhound sight from behind the leading cluster.

LIMITING SPEED OF GREYHOUND

5.24 Due to greyhound dynamics in the bend as shown in Figure 333, the maximum galloping speed for greyhounds in the track with a bend section is a function of the track's bend radius, the track's ground shear strength and the track's surface grade.

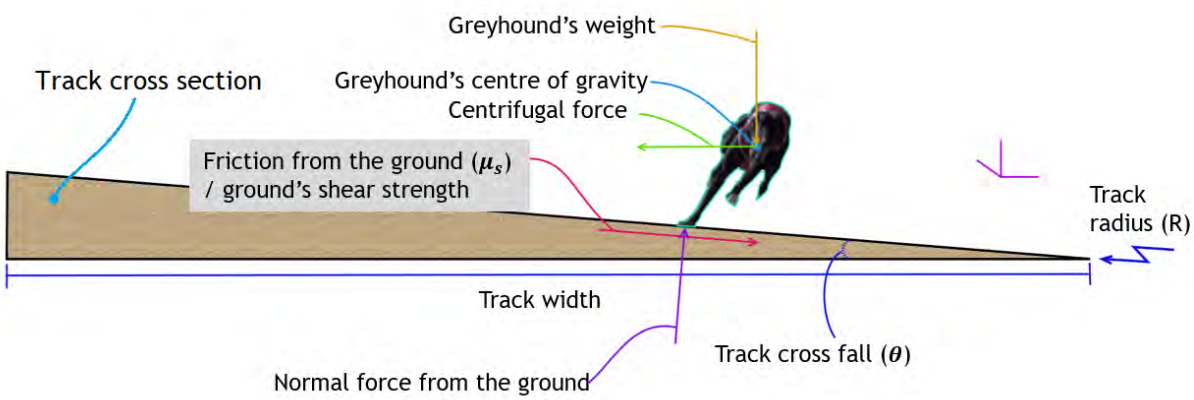

Figure 333: Major forces on greyhounds in the bend.

5.25 Figure 334 shows the maximum speed possible for greyhounds in the GRNSW TAB tracks as limited by greyhound bend dynamics. It can be seen from the bar graph that all TAB tracks have a limiting speed below the average greyhound maximum speed of 18.5 m/s or 67 km/h which will force greyhounds to slow down in the track bends.

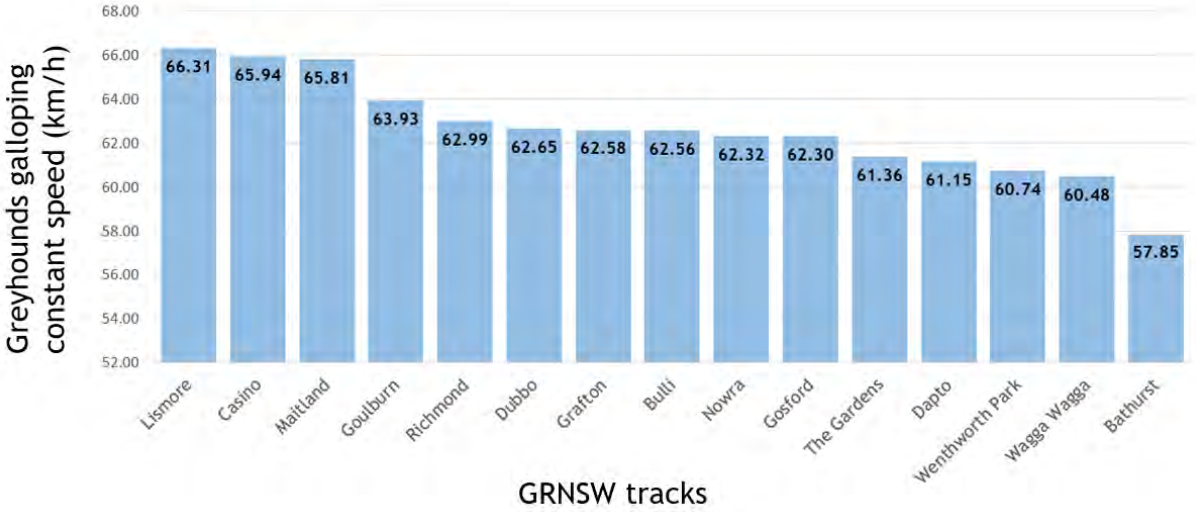

Figure 334: Maximum speeds of greyhounds as limited by the physics

TRACK SHAPE (PLAN VIEW)

5.26 Modelling all GRNSW TAB tracks showed that the tracks lack adequate transitions between the straights and bends as denoted by the First order in the Figure 335.

5.27 A transition, shown in the Second order graph in the Figure 335, will allow for a gradual loading of centrifugal forces whilst greyhounds enter and exit the bend.

5.28 With no GRNSW TAB track having a transition between the straight and the entrances and exits of bends, greyhounds will experience greater levels of horizontal jerk and the probability of injuries remains greater than if a transition were implemented.

