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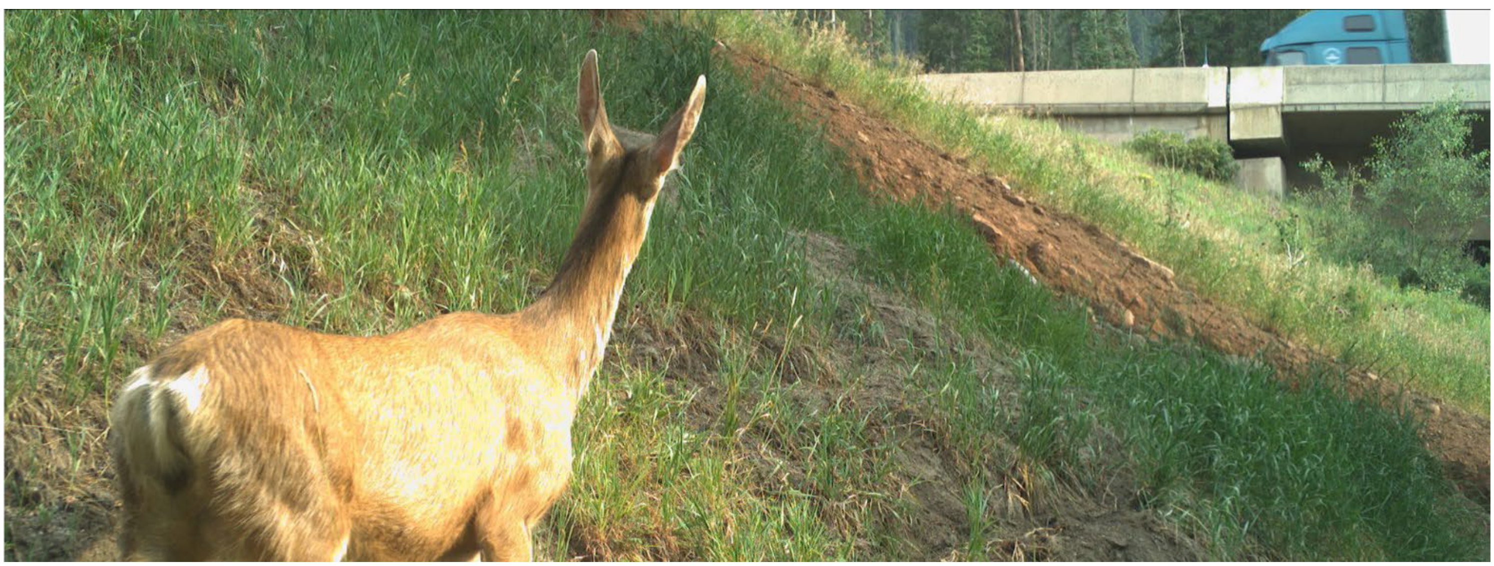
A Literature Analysis and Study to Determine Optimal Wildlife Crossing Structure Size



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16. Abstract

The *Literature Analysis to Determine Optimal Wildlife Crossing Structure Size Study* (Study) emerged from Colorado Department of Transportation's (CDOT's) desire to determine if there is a point of diminishing return of effectiveness based on target species success rates when it comes to sizing highway wildlife passages. This Study's objectives are to review and analyze existing monitoring data to determine if there are optimum structure dimensions for underpasses and overpasses for mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), pronghorn (*Antilocapra americana*), moose (*Alces alces*) and Canada lynx (*Lynx canadensis*), particularly the point at which increasing structure sizes may reach a range of diminishing returns relative to cost and predicted increase in successful crossings. The Study results infer recommendations for a repeatable process to analyze effectiveness and diminishing returns in the future when new field studies are performed, new literature and data may be available, or a new species of interest is the subject. This Study identifies gaps in the literature, available data, and study processes that challenge the effective realization of diminishing return determinations in relation to success rates and highway wildlife passage dimensions. This Study's results, using regression modeling, may inform development and sizing of highway wildlife passages relative to defining success criteria for larger wildlife and reducing wildlife-related vehicle collisions across Colorado. The results indicate that, given a statistically valid sample size, modeling can be done to determine which structure dimensions (length, width, and height) most strongly influence a species' (such as mule deer) success rate through wildlife underpass crossing structures. Given this analysis, modeling to predict success rates for a given species and a range of structure dimensions can be generated. It is also possible to determine if a given species has a preference regarding underpass type (bridges or culverts). It is critical that monitoring of wildlife crossings be done to determine success and repel rates because this data will allow further application of predictive modeling for other species. In addition, the project team recommends that success criteria for wildlife mitigation projects be clearly defined and measures identified to determine whether they have been achieved.

Statement of Purpose

The goal of this Study is to determine via existing published literature, unpublished study data, and reports (if accessible) if there is a point of diminishing returns of effectiveness based on wildlife success rates when it comes to sizing highway wildlife passages.

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Executive Summary

Wildlife crossing structures (WCSs), underpasses, and overpasses are widely used for the safe travel of larger wildlife species across roads and highways, reducing wildlife-related vehicle collisions to drivers (Denneboom et al. 2021). WCSs are often expensive to build and maintain, and therefore determining a cost-effective, optimal design is a challenge faced by departments of transportation across the United States and elsewhere. Although much research has been conducted on the variables affecting the usage of WCSs by wildlife (Clevenger and Waltho 2000, 2005; Cramer et al. 2015; Dodd et al. 2007; Huijser et al. 2016), few attempts have been made to correlate cost-diminishing returns in relation to the success rates and optimal sizing of WCSs. We conducted a systematic review of the scientific, professional, and grey literature to assess effectiveness of WCSs and a meta-analysis to explore the structural variables that influence their effectiveness on success rates of mule deer (*Odocoileus hemionus)*, elk (*Cervus canadensis*), and other target species. Ultimately this meta-analysis was used to construct regression modeling for a repeatable approach to determining diminishing return on effectiveness in relation to WCS dimensions. The database provides inputs to run statistical analyses and regression models using Microsoft Excel and R statistical program.[1] Four models were analyzed to evaluate success rate and independent variables, and a fifth model evaluated costs and structure dimensions.

Based on the data set, modeling, and statistical analysis, success rates for mule deer use of underpasses (culverts and bridges) is most strongly influenced by structure length and width, and the project team was able to generate a tabular summary of predicted success rates for underpasses given length and width dimensions. Mule deer do not show a preference between bridges or culverts, while elk prefer bridges to culverts. However, the team did not have adequate data to determine strongest drivers of success rate relative to bridge or culvert underpass size dimensions for elk. Based on the modeling and statistical analysis with the database, the success rate could be the same for mule deer and elk for a combination of underpass structure dimensions. The team attempted to determine if mule deer or elk exhibited a preference for overpasses as compared to underpasses and if so, the range of dimensions (length, width, and

[1] R is a free software environment for statistical computing and graphics (https://www.r-project.org/).

height) correlated to success rate. However, the data for overpasses used by mule deer and elk to evaluate this scenario were insufficient.

There is not enough monitoring data available currently to perform a separate statistical analysis to determine predicted success rates for any given structural types or dimensions for moose (*Alces alces*), pronghorn (*Antilocapra americana*), Rocky Mountain bighorn sheep (*Ovis canadensis*), or Canada lynx (*Lynx canadensis*).

A single point of diminishing return where incremental costs to increase structure size outweighed predicted increase in success rate could not be identified. Using the results of Model 4 predicted success rates for mule deer, the team was able to demonstrate an example where once a desired success rate or range of success rates (for example, 60-75%) is identified, a predicted range of structural dimensions can be identified that may achieve that success rate. Evaluation of biological, engineering and cost constraints of a project can be worked through to balance project needs and achieve desired outcomes.

Implementation Statement

Based on the literature review and modeling, the project team recommends use of the Eastern Slope and Plains and Western Slope wildlife prioritization studies (Kintsch et al., 2019; Kintsch et al., 2022) to identify priority locations to perform wildlife mitigation. In addition, there is a need for developing a systematic monitoring protocol for wildlife mitigation projects—in particular, those projects addressing species such as elk, moose, pronghorn, Rocky Mountain bighorn sheep, and Canada lynx where success and repel rates are determined. This additional data will allow further modeling and analysis to determine predicted optimal sizing for WCSs for these species. A key recommendation is clearly defining success for mitigation projects by defining a range of expected wildlife crossing success rates and expected reductions in wildlife-vehicle collisions. This can best be accomplished by developing interdisciplinary design teams of biologists and engineers.

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Acronyms and Abbreviations

AIC	Akaike Information Criterion
ANOVA	analysis of variance
CDOT	Colorado Department of Transportation
DVC	deer vehicle collision
HSD	honestly significant difference
I-	Interstate
MDT	Montana Department of Transportation
N/A	not applicable
Study	*Literature Analysis to Determine Optimal Wildlife Crossing Structure Size Study*
SH	State Highway
U.S.	United States
US	U.S. Highway
WCS	wildlife crossing structure
WVC	wildlife-related vehicle collision

1. Introduction

In North America, wildlife-related vehicle collisions (WVCs) are a serious safety concern for state departments of transportation and the traveling public. Between 1 and 2 million collisions with large wildlife are estimated to occur in the United States (U.S.) each year (Conover et al. 1995; IIHS 2018; State Farm 2021), resulting in wildlife mortalities and human fatalities and injuries, as well as associated costs of more than 10 billion U.S. dollars annually (Huijser et al. 2007, adjusted for inflation to 2021 dollars). From July 2020 through June 2021, 1 out of every 179 Colorado drivers submitted a claim from hitting an animal, which was a 7% increase from 2018 (State Farm 2021).

