An Evaluation of the Effectiveness of High Speed Seagull Intersections in the Metropolitan Area of Perth, Western Australia

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Title

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Abstract

Seagull islands are a common “at-grade” treatment for three legged T-intersections used on high traffic volume roads and dual carriageways in countries such as Australia, New Zealand and the United States.

The aim of this study is to evaluate the effectiveness of high speed seagull intersections on WA roads located in the metropolitan area. The results found that the treatment has been effective on Marmion Avenue, reducing all reported crashes by 21.4% and casualty crashes by 62.4% for treated sites in the study sample. The treatment could potentially also be effective on roads of similar conditions and characteristics, but there no definitive conclusion for roads with different conditions, pending the availability of more usable data for future study.

Results from the analysis will help to provide Western Australian road authorities with more objective information to guide future investment and implementations of seagull intersections at high speed rural settings.

Keywords

Seagull intersections, seagull islands, dual carriageway T-intersections, crash frequency, crash severity

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EXECUTIVE SUMMARY

This report presents the results of an evaluation of seagull intersection treatments which were implemented on a high speed metropolitan road (speed limit = 80 km/h) in Perth, Western Australia (WA). It evaluated the effectiveness of the seagull intersection treatment in terms of reduction in crash frequency (presented for casualty crashes and all reported crashes) at the study locations. It is anticipated that these results will help to provide Main Roads WA and other road safety organisations with reliable, objective information for enhancing strategies for future road safety investment.

The findings from the evaluation are summarised below.

Methods

A "before and after" study was undertaken. The sample consisted of 6 treated sites which were dual carriageway T-intersections on a high speed road (speed limit ≥ 80 km/h). The 6 sites were all located on Marmion Avenue with the seagull intersection treatment implemented between the years 2002 and 2007, each with a "before" exposure of 5 years and also an "after" exposure of 5 years.

To test the effectiveness of treated sites, each treated site was matched with a comparison site with similar speed limit and road characteristics. The 6 comparison sites were from Wanneroo Road.

Results

The results found that the treatment has been effective overall, reducing all reported crash frequencies by 21.4% and casualty crash frequencies by 62.4%. The results are specific to the particular environment and conditions on Marmion Avenue, and might represent sites on other roads with similar conditions, but possibly not roads of non-similar characteristics.

Seagull Intersection Treatment Effect on Crash Reductions

All Reported Crashes		Estimate (β)	Standard Error	Probability 0 < p < 1	Incidence Rate Ratio IRR	Crash Reduction (%)
6 treated + 6 untreated sites (n = 12)						
Group	0 = untreated site 1 = treated site	1.247	0.167	< 0.001	3.478	
Time	0 = before treatment 1 = after treatment	-0.022	0.082	0.788	0.978	
Time * Group		**-0.241**	**0.095**	**0.011**	**0.786**	**21.4%**

Casualty Crashes		Estimate (β)	Standard Error	Probability 0 < p < 1	Incidence Rate Ratio IRR	Crash Reduction (%)
6 treated + 6 untreated sites (n = 12)						
Group	0 = untreated site 1 = treated site	1.335	0.355	< 0.001	3.800	
Time	0 = before treatment 1 = after treatment	0.336	0.315	0.285	1.400	
Time * Group		**-0.978**	**0.380**	**0.010**	**0.376**	**62.4%**

Limitation of the Study

Limitations to the study included the lack of suitable sites in WA that had usable "before and after" exposure data to account for design specifications of each seagull intersection such as angle and median width. The lack of suitable sites also led to the decision to omit the more complex adjustment for traffic volume that would have taken into account all interactions between flows from different directions of the thru and side traffic.

Another limitation was the lack of accurate information regarding the time of installation of the seagull intersection treatment at each site. It was crucial that neither the before treatment period nor the after treatment period overlapped the construction period, in which case estimates of the treatment effect could result in bias towards the lesser or greater magnitude compared to the true value.

To help gain a better understanding of the effectiveness of the seagull intersection treatment on roads with characteristics not similar to Marmion Avenue, further descriptive statistics and preliminary results (seagull treatment only) from a yet to be published C-MARC study on all WA State Black Spot treatments 2000-2012 combined (Chow et al. 2016) were also considered (Appendices C and D).

A sample of 17 seagull sites and 12 non-seagull comparison sites on 110 km/h sections of WA roads were identified by Main Roads WA and considered. A full "before and after" study was not possible over these sites because of their lack of "before" exposure so only the distribution of crashes in the "after" period was examined. For the 110 km/h sections, overall, the seagull sites experience much higher frequency of all reported crashes per site (average per site: 746 crashes per million vehicles) than their non-seagull counterparts (average per site: 193 crashes per million vehicles). However, the proportion of all crashes being Casualty Crashes were much less at the seagull sites (24%) than the non-seagull ones (41%). But the proportion of Killed or Seriously Injured (KSI) Crashes appeared to be no different for the seagull sites (15%) and the non-seagull ones (15%).

Such results appear to suggest a hypothesis that the 110 km/h locations chosen to receive the seagull treatment could have experienced a higher frequency of all reported crashes, potentially due to the specific conditions at each location rather the seagull treatment itself. However, the seagull treatment could have possibly reduced the severity of most crashes (therefore a smaller proportion of all crashes being Casualty Crashes). Though the seagull treatment alone might not have been able to reduce the more extreme of the severities. The definitive confirmation of such a hypothesis will only be possible should more usable data become available for a future study.

The yet to be published C-MARC study on all WA State Black Spot treatments 2000-2012 combined (Chow et al. 2016) considered a sample of 41 metropolitan and 5 rural seagull treatment sites with different speed limits, not focusing on the high speed 110 km/h roads that are of particular interest. The preliminary results suggest that the 46 sites sampled experienced a slight increase in All Reported Crashes (1.5%), but no significant change in Casualty Crashes after receiving the seagull treatment. However, as Chow et al. (2016) acknowledged the steady increase in traffic volume over the years but made an assumption that it was negligible for the purpose of modelling due to similar limitations as noted in this standalone study of the seagull treatment, the results from Chow eta al. (2016) could also be conservative.

Recommendations and Conclusion

Given some of the difficulties experienced in the current study, it is recommended that a comprehensive and systematic method of data collection be implemented to facilitate future evaluations of seagull intersections or other road safety treatments.

Should more case sites with suitable exposure data become available, it is also recommended that this evaluation be repeated and adjust for traffic flow, as well as account for design specifications of each seagull intersection such as angle and median width.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

A seagull island is defined as "*a triangular island used to separate right turning traffic from through traffic in the same carriageway*" (Austroads, 2005). The seagull layout is a common "at-grade" treatment for three legged T-intersections and is usually used on high traffic volume roads and dual carriageways (Tang & Levett, 2009). There are many seagull intersection layouts across the road network in Western Australia and may vary in terms of design layout, road geometry and site conditions (Harper et al., 2011).

A T-intersection/T-junction which utilises a seagull island is known as a seagull intersection (Harper et al., 2011). In countries such as the United States, these intersections are more commonly known as a "continuous green T-intersections", T-intersections utilising continuous green through lanes (CGTLs), turbo-T intersections, or high-T intersections (Jarem, 2004; Reid, 2004; Federal Highway Administration, 2010).