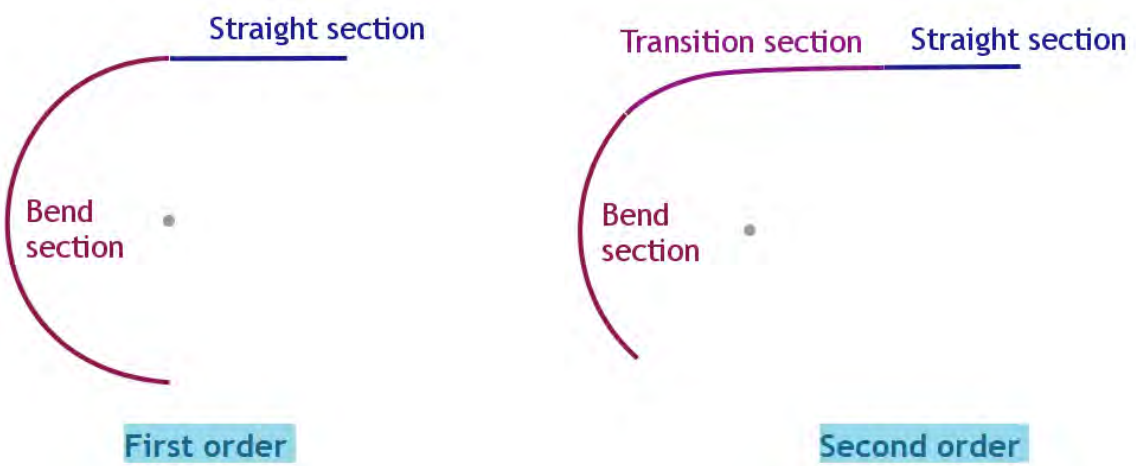

Figure 335: Continuity and smoothness of track path

5.29 Figure 336 shows section plan view of Wentworth Park track showing track curvature. As can be seen from the Figure 336, the curvature of the track changes

abruptly at point A and B indicating less than ideal transition between straight and bend track sections.

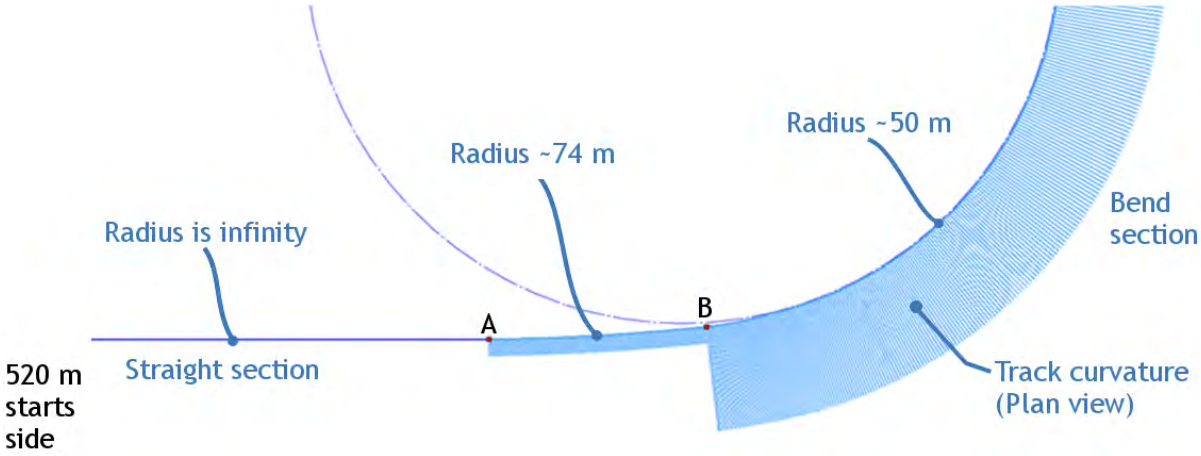

Figure 336: Wentworth Park track 520 m start immediate corner

5.30 Figure 337 shows a transition configuration for Greyhound Racing SA Mt Gambier track lure rail path which was found to reduce centrifugal jerk by 70%.