Over the past 5 years, Colorado Department of Transportation (CDOT) and Colorado Parks and Wildlife (CPW) have developed statewide priority planning for wildlife mitigation, and funding has been put in place to address migration and habitat connectivity at both state and national levels. Specific examples include the following:

- Department of the Interior Secretarial Order 3362 (Improving Habitat Quality in Western Big Game Winter Range and Migration Corridors)
- Colorado Governor's Executive Order D 2019 011 (Conserving Colorado's Big Game Winter Range and Migration Corridors)
- Colorado's Western Slope and soon-to-be-completed Eastern Slope and Plains Wildlife Prioritization Studies (Kintsch et al., 2019; Kintsch et al., 2022)
- Recent passage of the 2021 Bipartisan Infrastructure Investment and Jobs Act and its provisions for wildlife mitigation funding

Wildlife crossing structures (WCSs), underpasses, and overpasses are widely used for the safe travel of larger wildlife across roadways and highways, reducing WVCs to drivers (Denneboom et al. 2021). WCSs are often expensive to build and maintain; therefore, a cost-effective optimal design is essential. Although much research has been conducted on the variables affecting the usage of WCSs by wildlife, few attempts have been made to correlate cost-diminishing returns in relation to success rates and optimal sizing of WCSs. The purpose of this Study) is to review and analyze if science-based, practical recommendations for the dimensions and types of WCS used primarily by mule deer (*Odocoileus hemionus)*, elk *(Cervus canadensis)*, pronghorn (*Antilocarpa* *americana*), moose (*Alces alces*), and Canada lynx (*Lynx canadensis*) can be identified from published and grey literature, as well as if a point of diminishing returns on costs associated with the success rates of target species can be determined.

1.1 Study Objectives

The Study objectives are as follows:

1) Review and analyze existing literature and data to determine the optimum size of underpasses and overpasses for wildlife species, including mule deer, elk, Canada lynx, moose, Rocky Mountain bighorn sheep (*Ovis canadensis*), and pronghorn—particularly, the point at which increasing structure sizes may reach a point of diminishing returns in effectiveness.
2) Recommend a repeatable process to achieve objective 1 in the future, to be implemented when new field studies are performed, new literature and data may be available, or a new species of interest is the subject.
3) Identify gaps in the literature, available data, or study process that challenge the effective realization of objectives 1 and 2. In addition, provide recommendations for filling gaps in a potential future phase of research on this topic.

1.2 Hypothesis

The hypothesis, in two terms, is as follows:

1) If optimal sizing of WCSs can be determined through analysis of published and unpublished wildlife crossing monitoring data (such as repel rate or success rate) for the readily available data on structures (such as length, width, and height) for different species (such as mule deer, elk, pronghorn, moose, Canada lynx, and other species), optimal WCS size can be estimated based on dependent success criteria for desired passage rates.
2) If optimal structure sizing can be estimated, a determination of when a structure size may reach the point of diminishing returns can be estimated through analysis of structure cost and the strongest potential variables, such as structure dimensions and other factors to support desired species, that may affect successful passage.

2. Methods

2.1 Literature Analysis and Database Development

To test the hypothesis, published and unpublished data were gathered from multiple studies for use in statistical analyses. Literature was deemed suitable for use in the meta-analysis if the data collected for the WCSs in the studies contained complete data sets. A complete data set is defined as a singular WCS (either an underpass or overpass) with dimension measurements (such as length, width, and height), and structure class (such as culvert or bridge). In addition, a complete data set includes the number of crossings, success rates, and repel rates for a target species (such as mule deer, elk, and other species). Studies that were unpublished data sets were given titles based on the source for the data, such as files received from CDOT or other researchers or transportation agencies.

Eighteen studies primarily focusing on western U.S. and Canada were used in the initial data collection to construct the database. However, only 16 studies were used in the final database because 2 omitted studies did not have complete data sets. Studies used in this analysis are provided in Appendix A.

2.2 Model Selection Analysis

Several analytical methods were used to determine the significant influence of independent variables for model determination. In addition to the standard descriptive statistics for each data set, the feasibility of a regression analysis was determined using a sample size calculator. The factors used in this calculation are power = 0.8, an 'f' distribution with a medium size of 0.39, and three independent variables. It was determined, using a sample size calculator, that the minimum size for a regression analysis with three independent variables was 76 (Statistics Kingdom 2021). Where the data set became too small for multiple regression analysis and did not meet the minimum statistical sample size, a simple linear regression analysis was performed individually on each variable; this was done as an exploratory exercise to determine probable independent predictor of success. For data sets with a sufficient sample size, a multiple linear regression was performed in addition to descriptive analysis.

Regression analysis describes the magnitude of the relationship between independent (predictor) variables and a dependent (response) variable. Numerous types of regression models exist. For continuous data, such as the structure dimensions (for example, length, width, height), a multiple linear regression serves as an appropriate statistical technique. For the evaluation of categorical independent variables, such as a structure type (for example, culvert, bridge, overpass), a logistical regression is used and the categorical variables are coded as 0 or 1 when inputting the data into R statistical program[2] for analysis. Model selection analysis was performed in R using the explanatory variables as described in Table 1.

Table 1. Regression Model and Model Variables

Regression Model	**Success Rate**	**Structure Dimensions[b]**	**Species**	**Structure Class[c]**	**Structure Type[d]**	**Costs**
Variables[a]	***Dependent***	***Independent***	***Indicator***	***Indicator***	***Indicator***	***Dependent***
Model 1	X	X				
Model 2	X	X	X			
Model 3	X	X		X		
Model 4	X	X	X		X	
Model 5		X				X

[a] Variables used in the modeling analysis are defined as dependent, independent, or indicator variables.

[b] Structure dimension variables, expressed in feet, are defined as the length, width, or height (if appropriate) of an individual WCS.

[c] Structure class variables are defined as either a wildlife crossing overpass or an underpass.

[d] Structure type variables are defined as either a bridge or culvert WCS type.

2.3 Regression Model Variable Assumptions, Limitations, and Definitions

In addition to model selection analysis, the following list of assumptions (with constraints that may impact the statistical analyses) was determined:

- The purpose of the structures is to minimize wildlife-vehicle collisions and provide environmental benefits (such as connectivity). Benefits are not quantified as part of the Study.
- For all structures, assume wildlife fencing is present.

[2] R is a free software environment for statistical computing and graphics (https://www.r-project.org/).

- Report data are reasonably accurate and can be used to inform the Study.
- The Study uses readily available data and does not perform additional monitoring activities.
- Independent variables are limited or constrained by readily available data in published and unpublished data.
- Cost information is readily available for structures. Where cost information is unavailable, additional assumptions will be developed to estimate costs, which may impact the analysis.
- Lack of any specific species in the Study does not indicate a lack of use by that species.
- Studies used in the formation of the database for this study evaluated underpasses constructed of various material types (reinforced concrete box, concrete round or elliptical, structural steel plate pipes, concrete arches, and bridges). Some studies analyzed a continuous single underpass under two or more lanes or two underpasses (one each) under two or more lanes of a divided highway with an open atrium.

In addition, the definitions of the variables used in the statistical analyses are as follows:

- **Structural Dimensions**:
  - *Length*: the distance wildlife have to travel to get from one side of the highway to the other either through or over a WCS. This distance may include an atrium in addition to structure length dimension.
  - *Width*: the lateral distance from one side of a WCS to the other as wildlife move through or over the length of a WCS.
  - *Height*: the distance from the finished grade or substrate of an underpass to the top of the inside of a culverted underpass or low beam elevation of a bridge.
- **Repel Rate**: If available from monitoring data, percentage of instances in which wildlife approach structure but do not completely cross the structure, determined by dividing the total number of repels by the total number of approaches.
- **Success Rate**: If available from monitoring data, percentage of instances in which wildlife completely cross the structure, determined by dividing total number of successful crossings by the total number of approaches.

- **Optimal Sizing**: A deterministic estimate of WCS size based on a regression model with repel or success rates as the dependent and independent variables, which includes dimensions of structures.
- **Diminishing Return**: Additional inputs (such as increase) to the size of the structure resulting in an observed increase in the success rate (such as a decrease in repel rate) when all other inputs remain constant (follows use of the term "diminishing return" in traditional economics); for example, an increase in dimensions (such as length, width, or height) that would not result in a decrease to the repel rate or an increase to success rate.
- **Wildlife Crossing Structure**: A structure in connection to a roadway that allows wildlife to cross separated from traffic either under or over the roadway.