Seagull islands/intersections are named due to the two right-turn lanes (or the two left-turn lanes in countries driving on the right) looking similar to the wings of a seagull when viewed from the sky. These intersections allow both directions of traffic on a through road to flow with minimal interruptions. The advantage of this design type over a more traditional T-intersection design is that delay(s) through the intersection can be reduced – with the flow of traffic on the main road being maintained (straight both ways as well as into the side road), even at the most basic implantation. The flow of traffic out of the side road can also be smoothened with the addition of filter lanes. For example, a left-turn filter lane from the side road into the main road and another filter lane that merges with the main road traffic after right-turn from the side road. In theory, the reduction in delay time and smoother traffic flow through the intersection can lead to reduction in vehicle emissions as well as other potential economic and social benefits (Litsas, 2002). In terms of road safety, one advantage of the seagull layout is the separation of conflicting vehicle paths resulting in a reduction of right angle crashes (Radalj et al., 2006).

A previous literature review performed by C-MARC found that earlier international studies with different methodologies often led to conclusions that contradicted one another. The literature review found that the more appropriate analytical method to examine the road safety effectiveness of seagull intersections should be, at the foremost, of an experimental "before and after" study design; then, if possible, adjusted for traffic volume as well as accounting for the design specifications of each seagull intersection such as angle and median width (Chow & Meuleners, 2015).

1.1 Aim

Seagull intersections have varying safety records and have been the object of much discussion (Harper et al., 2011). The aim of this study is to evaluate the effectiveness of seagull intersections in terms of the net reduction in crash frequency at high speed sites treated in the Perth metropolitan area, WA.

1.2 Significance

The results of this study will provide Main Roads WA and other responsible agencies with reliable and objective information for future investments in seagull intersections and implementations of such treatments at high speed settings, as well as assist road authorities to manage future resources so that injury from road trauma is minimised.

2. METHODS

2.1 Study Design

A quasi-experimental, “before” and “after” design was adopted for the study. The use of comparison sites was incorporated into the study design to determine the change in crash frequencies at six high speed sites (speed limit ≥ 80 km/h) treated with the seagull intersection treatment on Marmion Avenue, metropolitan Western Australia, between the years 2002 and 2007. The study analysed the frequencies of all reported crashes (including all fatal crashes, hospitalisation crashes, medical treatment crashes, and property damage only (PDO) crashes) and casualty crashes (including all fatal crashes, hospitalisation crashes, and medical treatment crashes). Treatment effect was estimated by comparing all reported crash and casualty crash frequencies at each treated site to those at an appropriately matched comparison site. The use of a comparison group provided an adequate measure of the reductions in crash frequency due to factors other than these treatments over the study period.

2.2 Selection of Sites

2.2.1 Case Sites

A number of seagull intersections implemented on high speed (speed limit ≥ 80 km/h), dual carriageway T-intersections in WA rural regions were identified. In particular, a list of nine seagull intersections was identified on Forrest Highway, all on high speed sections of the highway with speed limit of either 100 or 110 km/h. Additionally, a further 11 seagull intersections were identified on Bussell Highway, all on sections with a speed limit between 80 km/h and 110 km/h. However, these seagull intersections had no “before” exposure crash period. A further list of 6 seagull intersections on Marmion Avenue that had “before” and “after” exposure periods was then identified. While these 6 intersections were not implemented in rural regions, they all had a high speed limit of 80 km/h and experienced higher daily traffic then the Forrest Highway and Bussell Highway intersections. It was expected that any reduction in crashes experienced by the Marmion Avenue intersections would act as a more conservative indication of the potential reductions at Forrest Highway and Bussell Highways. The 6 seagull intersections on Marmion Avenue, treated between the years 2002 and 2007, formed the final sample of case sites for this study. Figure 2.1 shows the “triangular island” of the seagull intersection treatment on one of the Marmion Avenue sites. See Appendix A for the location and a picture of each of the six sites.

Figure 2.1 A Seagull Intersection on Marmion Avenue

2.2.2 Comparison Sites

To test the effectiveness of treated sites, the best method is to have each treated site matched with a comparison site having similar road characteristics. However, in a quasi-experimental study design the selection of comparison sites is a balance between matchings of specific site characteristics in order to control for confounding influences on crash trends. The basic assumption is that if the characteristics of matched sites are similar, then their crash rates (adjusted for traffic volume) should be too. The comparison sites are used to indicate what would have happened at the treated sites if no treatment was applied.

Six comparison sites were chosen on Wanneroo Road to match the 6 Marmion Avenue case sites with the seagull intersection treatment. This group of comparison sites was chosen because they were located on a section of Wanneroo Road that was "parallel" to the section of Marmion Avenue which contained the 6 case sites, and that similar traffic characteristics such as flow and volume could be assumed. Both of these road sections had one end intersecting with Warwick Road and the other end intersecting with Whitfords Avenue. The pre- and post- exposure periods for the comparison sites were chosen such that the first comparison site along Wanneroo Road from the Warwick Road to Whitfords Avenue direction had its exposure periods matching those of the first case site along Marmion Avenue also from the Warwick Road to Whitfords Avenue direction. The second comparison site along Wanneroo Road also had its exposure periods matching those of the second case site along Marmion Avenue, and so on. See Appendix B for the location and a picture of each site.

2.3 Data Collection – Integrated Road Information System (IRIS)

The Road Safety Section at Main Roads, WA (MRWA) provided information on each treated site. Crash data for the before and after installation of treatment was obtained from the Integrated Road Information System (IRIS) using police reported data which is maintained by MRWA.

The IRIS database contains detailed information on the characteristics of the vehicles involved in road crashes, crash circumstances, Police reported injury and road information related to the crash location. Crash data for the evaluation was obtained up to and including 31st December, 2014.

The definition of a crash used throughout this report is the definition used by the Road Safety Council in its annual publication "Reported Road Crashes in Western Australia 2013" (Office of Road Safety, 2014). That is, a crash is "*any unpremeditated incident where in the course of the use of any vehicle on a road that was not temporarily closed off to the public, a person is injured or property is damaged. The crash must involve vehicle movement. Does not include collisions that occur due to a medical condition, deliberate acts (e.g. suicide attempts) or police chases*".

The severity of a crash is derived from "*the most serious injury in a crash*". A fatal crash is "*a road crash in which at least one person was killed immediately or died within 30 days of the crash, as a result of the crash*". A hospitalisation crash is a road crash that involved at least one admission to hospital but "*no fatalities within 30 days of the crash*". A medical treatment crash (or medical attention crash) is "*a road crash in which the most serious injury resulted in a person requiring medical treatment, but without being admitted to hospital*". A property damage only (PDO) crash involved no/unknown injuries only.

For the purpose of this report, casualty crashes include all fatal crashes, hospitalisation crashes, and medical treatment crashes. All reported crashes include all fatal crashes, hospitalisation crashes, medical treatment crashes, and PDO crashes.

In WA, it is mandatory for the driver of a vehicle to report a traffic crash when the incident occurred on a road or any place commonly used by the public, e.g. carparks; and

- the incident resulted in bodily harm to any person; or
- the total value of property damaged to all involved parties exceeds $3000; or
- the owner or representative of any damaged property is not present.

Critical data retrieved for use in the study were:

- crash date;
- crash severity;
- local government area of crash; and
- specific crash location.

The study adopted an approach that utilised five years of pre-treatment crash data as well as five years of post-treatment crash data which excluded the construction period. Crash data which was used in the analysis included all fatal, hospitalisation, medical treatment and PDO crashes. This was consistent with MRWA's intention to ensure application of funds to a wider range of projects at hazardous situations using different thresholds such as all reported crashes rather than casualty crashes only. A separate analysis by casualty crashes only was also undertaken.

2.4 Factors that may Affect Evaluation of Road Safety Treatments such as Seagull Intersection

When estimating the treatment effect, all known factors that have the potential to affect the evaluation of a road safety treatment should be accounted for. However, Elvik (1997) found that the more factors that are accounted for, the less effective the treatment appears to be.