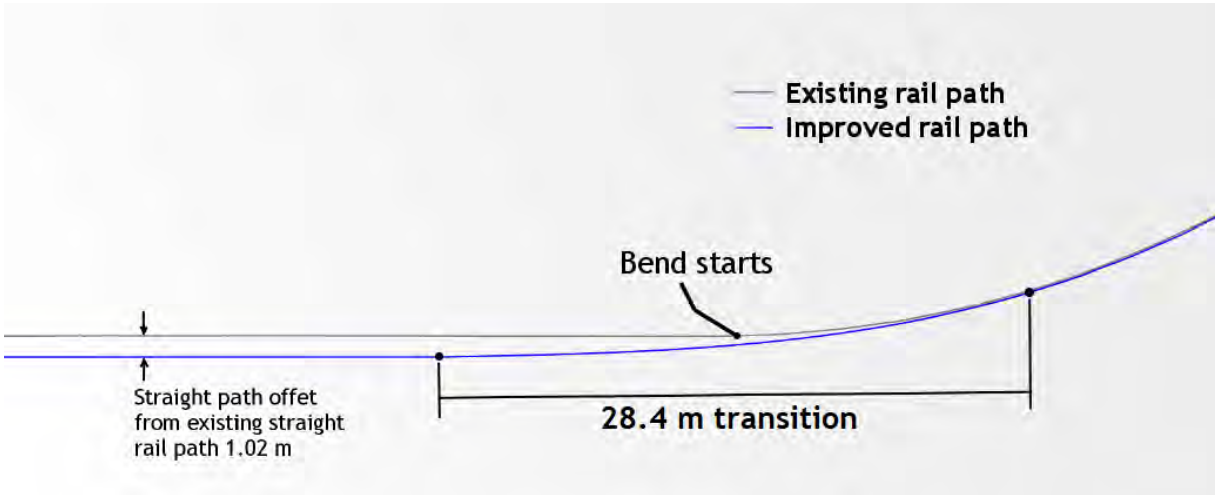

Figure 337: Mt Gambier track improved rail path design by adding horizontal transition

TRACK GRADE (SECTIONAL VIEW)

5.31 GRNSW TAB tracks survey data show non-uniform surface grades along the width of the track as shown in Figure 338. Moreover, it was found that many times the inner region of the bend (lure rail side) has inadequate surface grade (Figure 338). The surface grade of the track region close to the rail is important because most greyhounds pass through this region around the bend.

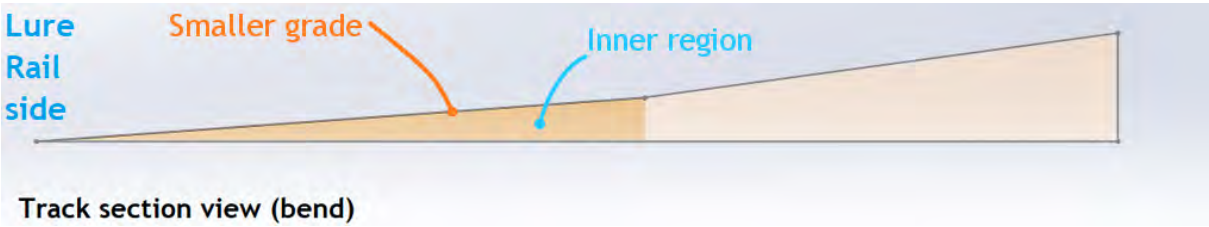

Figure 338: Cross section of track bend showing non-uniform surface grade

5.32 Figure 339 shows the theoretical minimum [1]surface grades required for all GRNSW TAB tracks bends.

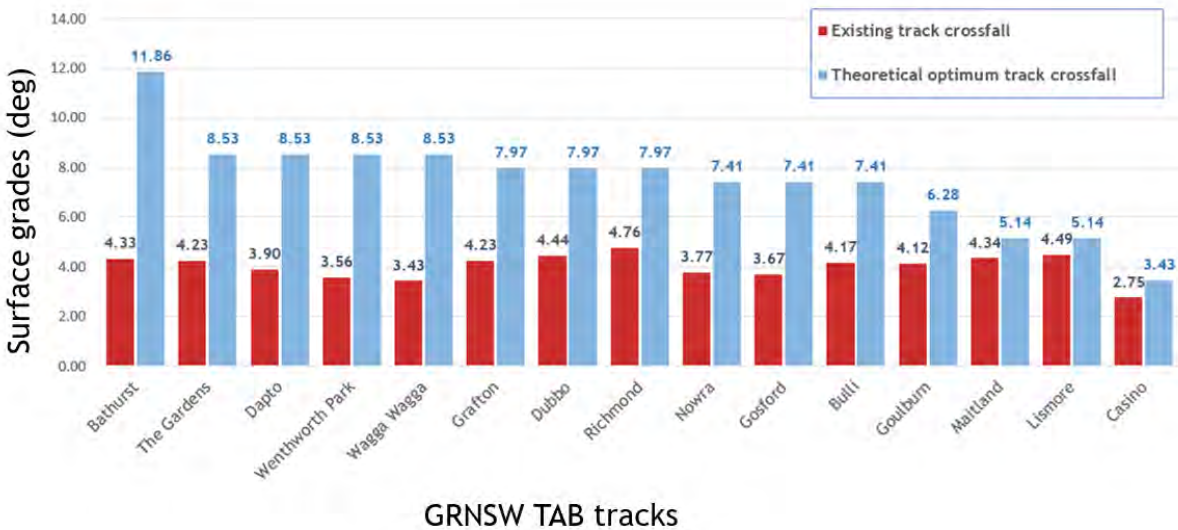

Figure 339: Surface grades for constant radius bends (theoretical minimum vs existing)

5.33 The following figure shows typical surface grade configuration of GRNSW TAB tracks as analysed from surveyed data. As can be seen from the Figure 340, Richmond and Casino have the maximum and minimum average bend surface grade of about 8.32% and 4.81% respectively whereas Wagga Wagga and Goulburn have the maximum and minimum average straight surface grade roughly 4.85% and 2.2% respectively. Furthermore, the surface grade along the bends for GRNSW TAB tracks was found to be variable where surface grades gradually increased to

[1]The minimum required surface grade was calculated based on the assumptions that greyhounds would gallop with an average speed of 18.5 m/s and the track would provide a constant static friction coefficient of about 0.5.

maximum at the apex of the bends (Figure 340). This configuration as shown in Figure 340 was found to have flaws. The variable surface grade around the bend (Figure 340) causes undesirable vertical transient loading to greyhounds which increases the chances of injuries.