Some studies include an analysis of parallel rates or visitation rates that are not considered a successful crossing nor a rejection of the crossing. Therefore, to provide consistency across studies, the project team focused efforts on defining what makes a successful crossing and determined that all studies identified the term consistently. The project team has identified and used a repeatable method to test for optimal sizing of WCS and at what point cost hits a point of diminishing return effectiveness in the future when new field studies are performed, new literature and data may be available, or a new species of interest is the subject.

2.4 Model Analysis and Development Justification

The project team developed five models for analysis:

1) Model 1 evaluates a weighted average success rate for all species (mule deer, elk, moose, Rocky Mountain bighorn sheep, Canada lynx, and pronghorn), all underpasses (bridges and culverts), and structural dimensions (length, width, and height). The purpose of this model is for comparison to other models that are limited by species and underpass type. The results could be used for general reference when species and structure type are not identified.
2) Model 2 evaluates the success rate for deer and elk species, relative to underpasses holding all structural dimensions the same. The purpose of this model is to evaluate differences between species (deer and elk) and success rates relative to underpasses (bridges and culverts).

3) Model 3 evaluates the success rate for two WCS classes (underpass and overpass) and structural dimensions. The purpose of this model is to evaluate differences between structure classes. The results could be used for conditions in which structure class is identified.

4) Model 4 evaluates the success rate for deer and elk species, for two wildlife crossing underpass types (culvert and bridge), and structural dimensions. The purpose of this model is to evaluate differences between species and underpass structure type. Four analyses were performed: deer to (1) structure type and to (2) structure dimension, and elk to (3) structure type and to (4) structure dimension.

5) Model 5 evaluates the costs and structure dimensions. The purpose of this model is to identify a predictive model to estimate costs for data points that do not identify costs.
   Model 4 also can help inform further evaluation of diminishing return by identifying ranges of success rate (output) given structural dimensions (inputs) and the costs associated with a diminishing return at a particular structure dimension. Also, the predictive model can be applied in further evaluations such as benefit-cost analysis. The predictive model for costs is meant only to be used for this analysis and is not intended for engineering cost estimates.

3. Results

While initially tasked with considering multiple species as identified in objective 1 for all five models, only model 1 included data for mule deer, elk, moose, pronghorn, Rocky Mountain bighorn sheep, and Canada lynx. Analysis for models 2 and 4 could only be run with data for mule deer and elk. Due to insufficient monitoring studies and not having a minimum statistical sample size for analysis, data for moose, pronghorn, Rocky Mountain bighorn sheep, and Canada lynx were excluded in models 2 and 4.

In addition, model 3 had insufficient sample sizes associated with studies that monitored overpasses in the U.S. and Canada that were used by mule deer and elk built. Table 2 provides the results of the R modeling analyses for each of the five models. Supplemental statistical graphics, R outputs, and data sets used for the analysis of each model are in Appendices B through E.

Table 2. Modeling Summary Results[a]

Regression Model	Model 1	Model 2	Model 4[b]	Model 5
Best-fit model[c]	Success Rate = 185.412 - 32.687*ln(Length) + 10.736*ln(Width)	Success Rate = 161.247 - (33.378*ln(length)) + (5.721*ln(width)) + (16.116*ln(height))	Success Rate = 188.528 - (33.663*ln(length)) + (10.428*ln(width))	y = 84,614 * height + 485,639
Adjusted R-squared	0.49	0.57	0.51	0.28
AIC	725.36	945.87	681.50	N/A
f-statistic	39.99 (2 and 78 df)	32.66 (4 and 101 df)	39.73 (2 and 73 df)	13.6 (1 and 35 df)
Significance of f	<0.001	<0.001	<0.001	<0.001

[a] Model 3 did not have sufficient statistical sample size nor viable modeling results

[b] Model 4 results in this table only present mule deer results. Refer to Model 4 Results section for more details.

[c] Refer to respective model results for information on transformations and best-fit model details.

AIC = The Akaike information criterion is a mathematical method for evaluating how well a model fits the data it was generated from. AIC estimates the quality of each model, relative to each of the other models and a null model within the same data set. A lower AIC score is better when comparing models run within a data set.

df = The degrees of freedom in statistics indicate the number of independent values that can vary in an analysis without breaking any constraints.

N/A = not applicable

4. Models to Evaluate Success Rate (Models 1 through 4)

4.1 Model 1 Results

Model 1 evaluated weighted average success rate for all species (weight based on observed animal counts), all underpasses, and structural dimensions. The purpose of this model is for comparison to other models that are limited by species and underpass type. The results could be used for general reference when species and underpass structure type are not identified. The model used 80 complete WCSs data sets (n=80).Table 3 gives total animal count by species]).

Table 3. Animal Count by Species for Model 1

Species	Animal Count	Percent of Total Animal Count	Number of Underpasses Used by Each Species
Deer	270,020	98.5%	75
Elk	3,810	1.4%	33
Bighorn Sheep & Pronghorn	127	>0.1%	5
Lynx	6	>0.1%	5
Moose	68	>0.1%	5
Wild Horse	unknown	-	3

Based on summary statistics and normality tests, the success rate, with an average of 65%, was found to have normal distribution. However, length, width, and height with an average of 138 feet, 46 feet, and 14 feet, respectively, did not have normal distribution (Appendix B). Structure dimensions were corrected for normality using a log transformation.

A multivariable analysis was then conducted regressing the weighted average success rate against the length, width, and height of the structures. Based on the regression analysis, the structure height ($p = 0.1382$) was not statistically significant in estimating success rate.
A multivariable regression was conducted using length and width ($R^2 = 0.49$, $F(2,78) = 39.99$, $p < 0.001$). The regression results indicated that approximately 49%, or R^2, of the variability in the success rate is explained by length and width and that the success rate could be influenced by other factors (Appendix B). R's "MuMin glmulti" function identified the best model as including length, width, and height, but it was not significantly better that just length and width ($p > 0.05$). Refer to Appendix B for detailed output from R software.

In evaluating the linear and multivariable options, each option was over the 95% level of evidence (100% and 97.4% respectively), adjusted R-squared value was slightly better for the first model (0.5016 and 0.4936 respectively), and the AIC scores were statistically the same (725.30 and 725.36 respectively); it was determined that the models would provide the same confidence level of results. In evaluating the coefficient t-scores, the Pr(>|t|) was insignificant for height (t=0.1382) and the width was marginally significant (t = 0.0727) within the first model. Based on all other considerations, the second model, length + width, was chosen as the preferred model.

The following is the best-fit model, with logarithmic transformation to correct for structure dimension non-normal distribution, for model 1:

$$\textbf{Success Rate} = 185.412 - 32.687 \cdot \ln(\text{Length}) + 10.736 \cdot \ln(\text{Width})$$

Table 4 provides the descriptive statistics and Figure 1 provides a summary of predicted success rates for all species for combinations of length and width dimensions, in Model 1.

Table 4. Descriptive Statistics for All Species Model 1

Descriptive Statistic	Structure Length (ft)	Structure Width (ft)	Structure Height (ft)	Average Success Rate
Minimum	38	6	6	0
1st Quartile	70	19	10	50
Median	105	24	12	69
Mean	138	46	14	65
3rd Quartile	185	38	15	91
Maximum	558	900	38	100

Success Rate = 185.412 - (32.687*ln(length)) + (10.736*ln(width))