Some of the factors that may affect the evaluation of the effectiveness of the seagull intersection treatment are described below. These include site-specific factors, regression to the mean, and crash migration.

2.4.1 Site Specific Factors

Some of the observed change in the number and severity of crashes at a site could be accounted for by specific events other than the treatment. These specific events could, for example, include weather conditions and increased publicity about the safety of the site. Both these may lead to an increase in driver caution which could lead to a reduction in crashes that has little to do with the treatment at the site. While this study was unable to assess all such effects, it appeared unlikely that site specific factors would significantly affect the evaluation of all treated sites in the sample as a whole (Bureau of Transport, 2001). However, any analysis at a particular site could be affected (Bureau of Transport, 2001).

2.4.2 Regression to the Mean

The high crash rates observed at some sites may possibly be due to chance or a combination of both chance and the hazardousness of the site. Even if no treatment is to be carried out, some of these sites will likely have fewer crashes in the subsequent period because the number of crashes will tend to gravitate to the long-term mean. Under these conditions, the effect of any treatment is likely to be over-estimated. Failing to allow for the regression to the mean effect can result in statistically significant results for treatments that are in fact ineffective.

On the basis of work reported by Nicholson (1986), at least three and preferably five years of data is the preferred before and after time period to smooth out any random fluctuations as well as to provide sufficient evidence of any trend or change in an established pattern of crashes. Five years of pre-treatment crash data as well as five years of post-treatment crash data were used for all sites evaluated in the study. The statistical methodology used in this report also recognised the level and distribution of random variation in the data and provided appropriate confidence intervals and significance levels.

2.4.3 Crash (accident) Migration

The term crash migration (also referred as accident migration) describes an increase in crashes at sites in the vicinity of a treated site, away from the treated site to the surrounding area, following the treatment of that site. Whether crash migration is a real effect in road safety treatments such as Black Spot treatments or the seagull intersection treatment remains a controversial topic, which has not been adequately resolved by road safety experts. Therefore, the analysis has not attempted to deal with crash migration. For the purpose of this report, the assumption was made that no treatment could be associated with crash migration resulting from traffic migration away from the treated site.

For a more in-depth discussion of crash migration see Elvik (1997).

2.5 Statistical Analysis – Effectiveness of the Treatment

The frequencies of crashes between "*before*" and "*after*" treatment periods were compared in the analysis. The study used a generalised estimating equation (GEE) Poisson regression model to evaluate the high speed seagull intersections. The number of crashes in one year is a discrete "count" variable and assumed to follow a Poisson distribution. However, the application of standard Poisson regression analysis was inappropriate due to the longitudinal nature of the observations, while the GEE was one of the more appropriate methods that could accommodate the inherent correlation of the longitudinal data. The decision to use the GEE Poisson model took into account the correlated nature of the repeated measures taken before and after the seagull intersection treatment.

The correct effect of a treatment could also be estimated by the GEE Poisson regression model, as robust standard errors were generated to provide valid statistical inferences. The overall treatment effect was estimated by the model. As the number of high speed WA sites with the seagull intersection treatment that have appropriate "before" and "after" exposure periods were limited, the six case sites in this study were grouped together to attain a higher statistical power, regardless of the design specifications of each seagull intersection such as angle and median width. Details about the GEE technique can be found in Dupont (2002) and Twisk (2003).

Each model included an interaction term to examine the effect of the road treatment post intervention for the treated sites compared to the untreated or "comparison" sites. This was because the changes in the number of crashes over time were different between the treated and untreated sites. Therefore, an interaction term between time (before treatment and after treatment) and group (treated sites and untreated sites) would account for these changes in the model.

Information on traffic volumes over time at individual treated site would be useful to determine whether any changes in crash history were due to a treatment at the site or whether changes in traffic flow gave rise to the observed discrepancies before and after treatment. While it was possible to obtain estimated figures of annual average daily traffic (AADT) from MRWA for both the thru road and side road associated with each treated seagull intersection and have the crash data adjusted for traffic volume, in practice the interactions between flows of (1) both directions of thru traffic maintaining those same directions, (2) thru traffic of the two directions turning into side traffic, and (3) side traffic turning into one of the two directions of the thru traffic, would make for complex adjustment that would only be accurate or of meaningful value had more sites existed in the study sample. For the purpose of this analysis it was thus assumed that before and after traffic volumes remained constant. As traffic volume was known to grow from year to year, this would possibly result in a more conservative reporting of crash reductions. Sites with zero crashes would have been excluded from the analysis but there was no such site in the study sample.

The model was fitted to the data using the Stata (Version 12) statistical package.

3. RESULTS

This section details the results for all reported crash and casualty crash frequency. Table 3.1 shows the number of treated case sites, the exposure and number of crashes before and after treatment, as well as the untreated control sites and their details.

Table 3.1 WA High Speed Seagull Intersections and Comparison Sites Sampled for the Study

Case Site	Intersection ID	Intersection Description	Road No.	Road Name	Speed Limit (km/h)	Exposure "Before" Treatment (Days)	All Reported Crashes "Before" Treatment	Casualty Crashes "Before" Treatment	Exposure "After" Treatment (Days)	All Reported Crashes "After" Treatment	Casualty Crashes "After" Treatment
1	60423	Marmion Av & Marri Rd	H029	Marmion Av	80	1826	21	6	1826	10	1
2	60424	Marmion Av & Seacrest Dr	H029	Marmion Av	80	1826	43	4	1826	31	3
3	60426	Marmion Av & Harman Rd	H029	Marmion Av	80	1826	11	3	1826	14	2
4	60429	Marmion Av & Warburton Av	H029	Marmion Av	80	1826	50	10	1826	38	5
5	60432	Marmion Av & Giles Av	H029	Marmion Av	80	1826	18	9	1826	9	4
6	60434	Marmion Av & Cook Av	H029	Marmion Av	80	1826	17	6	1826	21	5

Comparison Site	Intersection ID	Intersection Description	Road No.	Road Name	Speed Limit (km/h)	Exposure "Before" (Days)	All Reported Crashes in Period "Before"	Casualty Crashes in Period "Before"	Exposure "After" (Days)	All Reported Crashes in Period "After"	Casualty Crashes in Period "After"
1	14043	Wanneroo Rd & Gorman St	H035	Wanneroo Rd	70	1826	4	2	1826	4	2
2	14042	Wanneroo Rd & Parin Rd	H035	Wanneroo Rd	70	1826	15	4	1826	10	3
3	11967	Wanneroo Rd & Daley St	H035	Wanneroo Rd	70	1826	0	0	1826	4	1
4	14041	Wanneroo Rd & Canham Wy	H035	Wanneroo Rd	70	1826	14	2	1826	12	4
5	11968	Wanneroo Rd & Kingfisher Wy	H035	Wanneroo Rd	70	1826	1	0	1826	5	3
6	14035	Wanneroo Rd & Hocking Rd	H035	Wanneroo Rd	70	1826	12	2	1826	10	1

All Reported Crashes

Table 3.2 and Figure 3.1 show the effect of the seagull intersection treatment on all reported crashes (fatal, hospitalisation, medical treatment and PDO crashes). In the table, β represents the regression coefficient in terms of the log-scale of the outcome variable so that the reduction rate is given by $1 - e^{\beta}$. A negative value for β indicates that all reported crash rate or casualty crash rate decreased following treatment, and vice versa for a positive value for β. The statistical significance of treatment is given by p. For example, $p < 0.001$ means that the probability of obtaining such a result by chance is less than one in a thousand. The percentage reduction in the number of all reported crashes and casualty crashes is shown in the last column of the table.