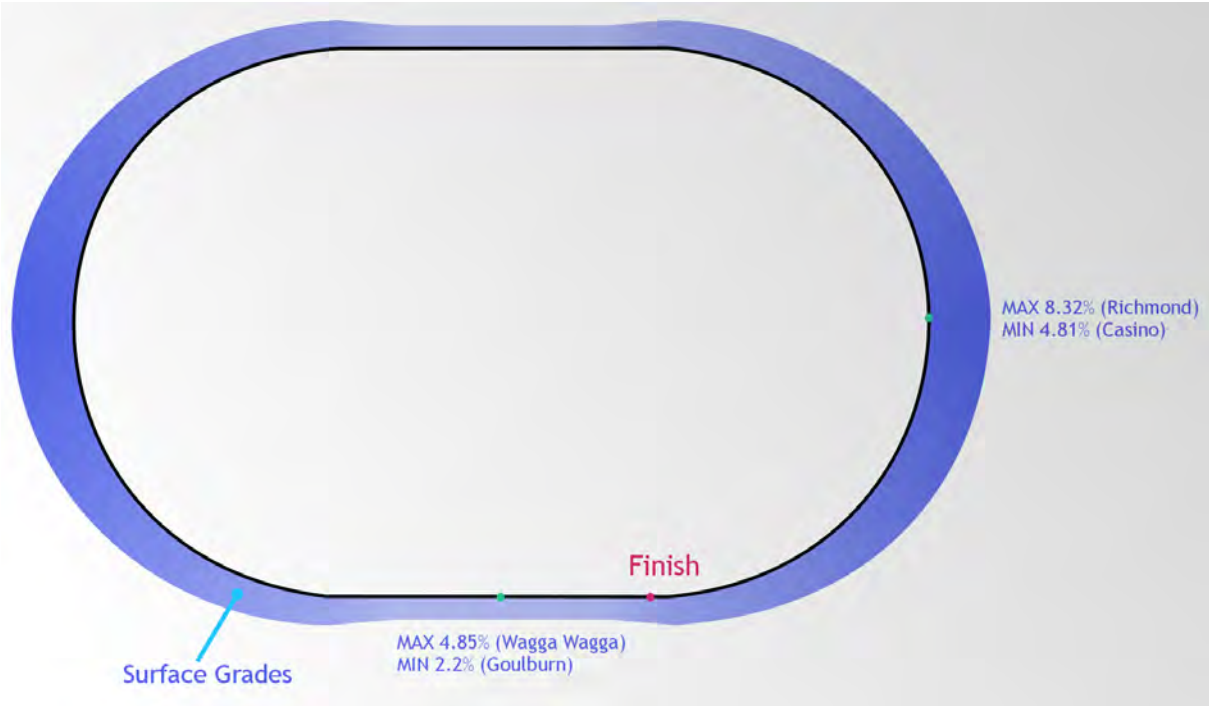

Figure 340: Surface grade configuration of GRNSW TAB tracks

5.34 An alternative to current surface grade configuration is shown in Figure 341 where vertical transient loading around the bends is eliminated by keeping surface grades constant. Figure 341 also shows improved surface grade values which limit excessive vertical transitions. This configuration exposes the greyhounds to a more stable transient loading.