Length (feet)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200
200	37	41	44	47	49	50	52	53	54	55	56	57	58	59	59	60	61	61	62	62	63	63	64	64	64	65	65	66	66	66	67	67	67	68	68	68	69	69	69
195	38	42	45	48	50	51	53	54	55	56	57	58	59	59	60	61	61	62	62	63	64	64	64	65	65	66	66	66	67	67	68	68	68	69	69	69	69	70	70
190	39	43	46	48	50	52	54	55	56	57	58	59	60	60	61	62	62	63	63	64	64	65	65	66	66	67	67	67	68	68	68	69	69	69	70	70	70	71	71
185	39	44	47	49	51	53	54	56	57	58	59	60	60	61	62	62	63	64	64	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	71	71	72
180	40	45	48	50	52	54	55	57	58	59	60	60	61	62	63	63	64	65	65	66	66	67	67	68	68	68	69	69	69	70	70	70	71	71	71	72	72	72	73
175	41	46	49	51	53	55	56	57	59	60	61	61	62	63	64	64	65	65	66	67	67	68	68	68	69	69	70	70	70	71	71	71	72	72	72	73	73	73	73
170	42	47	50	52	54	56	57	58	60	61	61	62	63	64	65	65	66	66	67	68	68	68	69	69	70	70	71	71	71	72	72	72	73	73	73	74	74	74	74
165	43	48	51	53	55	57	58	59	61	62	62	63	64	65	66	66	67	67	68	68	69	69	70	70	71	71	72	72	72	73	73	73	74	74	74	75	75	75	75
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120	54	58	61	63	65	67	69	70	71	72	73	74	75	75	76	77	77	78	78	79	79	80	80	81	81	82	82	82	83	83	83	84	84	84	85	85	85	86	86
115	55	59	62	65	67	68	70	71	72	73	74	75	76	77	77	78	79	79	80	80	81	81	82	82	83	83	83	84	84	84	85	85	85	86	86	86	87	87	87
110	56	61	64	66	68	70	71	73	74	75	76	77	77	78	79	79	80	81	81	82	82	83	83	84	84	84	85	85	86	86	86	87	87	87	88	88	88	88	89
105	58	62	65	68	70	71	73	74	75	76	77	78	79	80	80	81	82	82	83	83	84	84	85	85	86	86	86	87	87	87	88	88	88	89	89	89	90	90	90
100	60	64	67	69	71	73	74	76	77	78	79	80	80	81	82	83	83	84	84	85	85	86	86	87	87	88	88	88	89	89	89	90	90	90	91	91	91	91	92
95	61	66	69	71	73	75	76	77	79	80	81	81	82	83	84	84	85	85	86	87	87	88	88	88	89	89	90	90	90	91	91	91	92	92	92	93	93	93	93
90	63	67	70	73	75	76	78	79	80	81	82	83	84	85	85	86	87	87	88	88	89	89	90	90	91	91	91	92	92	92	93	93	93	94	94	94	95	95	95
85	65	69	72	75	77	78	80	81	82	83	84	85	86	87	87	88	89	89	90	90	91	91	92	92	92	93	93	94	94	94	95	95	95	96	96	96	97	97	97
80	67	71	74	77	79	80	82	83	84	85	86	87	88	89	89	90	90	91	92	92	93	93	94	94	94	95	95	96	96	96	97	97	97	98	98	98	99	99	99
75	69	73	76	79	81	82	84	85	86	87	88	89	90	91	91	92	93	93	94	94	95	95	96	96	97	97	97	98	98	98	99	99	99	100	100	100	100	100	100
70	71	76	79	81	83	85	86	87	89	90	90	91	92	93	94	94	95	95	96	97	97	97	98	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100
65	74	78	81	84	85	87	89	90	91	92	93	94	95	95	96	97	97	98	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
60	76	81	84	86	88	90	91	92	94	95	96	96	97	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
55	79	83	87	89	91	93	94	95	96	97	98	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
50	82	87	90	92	94	96	97	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
45	86	90	93	96	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
40	90	94	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Width (feet)

Legend for Predicted Success Rate %

<70	70 to 79	80 to 89	90 to 99	100

Figure 1. Predicted Success Rates for All Species Given Combinations of Length and Width

4.2 Model 2 Results

Model 2 evaluated the success rate (dependent variable), which used the success rate for individual species (mule deer and elk) and underpass structure dimensions (length, width, and height). The model used 106 complete WCS data sets (n=106). This occurred because some structures that were used by both deer and elk are counted twice. Analysis of significance showed no significant impact by species; therefore, species observations were pooled together for analysis (p =0.3716; Appendix C). Elk had 30 observations, and mule deer had 76 observations. Based on summary statistics and normality tests, all variables were found to have non-normal distribution.

Table 5. Model 2 Summary Output (106 Observations)

Quartiles	Success Rate %	Length	Width	Height
Minimum	N/A	38	6	6
1st Quartile	33	78	19	9
Median	66	132	26	12
Mean	60	149	54	14
3rd Quartile	88	190	42	15
Maximum	100	558	900	38

Note: all length, width, and height units are in feet.

AIC and regression analysis identified the best-fit model with length, width, and height as the variables with the most statistical significance. Test for univariate correlations between variables and multicollinearity among variables by calculating pairwise Pearson correlation coefficients and variance inflation factors were conducted. Values exceeding 0.7 or 4.0, respectively, were removed. In addition, the model was transformed to correct for normality. Refer to Appendix C for the detailed statistical analysis output from the R software.

The following is the best-fit model with transformation:

$$\textbf{Success Rate} = 161.247 - (33.378*\ln(\text{length})) + (5.721*\ln(\text{width})) + (16.116*\ln(\text{height}))$$

Based on the modeling and statistical analysis with the database, when evaluating each individual underpass (that is, fixed dimensions) for deer or elk use, success rate is indifferent for species. In other words, the success rate could be the same for deer and elk for a combination of underpass structure dimensions. This could be the result of two things: the relatively homogenous structure dimensions within the database and the overwhelming influence of mule deer use relative to elk use of underpasses in the database.

4.3 Model 3 Results

Model 3 evaluated the success rate for the WCS classes (underpass and overpass) and structure dimensions (length, width, and height). This analysis was tried, but the data for overpasses used by mule deer and elk to evaluate this scenario were insufficient. However, reports by Clevenger et.al. (2009) in Canada, Kintsch et.al. (2021) in Colorado, and Stewart (2015) in Nevada have conducted pairwise comparisons of overpass and underpass use for mule deer and/or elk because their studies included overpasses built in proximity to underpasses in their respective study areas.

4.4 Model 4 Results

Model 4 evaluated success rate (dependent variable) for mule deer and elk for two wildlife crossing underpass types (culverts and bridges) and structural dimensions (length, width, and height). Four analyses were performed: mule deer to (1) structure type and (2) structure dimension, and elk to (3) structure type and (4) structure dimension.

4.4.1 Mule Deer Model 4 Results

For the mule deer scenarios, the analysis used 76 complete data sets of underpasses. Performing one-way analysis of variance (ANOVA) and Tukey honestly significant difference (HSD) significant difference tests revealed no significant difference between underpass types (bridges or culverts) for mule deer ($p>0.05$), so bridge and culvert observations were pooled together for analysis. Based on summary statistics and normality tests, the success rate was found to have non-normal distribution with an average of 63.25%. Length, width, and height had non-normal distributions: Length with an average of 135.50 feet, width with an average of 46.89 feet, and height with an average of 13.29 feet (Appendix D). AIC and regression analysis revealed the best-fit model with length and width as the variables with the most statistical significance affecting mule deer success rates of underpasses (Appendix D). In addition, the model was transformed to correct for normality. Table 6 provides descriptive statistics and Figure 2 provides a summary of predicted success rates for mule deer with combinations of length and width dimensions, in Model 4.

The following is the best-fit model for deer with transformation:

Deer_SuccessRate = 188.528 - (33.663*ln(length)) + (10.428*ln(width))

4.4.2 Elk Model 4 Results

For the elk scenarios, the analysis used 33 complete data sets with two variables: 18 bridges and 15 culverts. Based on summary statistics and normality tests, the success rate was found to have normal distribution with an average of 32.53%. Length, width, and height with averages of 192.90 feet, 24.53 feet, and 11.40 feet respectively, all had non-normal distribution (Appendix 4) and a log transformation was applied. Performing one-way ANOVA and Tukey HSD significant difference tests revealed a statistically significant difference between underpass types for elk (p = 0.0306), with the data set used in this Study elk prefer bridges to culverts.

4.4.3 Elk and Underpass Models

Although a valid multiple regression analysis for elk relative to independent variables (length, width, and height) for underpass types (bridges and culverts) could not be conducted, an exploratory analysis of each variable independently revealed that length likely is the strongest driver of success for elk with culverts and width likely the second strongest driver. However, these exploratory results are not statistically validated due to lack of sufficient data (Appendix D).

Table 6. Descriptive Statistics for Mule Deer Model 4

Descriptive Statistic	Structure Length (ft)	Structure Width (ft)	Structure Height (ft)	Success Rate
Minimum	38	6	6	0.00
1st Quartile	68	17	10	48
Median	99	24	12	66
Mean	136	47	13	63
3rd Quartile	186	38	15	91
Maximum	558	900	35	100

Success Rate = 188.528 - (33.663*ln(length)) + (10.428*ln(width))