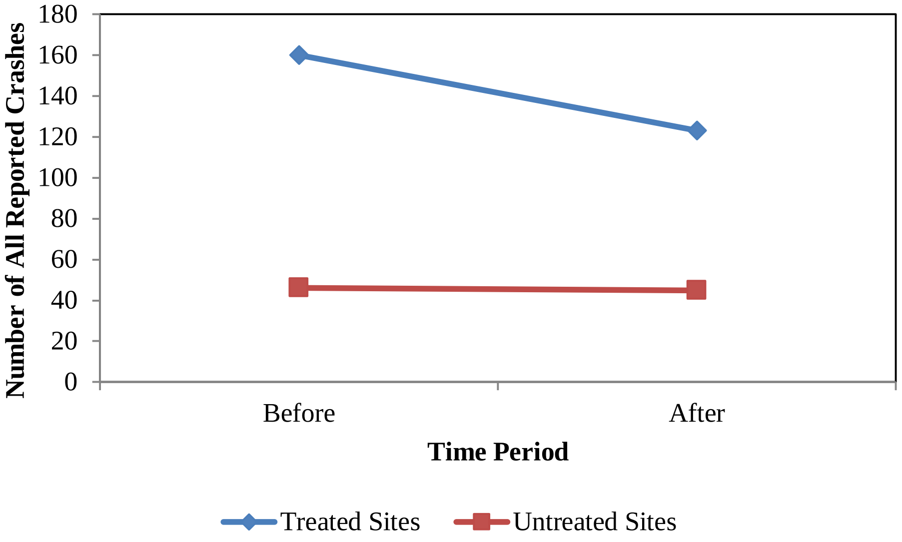
In this analysis, very strong evidence meant that the probability of an event occurring by chance is less than one in one thousand ($p < 0.001$); strong evidence meant that the probability is less than one in one hundred ($p < 0.01$); moderate evidence meant that the probability is less than one in fifty ($p < 0.02$); weak evidence meant that the probability is less than one in ten ($p < 0.1$) and not significant was indicated by $p \geq 0.1$. This was consistent with the criteria adopted by other evaluations of road safety programs such as the National Black Spot Program evaluation (BITRE, 2012).

Overall, there was a statistically significant 21.4% reduction in all reported crashes ($p = 0.011$) for the six seagull intersections compared to the comparison sites post treatment, indicating that the treatment was successful in reducing the risk of a crash.

Table 3.2 Seagull Intersection Treatment Effect on Reduction in All Reported Crashes

All Reported Crashes		Estimate (β)	Standard Error	Probability 0 < p < 1	95% C.I. - Lower Bound	95% C.I. - Upper Bound	Incidence Rate Ratio IRR	Crash Reduction (%)
6 treated + 6 untreated sites (n = 12)								
Group	0 = untreated site 1 = treated site	1.247	0.167	< 0.001	0.919	1.574	3.478	
Time	0 = before treatment 1 = after treatment	-0.022	0.082	0.788	-0.182	0.138	0.978	
Time * Group		**-0.241**	**0.095**	**0.011**	**-0.427**	**-0.055**	**0.786**	**21.4%**

Figure 3.1 Seagull Intersection Treatment Effect on Reduction in All Reported Crashes



Casualty Crashes

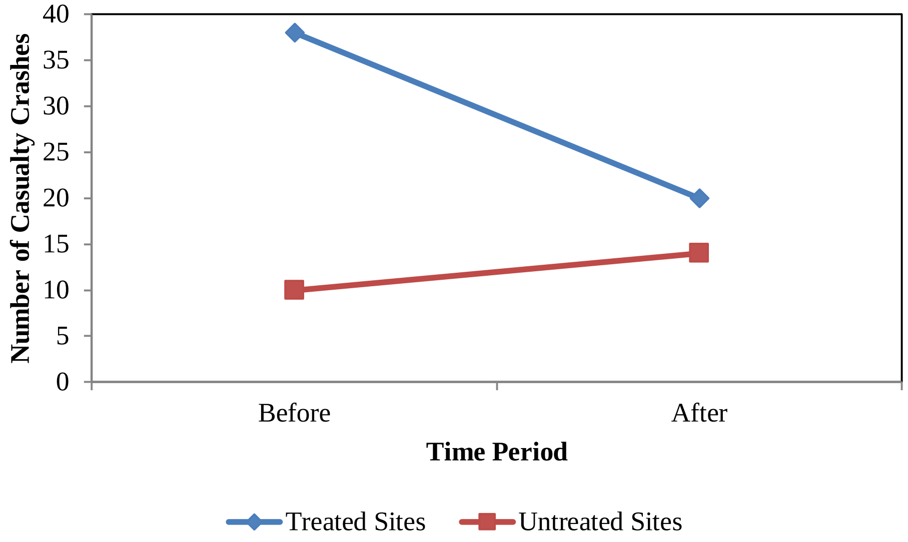
Table 3.3 and Figure 3.2 show the effect of the seagull intersection treatment on casualty crashes only (fatal, hospitalisation and medical treatment crashes).

Overall, there was a statistically significant 62.4% reduction in casualty crashes ($p = 0.010$), indicating that the treatment was also highly successful in reducing crash severity in the event of a crash.

Table 3.3 Seagull Intersection Treatment Effect on Reduction in Casualty Crashes

Casualty Crashes		Estimate (β)	Standard Error	Probability 0 < p < 1	95% C.I. - Lower Bound	95% C.I. - Upper Bound	Incidence Rate Ratio IRR	Crash Reduction (%)
6 treated + 6 untreated sites (n = 12)								
Group	0 = untreated site 1 = treated site	1.335	0.355	< 0.001	0.638	2.032	3.800	
Time	0 = before treatment 1 = after treatment	0.336	0.315	0.285	-0.280	0.953	1.400	
Time * Group		**-0.978**	**0.380**	**0.010**	**-1.722**	**-0.234**	**0.376**	**62.4%**

Figure 3.2 Seagull Intersection Treatment Effect on Reduction in Casualty Crashes



4. DISCUSSION

This report presents the results of the evaluation of the seagull intersection treatment on a high speed metropolitan road (speed limit = 80 km/h) in Western Australia in terms of its effectiveness in reducing the frequency for all reported crashes and casualty crashes. The analysis found the treatment to be effective overall in reducing the frequency of all reported crashes by 21.4% and casualty crashes by 62.4% for the treated sites in the study sample. The results are specific to the particular environment and conditions on Marmion Avenue, and might represent sites on other roads with similar conditions, but possibly not roads of non-similar characteristics.

A number of decisions were made regarding the analysis. The study examined the both the effects of the seagull intersection treatment on all severity of crashes (including PDO) and casualty crashes only. This was in keeping with Main Roads WA threshold criteria, which allowed for the application of funds to a wider range of projects based on the total number of crashes at sites which varied between regions and road types. The alternative to this would be to study treatment effect on only crash types most likely to be affected by the particular treatment being examined, in this case angled crashes (or right-angled crashes). However, an evaluation of specific crash types only may have the potential to miss all possible benefits of a treatment as well as potential detrimental effects. According to Newstead & Corben (2001) an evaluation that includes all crash types is more relevant when examining the effectiveness of road safety treatments which was the aim of the present study.