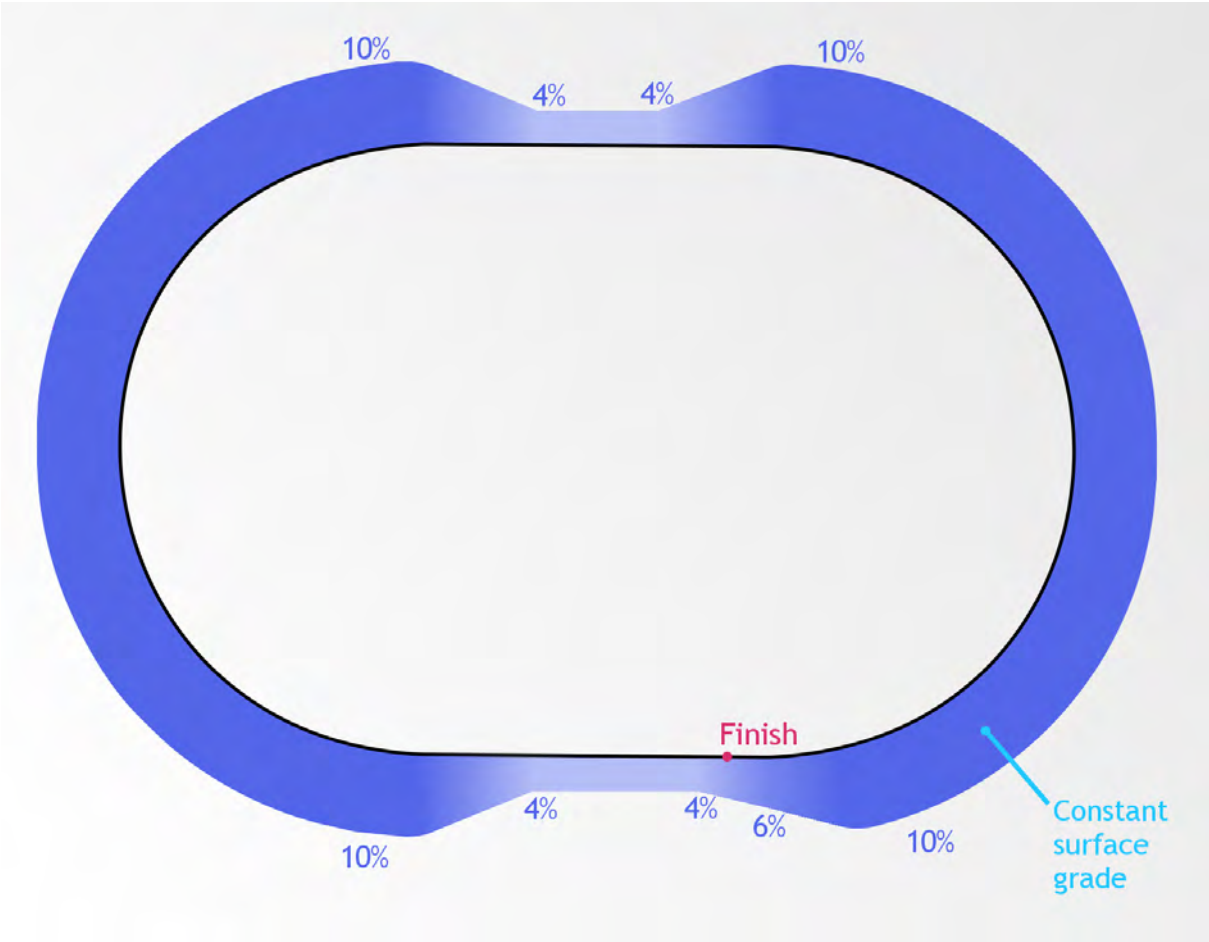

Figure 341: Surface grade configuration with no vertical transient loading in the bends

5.35 Figure 342 shows another alternative surface grade configuration where vertical transition into the bend is applied before the bend and the transition out of the bend occurs on the bend and before the straight. This configuration is tailored for tracks with only straight starts.