Length (feet)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200
200	34	38	41	44	46	47	49	50	51	52	53	54	54	55	56	56	57	58	58	59	59	60	60	61	61	61	62	62	62	63	63	63	64	64	64	65	65	65	65
195	35	39	42	45	46	48	49	51	52	53	54	55	55	56	57	57	58	59	59	60	60	61	61	61	62	62	63	63	63	64	64	64	65	65	65	65	66	66	66
190	36	40	43	45	47	49	50	52	53	54	55	55	56	57	58	58	59	59	60	60	61	61	62	62	63	63	63	64	64	64	65	65	65	66	66	66	67	67	67
185	37	41	44	46	48	50	51	52	54	55	55	56	57	58	58	59	60	60	61	61	62	62	63	63	64	64	64	65	65	65	66	66	66	67	67	67	68	68	68
180	38	42	45	47	49	51	52	53	55	56	56	57	58	59	59	60	61	61	62	62	63	63	64	64	64	65	65	66	66	66	67	67	67	68	68	68	68	69	69
175	39	43	46	48	50	52	53	54	55	56	57	58	59	60	60	61	62	62	63	63	64	64	65	65	65	66	66	67	67	67	68	68	68	69	69	69	69	70	70
170	40	44	47	49	51	53	54	55	56	57	58	59	60	61	61	62	63	63	64	64	65	65	66	66	66	67	67	68	68	68	69	69	69	69	70	70	70	71	71
165	41	45	48	50	52	54	55	56	57	58	59	60	61	62	62	63	64	64	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	71	71	72	72
160	42	46	49	51	53	55	56	57	58	59	60	61	62	63	63	64	65	65	66	66	67	67	68	68	68	69	69	70	70	70	71	71	71	72	72	72	72	73	73
155	43	47	50	52	54	56	57	58	60	61	61	62	63	64	64	65	66	66	67	67	68	68	69	69	70	70	70	71	71	71	72	72	72	73	73	73	73	74	74
150	44	48	51	53	55	57	58	60	61	62	63	63	64	65	66	66	67	67	68	68	69	69	70	70	71	71	71	72	72	72	73	73	73	74	74	74	75	75	75
145	45	49	52	55	56	58	59	61	62	63	64	65	65	66	67	67	68	68	69	70	70	70	71	71	72	72	73	73	73	74	74	74	75	75	75	75	76	76	76
140	46	50	53	56	58	59	61	62	63	64	65	66	66	67	68	69	69	70	70	71	71	72	72	73	73	73	74	74	74	75	75	75	76	76	76	77	77	77	77
135	47	52	55	57	59	60	62	63	64	65	66	67	68	68	69	70	70	71	71	72	72	73	73	74	74	75	75	75	76	76	76	77	77	77	78	78	78	78	79
130	49	53	56	58	60	62	63	64	65	66	67	68	69	70	70	71	72	72	73	73	74	74	75	75	75	76	76	77	77	77	78	78	78	79	79	79	79	80	80
125	50	54	57	60	61	63	64	66	67	68	69	70	70	71	72	72	73	73	74	75	75	75	76	76	77	77	78	78	78	79	79	79	80	80	80	80	81	81	81
120	51	56	59	61	63	64	66	67	68	69	70	71	72	72	73	74	74	75	75	76	76	77	77	78	78	79	79	79	80	80	80	81	81	81	82	82	82	82	83
115	53	57	60	62	64	66	67	68	70	71	71	72	73	74	74	75	76	76	77	77	78	78	79	79	80	80	80	81	81	81	82	82	82	83	83	83	84	84	84
110	54	59	62	64	66	67	69	70	71	72	73	74	75	75	76	77	77	78	78	79	79	80	80	81	81	81	82	82	83	83	83	84	84	84	84	85	85	85	86
105	56	60	63	65	67	69	70	72	73	74	75	75	76	77	78	78	79	79	80	80	81	81	82	82	83	83	83	84	84	84	85	85	85	86	86	86	87	87	87
100	58	62	65	67	69	71	72	73	74	75	76	77	78	79	79	80	80	81	82	82	83	83	83	84	84	85	85	85	86	86	86	87	87	87	88	88	88	88	89
95	59	63	66	69	71	72	74	75	76	77	78	79	80	80	81	82	82	83	83	84	84	85	85	86	86	86	87	87	87	88	88	88	89	89	89	90	90	90	90
90	61	65	68	71	73	74	76	77	78	79	80	81	81	82	83	83	84	85	85	86	86	87	87	87	88	88	89	89	89	90	90	90	91	91	91	91	92	92	92
85	63	67	70	73	74	76	77	79	80	81	82	83	83	84	85	85	86	86	87	88	88	88	89	89	90	90	91	91	91	92	92	92	93	93	93	93	94	94	94
80	65	69	72	75	76	78	79	81	82	83	84	85	85	86	87	87	88	89	89	90	90	90	91	91	92	92	93	93	93	94	94	94	95	95	95	95	96	96	96
75	67	71	74	77	79	80	82	83	84	85	86	87	87	88	89	90	90	91	91	92	92	93	93	94	94	94	95	95	95	96	96	96	97	97	97	98	98	98	98
70	70	74	77	79	81	83	84	85	86	87	88	89	90	91	91	92	92	93	94	94	95	95	95	96	96	97	97	97	98	98	98	99	99	99	100	100	100	100	100
65	72	76	79	82	83	85	86	88	89	90	91	92	92	93	94	94	95	95	96	97	97	97	98	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100
60	75	79	82	84	86	88	89	90	91	92	93	94	95	96	96	97	98	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
55	78	82	85	87	89	91	92	93	94	95	96	97	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
50	81	85	88	90	92	94	95	97	98	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
45	84	89	92	94	96	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
40	88	93	96	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Width (feet)

Legend for Predicted Success Rate %

<70	70 to 79	80 to 89	90 to 99	100

Figure 2. Predicted Success Rates for Mule Deer Given Combinations of Length and Width

4.5 Model 5 Results

4.5.1 Cost Analysis

As part of the Study, cost data for wildlife crossings were collected for projects documented in the studies identified in Appendix A and are used as part of the analysis presented herein. The analysis of the cost data is not intended to be used for engineering cost estimates, rather it is used as part of the Study to evaluate costs in the context of relationships with structural dimensions and order of magnitude. Depending on the results of the regression models for success rate, cost data could be used to identify marginal and average costs at an estimated point or range of diminishing return(s). However, the results of Model 4 do not provide data that can be used to identify a single point, but rather a range. The predictive model for costs (Model 5) has different statistically significant input variable (height) than the predictive models (Model 4) for success rate.

Of the data collected, 37 projects included cost information along with structural dimensions. The project implementation years ranged from 1998 to 2020, and costs were adjusted for inflation using the Consumer Price Index to express cost in 2021 dollars. Forty-five projects had cost information, but eight of the projects did not include structural dimension. Table 7 summarizes the structure costs for the 45 identified projects. Some project data were excluded because the estimated costs were 10 million dollars and skewed the analysis.

Table 7. Summary of Structure Cost Data

Descriptive Statistics	Inflation Adjusted Costs ($,1000)[a]
Mean	$1,922
Standard deviation	$922
Median	$1,640
Count	45

[a] Expressed in 2021 dollars

A regression analysis of costs and structural dimensions was conducted to identify a predictive model that could be used for the purposes of the Study to estimate costs based on structure dimensions for those projects that did not report costs. This predictive formula is not intended for engineering cost estimating, rather it is used to estimate costs based for projects documented in other studies and that did not identify costs. Appendix F provides the detailed regression output and key components are summarized as follows.

A multivariable analysis was conducted regressing costs against the length, width, and height of the structures. Based the regression analysis, the structure length ($p = 0.92$) and width ($p = 0.43$) were not statistically significant in estimating costs. Based on these results, a linear bivariate regression was conducted using height ($R^2 = 0.25$, $F(1,35) = 11.93$, $p = 0.001$). The regression results indicated that approximately 25% of the variability in cost is explained by height and that costs are influenced by other factors. The intent of the predictive model is not to determine success rate, rather it is used to estimate costs for projects without cost data. Ideally, length and width should be used, but these variables were not found to have statical significance for model 5. Figure 3 summarizes the bivariate analysis regressing costs against height (y = 84,614 * height + 485,639). Figure 4 compares the predicted and estimate costs.

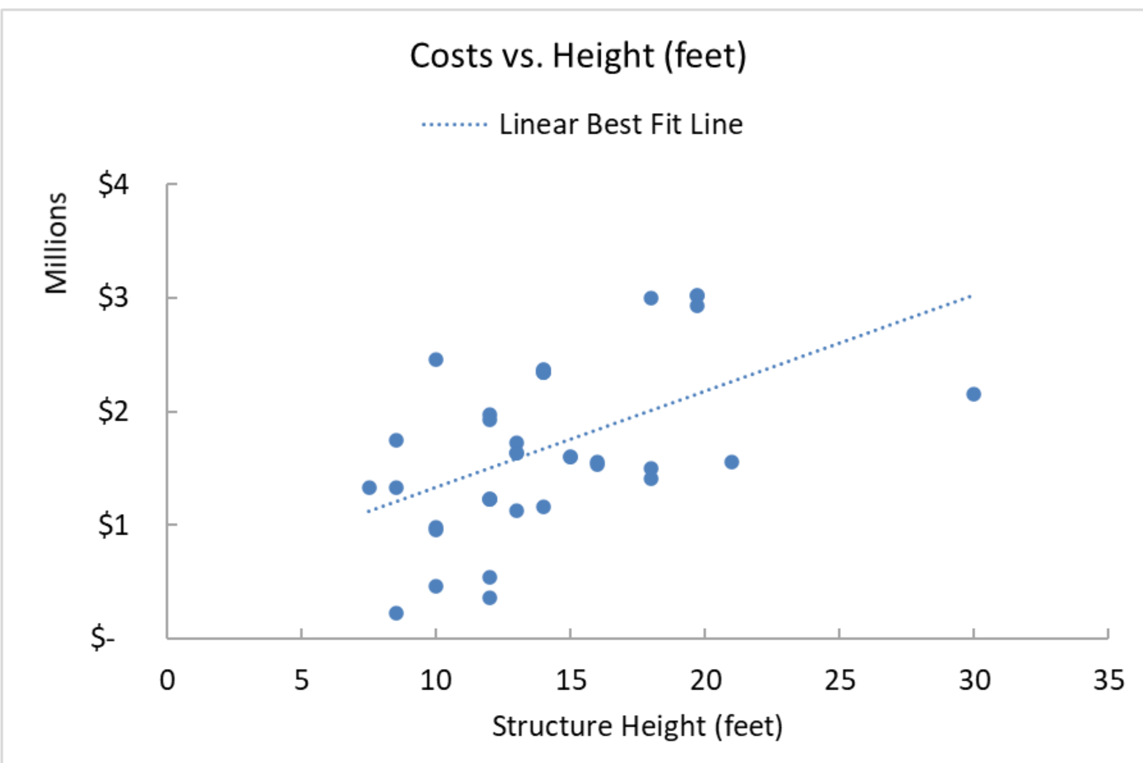

Figure 3. Bivariate Analysis of Cost Data Plotted Against Wildlife Crossing Structure Height