The results of this new study are largely consistent with results reported in recent State Black Spot evaluations undertaken in Western Australia. Zhang et al. (2014) reported a significant 24.1% reduction in all reported crashes ($p < 0.001$) and also a 54.5% reduction (though not statistically significant) in casualty crashes ($p = 0.119$) at 3 sites treated with the seagull intersection treatment under the 2007-2008 WA State Black Spot Program. Meuleners et al. (2014) examined 2 sites treated under the 2009-2010 State Black Spot Program and also reported a 35.1% reduction (though not statistically significant) in all reported crashes ($p = 0.463$), but no significant change in casualty crashes ($p = 0.289$) though this could be due to the very small sample size. Chow et al. (2015) reported preliminary increases in both all reported crashes and casualty crashes at 2 sites treated under the 2011-2012 State Black Spot Program but commented that a small sample size and/or inadequate exposure time post treatment available to that study (21 months) might have produced the misleading results.

The lack of WA high speed sites with the seagull intersection treatment that had usable "before and after" exposure data was the main limitation of the study. A much larger sample would be required to provide the necessary statistical power to account for design specifications of each seagull intersection such as angle and median width.

Also, a proper adjustment for traffic volume would only be accurate or of meaningful value had more sites existed in the study sample. For the purpose of this analysis it was assumed that the before and after traffic volumes remained constant, which could have possibly resulted in a more conservative reporting of crash reductions.

Another limitation was the lack of accurate information regarding the time of installation of the seagull intersection treatment at each site. It was crucial that neither the before treatment period nor the after treatment period overlapped the construction period, in which case estimates of the treatment effect could result in bias towards the lesser or greater magnitude compared to the true value. With the assistance from MRWA, the MRWA system "Skyview" was utilised to estimate the latest date before the treatment was installed and the earliest date after the completion of the treatment, using archived aerial photographs. As the aerial photography at each site was often taken at an annual basis, a more exact installation period could not be determined. Instead, a whole year of installation period had to be assumed for each treatment for the purpose of GEE Poisson modelling.

To help gain a better understanding of the effectiveness of the seagull intersection treatment on roads with characteristics not similar to Marmion Avenue, further descriptive statistics are provided in Appendix C, and preliminary results (seagull treatment only) from a yet to be published C-MARC study on all WA State Black Spot treatments 2000-2012 combined (Chow et al. 2016) were also extracted and provided in Appendix D.

Appendix C examines the distribution of crashes at different levels of severity at a number of seagull-treated and non-seagull comparison sites, specifically found on 110 km/h high speed sections of Forrest and Bussell Highways, which are of particular interest to Main Roads WA. A full "before and after" study was not possible over these sites, as they were effectively "greenfield" and lack an usable "before" exposure for analysis. As such, only the distribution of crashes in an "after" period (5 years, 2010-2014) can be examined, providing an alternative look but one that would be neither definitive nor conclusive.

Appendix C suggests that the seagull intersections on 110 km/h sections of Forrest Highway experienced, on average, much higher frequency of all reported crashes per site (n = 10; average per site: 341 crashes per million vehicles through the thru road of the intersection) than their non-seagull counterparts (n = 2; average per site: 104 crashes per million vehicles through the thru road of the intersection) in a same 5 year period. However, the proportion of all crashes being Casualty Crashes, were much less at the seagull sites (23%) than the non-seagull ones (66%). Similarly, the proportion of the more severe Killed or Seriously Injured (KSI) crashes were also much less at the seagull sites (10%) than the non-seagull ones (34%). The seagull sites though, did experience Fatal Crashes (2%) while the non-seagull ones experienced none in the same 5 year period.

On the 110 km/h sections of Bussell Highway, the seagull intersections also experienced, on average, much higher frequency of all reported crashes per site (n = 5; average per site: 484 crashes per million vehicles) than their non-seagull counterparts (n = 7; average per site: 130 crashes per million vehicles) in the same period. However, there appeared to be no difference in terms of the proportion of all crashes being Casualty Crashes for the seagull sites (38%) and the non-seagull ones (38%). The seagull sites experienced KSI Crashes (17%) and Fatal Crashes (7%) but the non-seagull ones experienced none. Such differences suggest that the conditions on Bussell Highway could possibly be quite different than Forrest Highway.

Appendix C also considered an overall 17 seagull sites (Bussell Hwy, Forrest Hwy, & Indian Ocean Dr) and 12 non-seagull comparison sites (Bussell Hwy, Forrest

Hwy, & Great Eastern Hwy) on 110 km/h sections of WA roads identified by Main Roads WA. For the 110 km/h sections, overall, the seagull sites experience much higher frequency of all reported crashes per site (average per site: 746 crashes per million vehicles) than their non-seagull counterparts (average per site: 193 crashes per million vehicles). Overall, the proportion of all crashes being Casualty Crashes were much less at the seagull sites (24%) than the non-seagull ones (41%). However, the proportion of KSI Crashes appeared to be no different for the seagull sites (15%) and the non-seagull ones (15%). The seagull sites experienced the most severe Fatal Crashes (3%) but the non-seagull ones experienced none.

Such results from Appendix C appear to suggest a hypothesis that the 110 km/h locations chosen to receive the seagull treatment could have experienced a higher frequency of all reported crashes, potentially due to the specific conditions at each location rather the seagull treatment itself. However, the seagull treatment could have possibly reduced the severity of most crashes (therefore a smaller proportion of all crashes being Casualty Crashes). Though the seagull treatment alone might not have been able to reduce the more extreme of the severities. The definitive confirmation of such a hypothesis is beyond the scope of this report due to the lack of available data, but nonetheless an interesting hypothesis to be tested should more usable data become available in future.

Appendix D provides an extract of the preliminary results (seagull treatment only) from another C-MARC study on all WA State Black Spot treatments 2000-2012 combined (Chow et al. 2016). The Black Spot study also employed a "before and after" design utilising GEE Poisson modelling that is similar to the study in this report.

Appendix D (Chow et al. 2016) provided an overall look at seagull treatments implemented at a sample of 41 metropolitan and 5 rural sites with different speed limits, not focusing on the high speed 110 km/h roads that are of particular interest. The preliminary results suggest that the 46 sites sampled experienced a slight increase in All Reported Crashes (1.5%), but no significant change in Casualty Crashes after receiving the seagull treatment. However, as Chow et al. (2016) acknowledged the steady increase in traffic volume over the years but made an assumption that it was negligible for the purpose of modelling due to similar limitations as noted in this standalone study of the seagull treatment, the results from Chow eta al. (2016) could also be conservative.

5. CONCLUSIONS AND RECOMMENDATIONS

The results found seagull intersection treatment to be effective and producing positive outcomes for the community in terms of road safety, on Marmion Avenue and potentially roads of similar conditions and characteristics. The treatment has reduced all reported crash numbers by 21.4% and casualty crashes by 62.4% for treated sites in the study sample. After considering additional information as presented in Appendices C and D, there is, however, no definitive conclusion for the treatment on roads with different conditions, pending the availability of more usable data for future study.

Recommendations include:

- Accurate information regarding the time of installation of the seagull intersection treatment at each site needs to be properly maintained and documented for any future evaluation to ensure the validity of the results. It is crucial that neither the before treatment period nor the after treatment period overlaps the construction period, in which case estimates of the treatment effect could result in bias towards the lesser or greater magnitude compared to the true value. Given some of the difficulties experienced in the current study, it is recommended that a comprehensive and systematic method of data collection be implemented to facilitate future evaluations of seagull intersections or other road safety treatments.
- It is also recommended that this evaluation be repeated when more case sites with usable “before and after” exposure data become available.
- Should more case sites with suitable exposure data become available, future evaluations should also adjust for traffic flow and account for design specifications of each seagull intersection such as angle and median width.