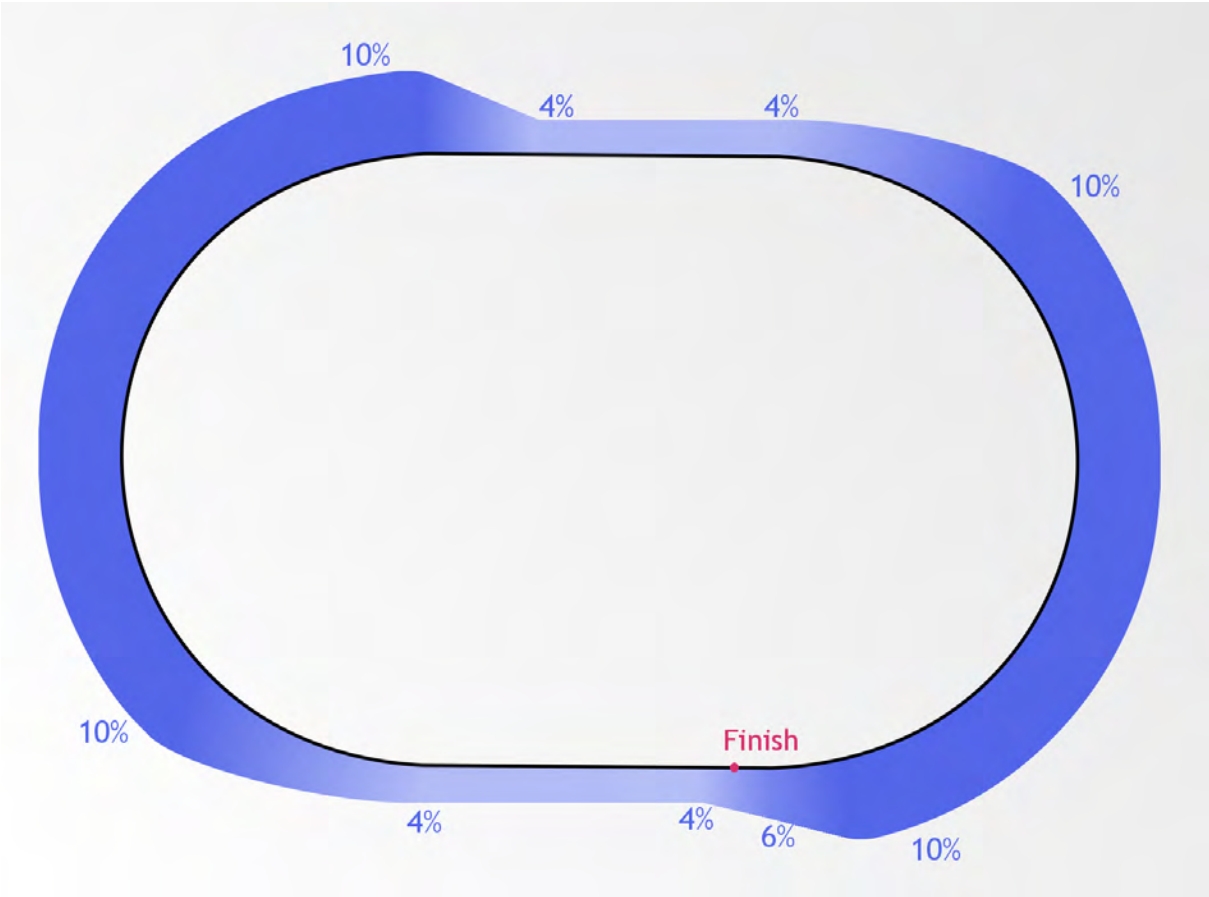

Figure 342: Surface grade configuration optimised for tracks with only straight starts

SIMULATION AND MODELLING WORK PLANS

5.36 It is important to note that availability of race related field data is vital for producing more reliable simulation and modelling results. During 2017 field data such as lure speed profile, precise greyhound location on the track during a race, greyhound acceleration from the box, and track ground shear strength for greyhounds were not readily available. As a result, significant simulation and modelling results were derived using theoretical averaged values.

5.37 The following immediate tasks have been identified to progress simulation and modelling for optimum greyhound race track design to stage 3:

- Position, velocity and acceleration data obtained from 8-dogs races;
- Verify that starting box alignments are optimum;
- Classify alternative starting box configurations;
- Further discretise simulation components for result verification purposes;
- Further field data fusion to simulation (drone footage data, lure speed profile data etc.);

- Develop easier simulation data extraction and mining methods; and
- Develop a more precise greyhound veering technique within simulation approximating field behavior.

APPENDIX A - PUBLICATIONS AND PRESENTATIONS

REPORTS

Mahdavi F., Hayati H., Hossain I. and Eager D., A preliminary investigation into the injury rate for 6 and 8 dog starts, UTS, Sydney, Australia, 06 April 2018

Eager D., Hayati H. and Hossain I., Mt Gambier track injury analysis and preliminary design, UTS, Sydney, Australia, 18 February 2018

Eager D., Hayati H. and Hossain I., Mt Gambier track injury design analysis drawing 5135, UTS, Sydney, Australia, 22 January 2018

Mahdavi F., Eager D. and Hayati H., Richmond track intervention analysis, UTS, Sydney, Australia, 01 December 2017

Eager D. and Hossain I., Alternative track design for Tweed Heads (Options A to D), UTS, Sydney, Australia, 27 November 2017

Hossain I., Hayati H., and Eager D., The Gardens track – rate of rotation analysis, UTS, Sydney, Australia, 26 September 2017

Eager D., Hayati H. and Hossain I., Identifying optimal greyhound track design for greyhound safety and welfare – Phase I Report, UTS, Sydney, Australia, 05 June 2017

Eager D., Hayati H. and Hossain I., A preliminary investigation into the Cranbourne Track for GRV, UTS, Sydney, Australia, 24 March 2017

Hayati H. and Eager D., Influence of box location and race distance on the rate of injury - Wentworth Park, UTS, Sydney, Australia, 03 November 2016

Hossain I., Hayati H., and Eager D., A comparison of the track shape of Wentworth Park and Murray Bridge track shape comparison, UTS, Sydney, Australia, 06 September 2016

Eager D, Canine safety and welfare - Proposed trials, UTS, Sydney, Australia, 20 June 2016

PRESENTATIONS

Eager D., UTS greyhound safety and welfare research, Dubbo Greyhound Club, Dubbo, 15 April 2018

Eager D., UTS greyhound safety and welfare research, Greyhound Owner Breeders and Trainer Association Board, Wentworth Park, 4 November 2017

Eager D., UTS greyhound safety and welfare research, Greyhound Racing NSW presentation Rhodes, 11 September 2017

Eager D., UTS track research for greyhound safety and welfare, Greyhound Australasia, Perth, 3 March 2017 (invited presentation)

Eager D., Identifying optimal greyhound track design for greyhound safety and welfare, GRNSW Veterinary Conference, Sydney, 26 February 2017 (invited plenary presentation)

Eager D., Some interim findings of GRNSW safety and welfare study, GRVHQ, Melbourne, 2 August 2016 (Invited plenary presentation)

ACADEMIC PAPERS

Hayati H., Eager D., Jusufi A., Brown T., A novel approach to analysing rapid tetrapod locomotion using inertia measurement units and stride length as a speed indicator in fast quadrupeds, International Society of Biomechanics Conference, Brisbane, Australia, 23-27 July 2017

Hayati H., Eager D., Jusufi A., Brown T., Stride length as a speed indicator in fast quadrupeds, International Society of Biomechanics Conference, Brisbane, Australia, 23-27 July 2017