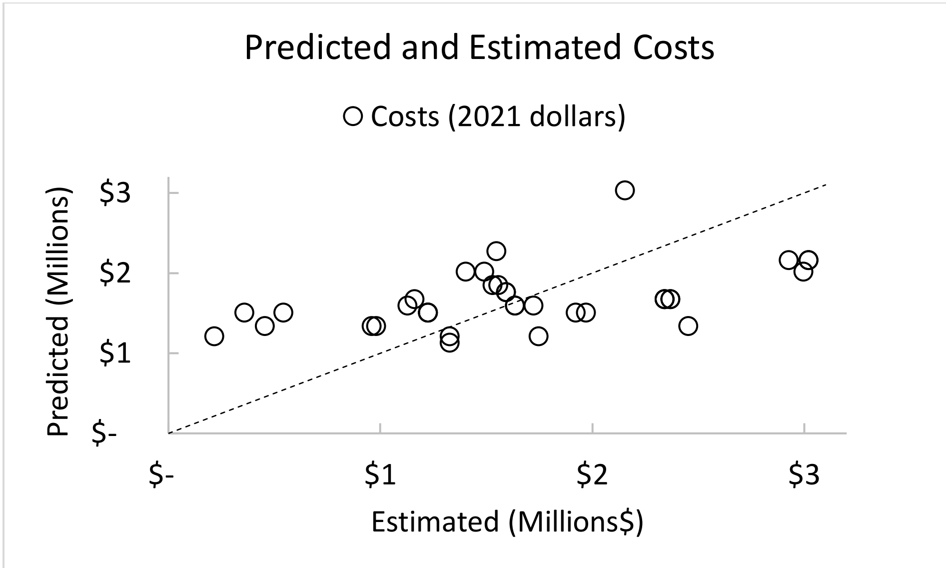

Figure 4. Predicted and Estimated Costs (in Millions) Plot Comparison

5. Diminishing Return

As noted in the objectives, part of this Study was to determine if a point of diminishing return of effectiveness based on mule deer, elk, and other target species success rates exists in relation to sizing highway wildlife passages. Based on review of readily available literature, a point of diminishing return of effectiveness has not been explored or documented. The Study attempted to evaluate relevant and available data regarding structure dimensions, species type, and success rates to explore the idea of diminishing return. In other words, when evaluating structure sizes, is there a point at which the cost of incremental increases in length, width or height exceeds the expected benefit relative to improved success rate? No single point of diminishing return could be identified.

The regression model results (presented in Model 4) for predicting success rates based on structure dimensions for mule deer were reviewed. The results suggest no difference between culvert and bridge underpasses. The variables length and width were significant ($p < 0.001$) and the predictive model for the success rate for mule deer is $y = 188.528 - (33.663*\ln(\text{length})) + (10.428*\ln(\text{width}))$, ($R^2 = 0.51$, $F(2,73) = 39.73$, $p < 0.0001$).

As part of the consideration of diminishing return, some of the inherent constraints regarding engineering and sizing of structure—the length of the structure is defined by the number of lanes for the roadway, fill heights and right-of-way medians; the width, and the distance between abutments—could be constrained by the topography. Figure 5 presents a tabular summary of Model 4, mule deer predicted success rates relating to combinations of length and width (note, this is the same as Figure 2). If points are selected for a 70% success rate, Figure 5 can be used to identify matching length and width pairs. For example, when length is 115 feet and width is 50 feet, the predicted success rate is 70%. Figure 5 can be used to identify ranges for purposes of understanding viable structure dimensions and predicted success rates. For a desired success rate of 70% to 79% for mule deer, the corresponding structure length dimensions are 65 to 140 feet; and the corresponding structure width are 20 to 95 feet. Figure 6 presents matching length and width pairs for 70% and 80% success rates.

Success Rate = 188.528 - (33.663*ln(length)) + (10.428*ln(width))

Length (feet) \ Width (feet)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200
200	34	38	41	44	46	47	49	50	51	52	53	54	54	55	56	56	57	58	58	59	59	60	60	61	61	61	62	62	62	63	63	63	64	64	64	65	65	65	65
195	35	39	42	45	46	48	49	51	52	53	54	55	55	56	57	57	58	59	59	60	60	61	61	61	62	62	63	63	63	64	64	64	65	65	65	65	66	66	66
190	36	40	43	45	47	49	50	52	53	54	55	55	56	57	58	58	59	59	60	60	61	61	62	62	63	63	63	64	64	64	65	65	65	66	66	66	67	67	67
185	37	41	44	46	48	50	51	52	54	55	55	56	57	58	58	59	60	60	61	61	62	62	63	63	64	64	64	65	65	65	66	66	66	67	67	67	68	68	68
180	38	42	45	47	49	51	52	53	55	56	56	57	58	59	59	60	61	61	62	62	63	63	64	64	64	65	65	66	66	66	67	67	67	68	68	68	68	69	69
175	39	43	46	48	50	52	53	54	55	56	57	58	59	60	60	61	62	62	63	63	64	64	65	65	65	66	66	67	67	67	68	68	68	69	69	69	69	70	70
170	40	44	47	49	51	53	54	55	56	57	58	59	60	61	61	62	63	63	64	64	65	65	66	66	66	67	67	68	68	68	69	69	69	69	70	70	70	71	71
165	41	45	48	50	52	54	55	56	57	58	59	60	61	62	62	63	64	64	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	71	71	72	72
160	42	46	49	51	53	55	56	57	58	59	60	61	62	63	63	64	65	65	66	66	67	67	68	68	68	69	69	70	70	70	71	71	71	72	72	72	72	73	73
155	43	47	50	52	54	56	57	58	60	61	61	62	63	64	64	65	66	66	67	67	68	68	69	69	70	70	70	71	71	71	72	72	72	73	73	73	73	74	74
150	44	48	51	53	55	57	58	60	61	62	63	63	64	65	66	66	67	67	68	68	69	69	70	70	71	71	71	72	72	72	73	73	73	74	74	74	75	75	75
145	45	49	52	55	56	58	59	61	62	63	64	65	65	66	67	67	68	68	69	70	70	70	71	71	72	72	73	73	73	74	74	74	75	75	75	75	76	76	76
140	46	50	53	56	58	59	61	62	63	64	65	66	66	67	68	69	69	70	70	71	71	72	72	73	73	73	74	74	74	75	75	75	76	76	76	77	77	77	77
135	47	52	55	57	59	60	62	63	64	65	66	67	68	68	69	70	70	71	71	72	72	73	73	74	74	75	75	75	76	76	76	77	77	77	78	78	78	78	79
130	49	53	56	58	60	62	63	64	65	66	67	68	69	70	70	71	72	72	73	73	74	74	75	75	75	76	76	77	77	77	78	78	78	79	79	79	79	80	80
125	50	54	57	60	61	63	64	66	67	68	69	70	70	71	72	72	73	73	74	75	75	75	76	76	77	77	78	78	78	79	79	79	80	80	80	80	81	81	81
120	51	56	59	61	63	64	66	67	68	69	70	71	72	72	73	74	74	75	75	76	76	77	77	78	78	79	79	79	80	80	80	81	81	81	82	82	82	82	83
115	53	57	60	62	64	66	67	68	70	71	71	72	73	74	74	75	76	76	77	77	78	78	79	79	80	80	80	81	81	81	82	82	82	83	83	83	84	84	84
110	54	59	62	64	66	67	69	70	71	72	73	74	75	75	76	77	77	78	78	79	79	80	80	81	81	81	82	82	83	83	83	84	84	84	84	85	85	85	86
105	56	60	63	65	67	69	70	72	73	74	75	75	76	77	78	78	79	79	80	80	81	81	82	82	83	83	83	84	84	84	85	85	85	86	86	86	87	87	87
100	58	62	65	67	69	71	72	73	74	75	76	77	78	79	79	80	80	81	82	82	83	83	83	84	84	85	85	85	86	86	86	87	87	87	88	88	88	88	89
95	59	63	66	69	71	72	74	75	76	77	78	79	80	80	81	82	82	83	83	84	84	85	85	86	86	86	87	87	87	88	88	88	89	89	89	90	90	90	90
90	61	65	68	71	73	74	76	77	78	79	80	81	81	82	83	83	84	85	85	86	86	87	87	87	88	88	89	89	89	90	90	90	91	91	91	91	92	92	92
85	63	67	70	73	74	76	77	79	80	81	82	83	83	84	85	85	86	86	87	88	88	88	89	89	90	90	91	91	91	92	92	92	93	93	93	93	94	94	94
80	65	69	72	75	76	78	79	81	82	83	84	85	85	86	87	87	88	89	89	90	90	90	91	91	92	92	93	93	93	94	94	94	95	95	95	95	96	96	96
75	67	71	74	77	79	80	82	83	84	85	86	87	87	88	89	90	90	91	91	92	92	93	93	94	94	94	95	95	95	96	96	96	97	97	97	98	98	98	98
70	70	74	77	79	81	83	84	85	86	87	88	89	90	91	91	92	92	93	94	94	95	95	95	96	96	97	97	97	98	98	98	99	99	99	100	100	100	100	100
65	72	76	79	82	83	85	86	88	89	90	91	92	92	93	94	94	95	95	96	97	97	97	98	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100
60	75	79	82	84	86	88	89	90	91	92	93	94	95	96	96	97	98	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
55	78	82	85	87	89	91	92	93	94	95	96	97	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
50	81	85	88	90	92	94	95	97	98	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
45	84	89	92	94	96	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
40	88	93	96	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Legend for Predicted Success Rate %