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APPENDIX A – Treated Case Sites Utilised for the Study

Case Site	Treatment Year	Period of Exposure "Before" Treatment	Period of Exposure "After" Treatment	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" Treatment (Days)	All Reported Crashes "Before" Treatment	Casualty Crashes "Before" Treatment	Exposure "After" Treatment (Days)	All Reported Crashes "After" Treatment	Casualty Crashes "After" Treatment
1	2003	1998-2002	2004-2008	60423	Marmion Av & Marri Rd	H029	Marmion Av	5	-31.83181	115.76384	80	1826	21	6	1826	10	1

Case Site	Treatment Year	Period of Exposure "Before" Treatment	Period of Exposure "After" Treatment	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" Treatment (Days)	All Reported Crashes "Before" Treatment	Casualty Crashes "Before" Treatment	Exposure "After" Treatment (Days)	All Reported Crashes "After" Treatment	Casualty Crashes "After" Treatment
2	2007	2002-2006	2008-2012	60424	Marmion Av & Seacrest Dr	H029	Marmion Av	5.52	-31.82731	115.76224	80	1826	43	4	1826	31	3

Case Site	Treatment Year	Period of Exposure "Before" Treatment	Period of Exposure "After" Treatment	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" Treatment (Days)	All Reported Crashes "Before" Treatment	Casualty Crashes "Before" Treatment	Exposure "After" Treatment (Days)	All Reported Crashes "After" Treatment	Casualty Crashes "After" Treatment
3	2007	2002-2006	2008-2012	60426	Marmion Av & Harman Rd	H029	Marmion Av	6.1	-31.82219	115.76109	80	1826	11	3	1826	14	2

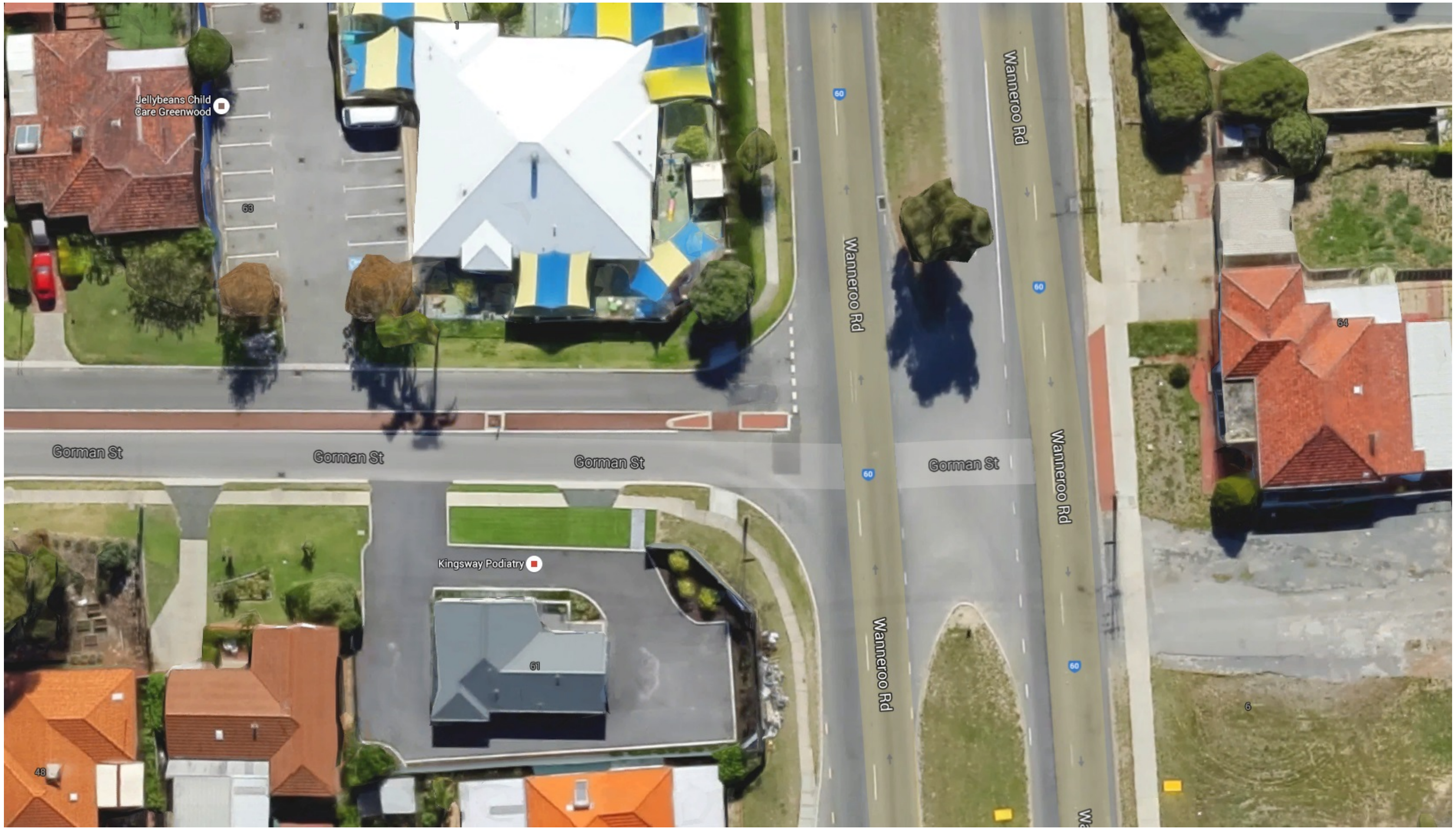
Case Site	Treatment Year	Period of Exposure "Before" Treatment	Period of Exposure "After" Treatment	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" Treatment (Days)	All Reported Crashes "Before" Treatment	Casualty Crashes "Before" Treatment	Exposure "After" Treatment (Days)	All Reported Crashes "After" Treatment	Casualty Crashes "After" Treatment
4	2007	2002-2006	2008-2012	60429	Marmion Av & Warburton Av	H029	Marmion Av	7.1	-31.81375	115.75853	80	1826	50	10	1826	38	5

Case Site	Treatment Year	Period of Exposure "Before" Treatment	Period of Exposure "After" Treatment	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" Treatment (Days)	All Reported Crashes "Before" Treatment	Casualty Crashes "Before" Treatment	Exposure "After" Treatment (Days)	All Reported Crashes "After" Treatment	Casualty Crashes "After" Treatment
5	2002	1997-2001	2003-2007	60432	Marmion Av & Giles Av	H029	Marmion Av	8.05	-31.80599	115.75603	80	1826	18	9	1826	9	4

Case Site	Treatment Year	Period of Exposure "Before" Treatment	Period of Exposure "After" Treatment	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" Treatment (Days)	All Reported Crashes "Before" Treatment	Casualty Crashes "Before" Treatment	Exposure "After" Treatment (Days)	All Reported Crashes "After" Treatment	Casualty Crashes "After" Treatment
6	2007	2002-2006	2008-2012	60434	Marmion Av & Cook Av	H029	Marmion Av	8.62	-31.80114	115.75481	80	1826	17	6	1826	21	5

APPENDIX B – Untreated Control Sites Utilised for the Study

Comparison Site	Treatment Year	Period of Exposure "Before"	Period of Exposure "After"	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" (Days)	All Reported Crashes in Period "Before"	Casualty Crashes in Period "Before"	Exposure "After" (Days)	All Reported Crashes in Period "After"	Casualty Crashes in Period "After"
1	not treated	1998-2002	2004-2008	14043	Wanneroo Rd & Gorman St	H035	Wanneroo Rd	13.06	-31.82826	115.82142	70	1826	4	2	1826	4	2