Hayati H., Eager D., Stevenson R., Brown T., Arnott E., The impact of track related parameters on catastrophic injury rate of racing greyhounds, 9th Australian Congress on Applied Mechanics ACAM9, Sydney Australia 27-29 November 2017

Hayati H., Eager D., Jusufi A., Brown T., A study of rapid tetrapod running and turning dynamics utilizing inertial measurement units in greyhound sprinting, ASME-IDETC/CIE29017, Cleveland, Ohio, USA, 6-9 August, 2017

Jusufi A., Hayati H., Eager D., Tucker B., Exploration of Rapid Tetrapod Running Performance utilizing Inertial Measurement Units, 8th Adaptive motion of animals and machines, Sapporo, Japan, 27-30 June 2017

HONOURS THESIS

A15-111 Nelson Ling 11034550 - Investigation of greyhound racing and related injuries
A preliminary literature review on greyhound racing common injuries in racing greyhounds. This thesis includes discussion on the greyhound rotary gallop. It also includes discussion of track surface and track design.
`https://cloudstor.aarnet.edu.au/plus/index.php/s/7fjQ1Zr5OAe7Bsn#pdfviewer`

A16-109 Alexis Tenedora 11034550 - Investigation of greyhound racing and related injuries
Kinematics and kinetics of racing greyhounds are analysed in this thesis using high frame rate (HFR) cameras to understand the locomotion dynamics of greyhound in a general manner. The footfall timing of both hind-legs and forelegs is calculated to

measure the forces upon contact to the sandy-loam surface of the track. The role that back bending play and how it can be studied using HFR is initially analysed which will be developed in future studies. The results of this study showed that ground reaction forces of hind non-leading legs are significantly higher in turning that sprinting in straight section. This suggests an increase in ground reaction forces while turning to maintain speed.
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A17-015 Ahmed Abbas 11205325 - The design and feasibility study of two straight greyhound tracks for Richmond Race Club
Feasibility of reconfiguring an existing straight slipping track into a TAB Grade racing track and developing a new replacement straight slipping track for Richmond Race Club to maximise the greyhounds' level of safety and increase their race life is analysed in this thesis. Civil engineering software called autoCAD is used to design the straight track. Three designs are introduced, a natural grass track, a synthetic grass track and a sandy loam track. All the three tracks are designed in a way to increase the grade of track to a TAB one though had their own advantages and disadvantages (please refer to page 34 of this thesis for more details). Although the synthetic grass track had the highest cost of construction, it had the lowest maintenance cost and effort, can accommodate 10 greyhounds in each race and had superior level of safety. Accordingly a synthetic grass track surface was recommended.
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A17-033 Issac Gonzalez 12684344 - Greyhound paw print analysis using drone technology
To understand the movement pattern of greyhound while racing, a drone technology is deployed. The results of this project are essential in race simulation and safer design of the track that can avoid greyhound collision. Drone can also be beneficial in capturing high-resolution picture of paw print which is beneficial in kinetics analysis of locomotion and injury prevention.
https://cloudstor.aarnet.edu.au/plus/index.php/s/gaXPA4fIHvKVai4#pdfviewer

A17-278 Mei Yingjie 12686200 - Improved design of greyhound lure machine used in racing
Lure is believed to be one of the leading causes of injury in racing greyhound i.e. short lure can cause clustering of greyhound and a better design of that can be beneficial for the welfare of the dogs. Accordingly, a new refinement in the current lure system is done in this project which is believed that due to the longer length of the lure (2m in length) can distribute dogs along the tracks and reduce the risk of collision. However due to the recommended light weighted carbon fibre reinforced polymer, the evaluated cost of the lure is expensive and should be considered in future design.
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S16-047 Stephanie Le 11194976 - A preliminary study into racing greyhound locomotion
The aim of this research was designing a prototype for a test rig to predict the risk of injuries. The test rig designed based on the hind-legs of greyhound using engineering software called Solid work. The test rig can also be used to evaluate the stiffness of

sandy-loam surface of the track.
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S16-057 Ryan Durkin 11196856 - Greyhound welfare - track speed history of Australasia
There is a correlation between the speed of racing greyhound and the track hardness as the harder the track, the faster the greyhound. Accordingly, the racing speed (winning dog finishing time) of 102 tracks over 30 years in Australia are collected and analysed in this thesis. Eighty-two tracks showed an increase in speed, seven showed speed reduction, and the rest did not have enough/accurate data. To conclude that tracks are becoming harder since the past 30 years closer attention should be given to breeding and training strategies which were deployed in a way to train faster dogs and is believed to have influence in speed increase in winning greyhounds.
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S16-061 Sushant Bista 11207863 - Validation for the use of inertial measurement units (IMUs) for locomotion analysis of racing greyhounds
Benefits of deploying IMUs in studying locomotion dynamics while other conventional methods are not applicable i.e. difficult terrain, galloping gait (focused on the aerial phase of the gait) is analysed in this research. The result showed that IMUs have this capability to be deployed in analysing firstly biomechanics of sprinting and turning and secondly for the safety and welfare of racing greyhounds. However, considering the complexity of IMU data, bigger data set and more research is required.
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S16-078 Joshua Sudjaja 11256827 - A preliminary investigation into the use of paw print and video capture to record and analyse of greyhound motion
A paw print analysis of racing greyhound is done to analyse the locomotion dynamics of sprinting and to assess whether there is a specific movement patterns in racing greyhounds. The handedness hypothesis i.e. change of the leading paw while entering and approaching the turn is also studied here. The results revealed that that paw print can be a good indicator of ground reaction forces i.e. the deeper the depth of paw print, the higher the force upon contact. moreover, stride length of sprinting around the bend was significantly lower than that of straight section suggestion speed alternation in these two sections.
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A17-101 Kelvin Ho 11380603 - Injury analysis and detection of the racing greyhound
The purpose of this study was to perform a locomotion analysis, using an IMU device and HFR camera, of greyhounds racing around varying tracks, at top speeds, to determine the forces being applied to them and how it affects bone and ligament injuries. The experiment was performed at eight (8) tracks varying in design. The results showed that the second turn at the Bathurst race track imposed the largest amount of centripetal forces on the greyhounds as they navigated the bend. However, the injury rate at Bathurst was the lowest of all the tracks tested. Also, the results also showed that the ground reactive forces in the bend were less than theorised and the general peak acceleration values on the straight sections were higher. These results