<70	70 to 79	80 to 89	90 to 99	100

Figure 5. Predicted Success Rates for Mule Deer Given Combinations of Length and Width

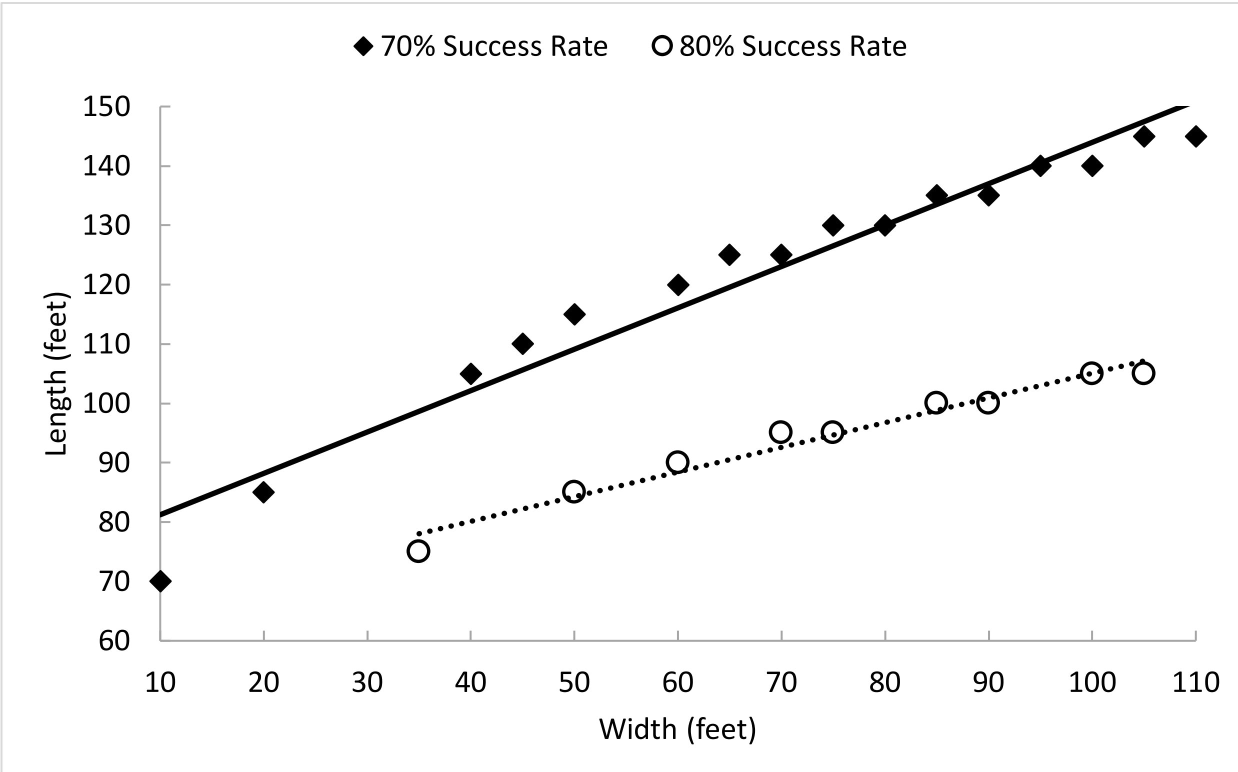

Figure 6. Success Rate Curves of Length and Width for Mule Deer

When sufficient data were available, the project team developed a repeatable method to test for optimal sizing of WCS, and once a desired success rate was identified, a range of structural dimensions were analyzed in determining how best to balance biological, engineering, and budgetary needs and constraints of a project. The methods and results presented can be used to aid in determining a range of structure dimensions and predicted success rates may occur and be updated in the future when new field studies are performed, new literature and data may be available, or a new species of interest is the subject.

In summary, model 1 evaluated the weighted average success rate for all species (weight based on observed animal counts), all underpasses, and structural dimensions. This model included data for mule deer, elk, moose, pronghorn, Rocky Mountain bighorn sheep, and Canada lynx. The results could be used for general reference when species and underpass structure type are not identified.

Model 2 found that success rate is indifferent for deer and elk, based on the modeling and statistical analysis with the database when evaluating each individual underpass (that is, fixed dimensions) for deer or elk use. In other words, the success rate could be the same for deer and elk for a combination of underpass structure dimensions. This could be the result of two things: the relatively homogenous structure dimensions within the database and the overwhelming influence of mule deer use relative to elk use of underpasses in the database.

Model 3 evaluated the success rate for the WCS classes (underpass and overpass) and structure dimensions (length, width, and height). Though this analysis was tried, the data for overpasses used by mule deer and elk to evaluate this scenario were insufficient. However, Clevenger et.al. (2009) in Canada, Kintsch et.al. (2021) in Colorado and Stewart (2015) in Nevada have conducted pairwise comparisons of overpass and underpass use for mule deer and/or elk because their studies included overpasses built in relatively close proximity to underpasses in their respective study areas.

Model 4 evaluated success rate (dependent variable) for mule deer and elk for two wildlife crossing underpass types (culverts and bridges) and structural dimensions (length, width, and height). Statistical modeling found that mule deer showed no preference between bridges and culverts, whereas elk showed a preference for bridges versus culverted underpasses. In addition, using a complete data set for mule deer, statistical modeling showed that length and width were the strongest drivers of successful crossings. Using this model, the team developed a graphic showing predicted success rates with various lengths and widths.

The team also found that conclusions should not be made regarding bridge or culvert underpass sizes for elk. A full multiple regression analysis was not possible because of the small number of elk observations for each underpass type. An exploratory look at the data suggests that length is likely a determining factor to the success of culverts and that length and height likely affect the success of bridges. However, this information is preliminary and should be used as a basis for further study. Additional data on elk success rates need to be obtained before further analysis and conclusions can be determined.

Model 5 generated a regression analysis of WCS costs and structural dimensions to identify a predictive model that could be used for the purposes of the Study to estimate WCS costs based on structure dimensions for those projects that did not report costs. In addition, using the results of Model 4 predicted success rates for mule deer, the project team was able to demonstrate an example where once a success rate is identified, a predicted range of structural dimensions can be identified that may achieve that success rate. Evaluation of biological, engineering, and cost constraints of a project can be worked through to balance project needs and achieve desired outcomes.

6. Discussion

This section addresses limitations to the data gathered from literature analysis, limitations to modeling analysis in conjunction with using wildlife monitoring data, and caveats to the inherent limitations of wildlife monitoring data. In addition, it presents findings from the literature review for species with insufficient information for individual species modeling in this Study, related to WCS use and other features that may influence use of crossing structures.

Minimum statistical sample sizes were unavailable for several of the target species (moose, pronghorn, Canada lynx, and others). Total observations after the literature analysis for moose, pronghorn, and Canada lynx yielded between five to seven observations per species, which is too small of a sample size to conduct practical statistical analyses. However, model 1 analyzed weighted average success rates for all species in the database combined and, therefore, could be used as a general guide for sizing underpasses for multi-species within our database.

Mule deer was the only target species that had enough observations to reach beyond a minimum statistical sample size for linear and multiple regression analysis. Mule deer do not appear to have a preference relative to culverts and bridges. Multiple regression analysis in model 4 yielded that length and width are the primary drivers of success for mule deer crossings; a graph with logarithmic curve was generated fitted with length and width fitted on the X and Y axes, and success rates were plotted on the graph to aid in determining predicted success rate fitted to varying lengths and widths for underpasses.

Elk had a marginal statistical sample size that could be used when data was pooled to determine elk preferences relative to underpass types, culverts, or bridges (one-way ANOVA and Tukey HSD models yielded a statistical significance for elk preference to bridges versus culverts). However, as stated in the Results section, elk observations could not be used to conduct for a multiple regression analysis to determine optimal length, width, or height for culverts or bridges in model 4. Conclusions should not be made regarding bridge or culvert underpass sizes for elk. The data were too homogenous and did not meet minimum statistical sample size for multiple regression analysis.