Comparison Site	Treatment Year	Period of Exposure "Before"	Period of Exposure "After"	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" (Days)	All Reported Crashes in Period "Before"	Casualty Crashes in Period "Before"	Exposure "After" (Days)	All Reported Crashes in Period "After"	Casualty Crashes in Period "After"
2	not treated	2002-2006	2008-2012	14042	Wanneroo Rd & Parin Rd	H035	Wanneroo Rd	13.32	-31.82594	115.82124	70	1826	15	4	1826	10	3

Comparison Site	Treatment Year	Period of Exposure "Before"	Period of Exposure "After"	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" (Days)	All Reported Crashes in Period "Before"	Casualty Crashes in Period "Before"	Exposure "After" (Days)	All Reported Crashes in Period "After"	Casualty Crashes in Period "After"
3	not treated	2002-2006	2008-2012	11967	Wanneroo Rd & Daley St	H035	Wanneroo Rd	13.52	-31.82422	115.8211	70	1826	0	0	1826	4	1

Comparison Site	Treatment Year	Period of Exposure "Before"	Period of Exposure "After"	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" (Days)	All Reported Crashes in Period "Before"	Casualty Crashes in Period "Before"	Exposure "After" (Days)	All Reported Crashes in Period "After"	Casualty Crashes in Period "After"
4	not treated	2002-2006	2008-2012	14041	Wanneroo Rd & Canham Wy	H035	Wanneroo Rd	13.73	-31.82226	115.82094	70	1826	14	2	1826	12	4

Comparison Site	Treatment Year	Period of Exposure "Before"	Period of Exposure "After"	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" (Days)	All Reported Crashes in Period "Before"	Casualty Crashes in Period "Before"	Exposure "After" (Days)	All Reported Crashes in Period "After"	Casualty Crashes in Period "After"
5	not treated	1997-2001	2003-2007	11968	Wanneroo Rd & Kingfisher Wy	H035	Wanneroo Rd	15.5	-31.80624	115.81972	70	1826	1	0	1826	5	3

Comparison Site	Treatment Year	Period of Exposure "Before"	Period of Exposure "After"	Intersection ID	Intersection Description	Road No.	Road Name	Straight Line Kilometres - SLK (km)	Latitude	Longitude	Speed Limit (km/h)	Exposure "Before" (Days)	All Reported Crashes in Period "Before"	Casualty Crashes in Period "Before"	Exposure "After" (Days)	All Reported Crashes in Period "After"	Casualty Crashes in Period "After"
6	not treated	2002-2006	2008-2012	14035	Wanneroo Rd & Hocking Rd	H035	Wanneroo Rd	16.04	-31.80168	115.81767	70	1826	12	2	1826	10	1

APPENDIX C – Distribution of Crash Frequencies and Severities at Non-signalised Dual-carriageway T-intersections at High Speed Locations on Selected WA Roads of Interest, 2010-2014

				All Reported Crashes (Adjusted* to Traffic Volume of Section of Thru Road at T-intersection)								Right-angle Crashes (Adjusted* to Traffic Volume of Section of Thru Road at T-intersection)								Right-thru / Thru-right Crashes (Adjusted* to Traffic Volume of Section of Thru Road at T-intersection)							
				Adjusted* Number of Crashes (Averaged over Number of T-intersections Sampled)				Adjusted* Crashes per T-intersection, as a Percentage of Crashes of All Severities				Adjusted* Number of Crashes (Averaged over Number of T-intersections Sampled)				Adjusted* Crashes per T-intersection, as a Percentage of Crashes of All Severities				Adjusted* Number of Crashes (Averaged over Number of T-intersections Sampled)				Adjusted* Crashes per T-intersection, as a Percentage of Crashes of All Severities			
Thru Road	**Type of Non-signalised Dual-carriageway T-intersection**	**Number of T-intersections Sampled**	**Traffic Volume of Section of Thru Road at T-intersection: Annual Average Daily Traffic (AADT) 2010-2014**	**Fatal**	**KSI**	**Casualty**	**All Severities**	**Fatal**	**KSI**	**Casualty**	**All Severities**	**Fatal**	**KSI**	**Casualty**	**All Severities**	**Fatal**	**KSI**	**Casualty**	**All Severities**	**Fatal**	**KSI**	**Casualty**	**All Severities**	**Fatal**	**KSI**	**Casualty**	**All Severities**
110 km/h Sections of	Non-seagull	2	14536	0	35	69	104	0%	34%	66%	100%	0	0	0	0					0	0	0	0				
Forrest Hwy	Seagull	10	16761	5	35	78	341	2%	10%	23%	100%	5	25	31	97	5%	25%	32%	100%	0	0	0	42	0%	0%	0%	100%
110 km/h Sections of	Non-seagull	7	14124	0	0	49	130	0%	0%	38%	100%	0	0	49	69	0%	0%	71%	100%	0	0	10	20	0%	0%	50%	100%
Bussell Hwy	Seagull	5	11913	33	84	184	484	7%	17%	38%	100%	16	33	83	233	7%	14%	36%	100%	17	34	101	185	9%	18%	54%	100%
80 km/h Sections of	Non-seagull	17	30350	0	23	95	293	0%	8%	32%	100%	0	6	31	85	0%	7%	36%	100%	0	10	31	60	0%	16%	52%	100%
Marmion Ave	Seagull	9	30804	0	48	174	729	0%	7%	24%	100%	0	11	65	272	0%	4%	24%	100%	0	26	69	200	0%	13%	35%	100%
110 km/h Sections of WA Roads	Non-seagull	12	13518	0	29	79	193	0%	15%	41%	100%	0	16	52	79	0%	20%	66%	100%	0	0	6	19	0%	0%	31%	100%
with Dual-carriageway	Seagull	17	14318	21	113	176	746	3%	15%	24%	100%	12	62	90	215	6%	29%	42%	100%	9	14	34	185	5%	8%	18%	100%
100 km/h Sections of WA Roads	Non-seagull	7	14947	0	54	98	397	0%	14%	25%	100%	0	40	44	92	0%	44%	48%	100%	0	13	31	42	0%	32%	73%	100%
with Dual-carriageway	Seagull	7	20534	9	168	245	909	1%	18%	27%	100%	9	134	161	308	3%	44%	52%	100%	0	28	48	275	0%	10%	18%	100%
90 km/h Sections of WA Roads	Non-seagull	8	17518	0	35	128	362	0%	10%	35%	100%	0	35	77	157	0%	22%	49%	100%	0	0	35	52	0%	0%	67%	100%
with Dual-carriageway	Seagull	11	14238	0	57	80	486	0%	12%	16%	100%	0	0	0	81	0%	0%	0%	100%	0	38	51	108	0%	35%	47%	100%
80 km/h Sections of WA Roads	Non-seagull	73	24416	2	27	70	313	1%	9%	22%	100%	2	12	32	118	1%	11%	27%	100%	1	7	15	50	1%	14%	29%	100%
with Dual-carriageway	Seagull	25	26297	0	60	162	611	0%	10%	27%	100%	0	27	82	264	0%	10%	31%	100%	0	22	43	123	0%	18%	35%	100%

* *Adjusted Number of Crashes = Crashes per Million Vehicles*$_{(Thru\ Road\ Section\ of\ Site)} = \frac{Number\ of\ Crashes \times 1{,}000{,}000}{AADT_{(Thru\ Road\ Section\ at\ Site)}}$