require a more in-depth analysis with more accurate tools to help grasp a better understanding of greyhound locomotive motion and if centripetal forces have a large role to play in racing related injuries.
https://drive.google.com/file/d/12V0LzkBWLQ8kRPd2XZJEmVTQ2nfcOev1/view?usp=sharing

A17-075 Kwan Hye Kim 11228006 - Greyhound racing optimised civil track design for the welfare and safety of canines
This report had the objective of redesigning the conventional greyhound racetrack in an effort to reduce the likelihood and the degree of injuries sustained by greyhounds when racing. Many factors such as weather conditions, track geometry, surface material, race grade, race distances and maintenance were identified as potential influences on the injury rates sustained by greyhounds when racing. However, the research showed that the primary issue regarding the tracks was the predisposition of injury occurrence due to tight curves and inadequate banking. Results from the study recommended increasing radius to reduce centrifugal force and banking to minimise the need for greyhounds to lean. The incorporation of transitions allowing for a gradual loading of centrifugal force and long starting distance from the first curve to reduce the maximum speed of which greyhounds enter the curves at to reduce centrifugal force.
https://drive.google.com/file/d/1c2m7UO_ce_FSIJ-Mn3Sy1HBQBFq_otu9/view?usp=sharing

A17-320 Thanh Vu Nguyen 11306040 - Greyhound Profile Race Track
The purpose of this study was to investigate the profile and characteristics of the soil in various greyhound racetracks across NSW. These characteristics included the firmness of the surface, the moisture content and the strength of the soil used for the racetrack. From the results there is clear issue with cracks forming in and on the top and middle section of the soil. The major causes of these problems is the shrinkage of the top level soil when experiencing a different rate of evaporation and the formations of crack in the middle layer from over compacting of the soil, causing the moisture content to drive out of the soil. This varying rate of changes alters the soil ability to withstand the forces being applied by the greyhound, which in turn can cause balancing issues, muscles to act abnormally and in the long term can cause severe injury for the greyhounds. To fix this problem the curator or manager of the track will need to keep the moisture content slightly above the optimum level and allow sufficient time for the water to absorb through the top section of the soil. Whilst for the middle layer will need to be harrowed at the correct depth to allow the racetrack to be re-compacted and improve the quality of the racetrack.
https://drive.google.com/file/d/1CeYohEBHMib8Vq5pgYqUdT2KbtZPCfP6/view?usp=sharing

A17-234 Jeffery Or 11763531 - Greyhound welfare - Study of camber and its effects
This report details the research and findings on the study of camber in greyhound racing and the effects it has on the speed of the greyhounds. The goal of this project is to conduct a study into the effects of camber in the field of greyhound racing and how it affects greyhounds in motion during races. The primary finding from this

study is that greyhounds do not decrease or increase their galloping speed as they approach, navigate through or exit the bend. Instead they can maintain the same velocity during the straight throughout the entire bend. The speed is only affected by the camber of the angle as the higher the angle the slower the gallop through cambered bends of the tracks. However, these results cannot be taken as fact as there was too little data collected, too many uncontrolled variables and limitations during the undertaking of this experiment.
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A17-044 Salim Aljunied 10869586 - Utilization of autonomous drone to reduce injuries during greyhound racing
This project details how a drone may be used to collect video footage of greyhounds racing, through a unique perspective, to obtain detailed information of trails and races. Research was also done into the feasibility of using an autonomous drone to replace the current mechanical lure system. The research showed that using the perspective obtained by a drone, throughout a race, can provide a more detailed analysis of races by providing the greyhounds exact positioning, timing, path taken to navigate bends, lines out of the starting boxes and down the straights. It can also give pin point accurate locations of where injuries occurred, during a race, helping provide more accurate information for the OTV's and injury statistics. Utilisation of a drone as a lure has many benefits over the current system. However, the current technologies used in autonomous drone control hasn't reached a stage where they can operate without possessing a safety risk to the greyhounds or spectators.
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