Fatal Crashes = road crashes in which at least one person was killed immediately or died within 30 days of the crash, as a result of the crash (Severity 1)
Killed or Seriously Injured (KSI) Crashes = Fatal Crashes + Hospitalisation Crashes (Severities 1 + 2)
Casualty Crashes = KSI Crashes + Medical Treatment/Attention Crashes (Severities 1 + 2 + 3)
All Reported Crashes (All Severities) = Casualty Crashes + Property Damage Only (PDO) Crashes (Severities 1 + 2 + 3 + 4 + 5)

APPENDIX D Part 1 – Preliminary Statistics on Individual Seagull Treatment from C-MARC Study on All WA State Black Spot Treatments 2000-2012 Combined (Chow et al. 2016)

Program	Site No.	Region	Treatment Type	Description	Exposure (days)		All Reported Crashes (Severity = 1, 2, 3, 4, 5)		Casualty Crashes (Severity = 1, 2, 3)	
					Before	After	Before	After	Before	After
2000 to 2002	049	Metro	MR2	Seagull in median	1826	1826	12	32	0	8
2000 to 2002	051	Metro	MR2	Seagull in median	1826	1826	6	8	2	3
2000 to 2002	056	Metro	MR2	Seagull in median	1826	1826	8	2	4	1
2000 to 2002	069	Metro	MR2	Seagull in median	1826	1826	17	14	5	5
2000 to 2002	086	Metro	MR2	Seagull in median	1826	1826	31	24	10	6
2000 to 2002	087	Metro	MR2	Seagull in median	1826	1826	17	10	5	4
2000 to 2002	094	Metro	MR2	Seagull in median	1826	1826	78	80	24	16
2000 to 2002	095	Metro	MR2	Seagull in median	1826	1826	30	28	9	6
2000 to 2002	096	Metro	MR2	Seagull in median	1826	1826	29	26	9	9
2000 to 2002	097	Metro	MR2	Seagull in median	1826	1826	7	13	2	2
2000 to 2002	098	Metro	MR2	Seagull in median	1826	1826	7	9	1	3
2000 to 2002	099	Metro	MR2	Seagull in median	1826	1826	5	3	3	0
2000 to 2002	102	Metro	MR2	Seagull in median	1826	1826	16	34	4	14
2000 to 2002	103	Metro	MR2	Seagull in median	1826	1826	12	13	2	3
2000 to 2002	107	Metro	MR2	Seagull in median	1826	1826	13	15	3	0
2000 to 2002	108	Metro	MR2	Seagull in median	1826	1826	7	20	0	6
2000 to 2002	116	Metro	MR2	Seagull in median	1826	1826	19	30	8	9
2000 to 2002	118	Metro	MR2	Seagull in median	1826	1826	32	34	8	12
2003 to 2004	045	Metro	MR2	Seagull in median	1826	1752	15	14	5	2
2003 to 2004	069	Metro	MR2	Seagull in median	1826	1325	22	9	4	3
2003 to 2004	073	Metro	MR2	Seagull in median	1826	1660	42	46	6	10
2003 to 2004	074	Metro	MR2	Seagull in median	1826	1706	22	14	10	7
2003 to 2004	087	Rural	MR2	Seagull in median	1826	1615	3	1	2	0
2003 to 2004	096	Rural	MR2	Seagull in median	1826	1256	10	4	4	1
2003 to 2004	111	Rural	MR2	Seagull in median	1826	1340	7	3	4	1
2003 to 2004	112	Rural	MR2	Seagull in median	1826	1418	8	13	0	4
2003 to 2004	202	Metro	MR2	Seagull in median	1826	1218	19	4	4	0
2003 to 2004	228	Metro	MR2	Seagull in median	1826	1286	13	1	7	0
2003 to 2004	262	Metro	MR2	Seagull in median	1826	1399	10	3	2	0
2003 to 2004	282	Metro	MR2	Seagull in median	1826	1355	14	13	5	5
2005 to 2006	046	Metro	MR2	Seagull in median	1826	1826	22	32	11	10
2005 to 2006	047	Metro	MR2	Seagull in median	1826	1826	12	2	2	1
2005 to 2006	176	Metro	MR2	Seagull in median	1826	1826	7	2	2	0
2005 to 2006	283	Metro	MR2	Seagull in median	1826	1826	13	14	2	5
2005 to 2006	317	Metro	MR2	Seagull in median	1826	1826	12	6	2	3
2005 to 2006	335	Metro	MR2	Seagull in median	1826	1826	30	21	5	4
2005 to 2006	339	Metro	MR2	Seagull in median	1826	1826	18	11	4	2
2007 to 2008	S045	Metro	MR2	Seagull in median	1826	1583	5	9	0	4
2007 to 2008	S047	Metro	MR2	Seagull in median	1826	1826	12	4	3	3
2007 to 2008	S096	Metro	MR2	Seagull in median	1826	1826	9	8	2	2
2007 to 2008	S097	Metro	MR2	Seagull in median	1826	1826	9	5	4	0
2007 to 2008	S164	Metro	MR2	Seagull in median	1826	1826	40	31	5	3
2009 to 2010	S374	Metro	MR2	Seagull in median	1826	1681	8	4	1	2
2009 to 2010	S405	Metro	MR2	Seagull in median	1826	1706	7	5	1	0
2011 to 2012	S601	Rural	MR2	Seagull in median	1826	549	1	0	0	0
2011 to 2012	S689	Metro	MR2	Seagull in median	1826	699	357	245	78	57

APPENDIX D Part 2 – Preliminary Statistics on Seagull Treatments (by Period/Year of Implementation) from C-MARC Study on All WA State Black Spot Treatments 2000-2012 Combined (Chow et al. 2016)

Program	No. of Sites	Metro Sites	Rural Sites	Exposure (days)		All Reported Crashes (Severity = 1, 2, 3, 4, 5)		Casualty Crashes (Severity = 1, 2, 3)	
				Before	After (average)	Before	After	Before	After
2000 to 2002	18 (39.1%)	18	0	1826	1826.0	346	395	99	107
2003 to 2004	12 (26.1%)	8	4	1826	1444.2	185	125	53	33
2005 to 2006	7 (15.2%)	7	0	1826	1826.0	114	88	28	25
2007 to 2008	5 (10.9%)	5	0	1826	1777.4	75	57	14	12
2009 to 2010	2 (4.3%)	2	0	1826	1693.5	15	9	2	2
2011 to 2012	2 (4.3%)	1	1	1826	624.0	358	245	78	57
All 13 Years	**46 (100%)**	**41**	**5**	**1826**	**1663.1**	**1093**	**919**	**274**	**236**

APPENDIX D Part 3 – Preliminary Results (GEE Poisson "Before and After" Study Design) on Seagull Treatments (All Years Combined) from C-MARC Study on All WA State Black Spot Treatments 2000-2012 Combined (Chow et al. 2016)

	Metro Sites	Rural Sites	Exposure Before (days)	Mean Exposure After (days)	Crashes Before	Crashes After	Estimate (β)	Standard Error	Probability 0 < p < 1	95% C.I. - Lower Bound	95% C.I. - Upper Bound	Incidence Rate Ratio IRR	Crash Reduction (%)
All Reported Crashes at sites treated with MR2 Seagull Intersection in 2000 - 2012 WA State Black Spot Programs	41	5	1826	1663.1	1093	919	0.014	0.007	0.047	0.000	0.029	1.015	-1.5% +
Casualty Crashes at sites treated with MR2 Seagull Intersection in 2000 - 2012 WA State Black Spot Programs	41	5	1826	1663.1	274	236	0.034	0.022	0.123	-0.009	0.078	1.035	-3.5% +*

** Increase/reduction in crashes per million vehicles is not statistically significant (p-value > 0.05).*
+ Negative reduction indicates an increase.