Similar to Van der Grift et. al. (2013), the fact that the database was limited to mule deer and marginal elk data meeting statistical modeling requirements depicts the inherent lack of monitoring data, and lower species density and distribution for other ungulate species (moose, pronghorn, and Rocky Mountain bighorn sheep) and most non-ungulate species that use WCSs, such as Canada lynx. Few monitoring studies include non-ungulate species or collected non-ungulate monitoring data, and those monitoring studies could not be used due to limitations of the data collection (Van der Grift et. al. 2015). To correct for this bias in model 1, the project team used weighted averages of the total number of crossings and all the species success rates for statistical analyses. In addition, several studies provided cumulative totals of number of crossings and number of repels across all WCSs; therefore, the project team calculated averaged success and repel rates for a single WCS to obtain complete data sets. During the initial literature review sources were categorized as potential data sources and those that addressed other factors. After further review 18 studies were read through, some studies had averaged success rates across WCSs with little or no data provided to back up success rates; two studies were excluded from the statistical analysis while the remaining 16 were used to build the database. The Recommendations section details several solutions toward the biases seen in monitoring data collection.

In addition, cost data for several WCSs used in this Study, particularly older WCSs studies, were difficult to obtain. Several of the studies averaged the cost of the WCSs, did not have individual cost totals, or had cost data that were a cumulative total of all WCSs for a project. Several studies provided cumulative totals of number of crossings and number of repels across for all WCSs; therefore, calculated averaged success and repels were used. In addition, some studies had averaged success rates across WCSs used in the monitoring studies.

Because there was insufficient data to conduct regression analysis for other species of interest in this Study, including Canada lynx, moose, Rocky Mountain bighorn sheep, and pronghorn, the remaining portion of this discussion is a brief synthesis of literature reviewed and findings relative to WCS use, sizes and other features that may influence successful crossings.

6.1 Canada Lynx

Data on Canada lynx use of crossing structures is sparse due to small population sizes combined with a limited number of crossing structures in occupied lynx habitat. Research in the mid-2000s monitored seven underpasses built to mitigate the impacts of highway projects on lynx in Colorado (Crooks et al. 2008). The monitored crossings included box and pipe culverts ranging from 6 to 12 feet wide by 4 to 10 feet high by 40 to 158 feet long; four of the underpasses had very short segments of wildlife fencing to guide animals to the location and three locations did not have fencing. The research did not detect any lynx passages or approaches, which may have been due to multiple factors:

1) Lynx are uncommon, wide-ranging, and have large home ranges.
2) The monitored underpasses were located across western Colorado, yet at the time of this research (2005 to 2007), few lynx had ventured outside of the southwestern portion of the state in the early years following the reintroduction effort.
3) In several cases, fencing was not provided to guide animals to the crossing locations instead of crossing the road at-grade.
4) Winter conditions may have impeded access to an underpass (Kintsch and Basting 2021).

Observations of lynx highway crossing behavior on Interstate (I-) I-70 at East Vail Pass based on three collared individuals indicate repeated use of existing large, span bridges under the eastbound lanes along natural drainages with no fencing (Baigas et al. 2017). The researchers also noted that lynx crossed I-70 at-grade during periods of low traffic volumes, primarily during the nighttime hours.

The Banff research study (Clevenger and Barrueto 2014) found that lynx used overpasses 10 times and various types of underpasses 8 times throughout a 17-year period. Success rates were not measured in this Study, but lynx were documented successfully passing through a variety of overpasses and various type and sizes of underpasses including bridges, large elliptical culverts, and a box culvert (Table 8).

Table 8. Lynx Use of Wildlife Crossing Structures, Trans-Canada Highway Twinning Project, Banff, Alberta, Canada

Phase	Structure	Structure Type	Width (feet)	Height (feet)	Length (feet)	Lynx Crossings
3B	COP	Overpass	185	N/A	345	1
3B	Moraine	Creek bridge	75	5.5	138	1
3A	WOP	Overpass	164	N/A	236	5
3A	WUP	Large culvert	24	11	205	1
3A	REOP	Overpass	164	N/A	236	4
3A	RECR	Creek bridge	38	7.2	185	1
3A	John	Box culvert	10	8	190	1
3A	Castle	Large culvert	24	11.5	185	2
1&2	Edith	Open span	34	9.2	84	1
1&2	5 Mile	Open span	unknown	unknown	unknown	1
Total						18

In Maine, camera traps have documented three lynx passages, each at a different structure (Maine DOT, pers. comm. 2022).

- Concrete pipe culvert: 4 feet diameter, 96 feet long
- Metal arch culvert with a concrete shelf: 54 inches high by 81 inches wide by 76 feet long
- Multi-use bridge: 20 feet high by 20 feet wide

A recent long-term, 8-year continuous monitoring study of wildlife mitigation on a divided four-lane highway with an open median in Northeastern Ontario, Canada documented lynx use of underpasses and an overpass (Eco-Kare International 2020). Mitigation measures monitored on Ontario Highway 69 included the following:

- Five concrete box underpasses
- Two bridge pathways along the Murdock River and one pathway along Lovering Creek
- One wildlife overpass
- Large animal exclusion fencing on both sides of the highway
- Twenty-seven one-way gates
- Two ungulate guards

Relative to structure use by Canada lynx, lynx used the overpass three times and the underpasses five times. One successful passage was approximately 16 feet wide by 16 feet high by 78 feet long twinned (northbound and southbound) with open median reinforced concrete box culvert. In the last 2 years of the monitoring study, either one or several lynx started to favor (four passages in 2 years) three smaller twinned box culverts (approximately 10 feet wide by 8 feet high by 78 feet long) installed for turtles that were built in and adjacent to wetland habitat (Eco-Kare International 2020).

While Eurasian lynx is a different species than the Canada lynx, they are similar in morphology and ecology (Helldin, pers. comm. 2022) In Sweden, during a 1-year monitoring period of two overpasses, one viaduct, and three underpasses, Helldin reported the data included in Table 9.

Table 9. Eurasion Lynx Use of WCS in Sweden

Structure Name	Type	Width (feet)	Height (feet)	Length (feet)	Lynx Crossings
Viltbro Hemmanet	Overpass	32	-	174	3
Viltbro Nolby	Overpass	32	-	184	13
Landbro Vapelbäcken	Viaduct	344	>16	69	1
Viltport Hemmanet	Underpass	26	16	69	10
Ridport Nolby	Underpass	13	13	144	8
Tunnel Sandmovägen	Underpass	134	16	125	14
Total					**49**

Multiple studies highlight the value of vegetative tree cover with regards to lynx habitat use and lynx highway crossing locations (Clevenger and Waltho 2005; Squires et al. 2013). Baigas et al. (2017) found that at a fine-scale lynx crossed highways in close proximity to vegetative cover, primarily conifer stands with high basal area. Dense forested habitat provides security cover adjacent to a roadway and the highest concentrations of snowshoe hares, lynx's primary winter food source. Where human activity and recreation overlap with lynx habitat, lynx have been shown to adjust their temporal patterns, becoming less active during the day, waiting for the disturbance to decline, and increasing activity at night (Olson et al. 2018); they appear to be fairly tolerant of non-motorized recreation winter recreation activities that overlap with preferred lynx habitat (Olson et al. 2018; Squires et al. 2019). The small number of WCSs built in lynx habitat combined with the small number and relatively dispersed nature of lynx, it appears lynx would use a variety of crossing structures and sizes. While it appears there is a general preference for overpasses, evidence is building regarding their acceptance and use of underpasses situated in appropriate locations.

6.2 Moose

Given their restricted range and lower population densities, few states have documented experience in accommodating moose in underpasses (Cramer et al. 2015). In Utah, moose have been documented using 10 feet high by 17 feet wide by 165 feet long corrugated steel culverts in the northern mountains (Cramer 2012). Sawyer and LeBeau (2011) have similarly reported moose use of culverts measuring 10 feet high by 20 feet wide by 60 feet long in Wyoming. Additionally, in Wyoming moose used overpasses and bridge underpasses at Trappers Point with 12% use of the overpass structures and 88% use of the bridge underpasses (Sawyer et al. 2015).

Across the WCSs combined (five underpasses and two overpasses) on State Highway (SH) 9 in Colorado, Kintsch et.al. (2021) recorded a success rate of 90% for moose crossings out of 83 approaches. The five underpasses along SH 9 are 42 feet wide by 14 feet high by 66 feet long, and the two overpasses are 100 feet wide by 66 feet long.

In Northeastern Ontario, moose successfully used a wide variety of structure types from overpass, bridge underpasses, turtle culverts (9 feet high by 11 feet wide by 78 feet long), and large underpasses (16 feet high by 16 feet wide by 46 feet long and 13 feet high by 13 feet wide by 52 feet long) (Eco-Kare International 2020).

In Montana, moose used two separate bridge underpasses during a long-term monitoring study for U.S. Highway (US) 93 South (Cramer and Hamlin 2017), and Sturm (pers. comm. 2018) used camera traps to monitor two three-sided concrete bridges along Montana Highway 200 east of Lincoln, Montana, where he has also documented use of these structures by all age classes of moose. These two structures are approximately 12 feet high by 20 feet wide by 45 feet long. In summation, it appears moose seem to be highly adaptive to use a wide variety of WCS types and sizes; location relative to suitable habitats (riparian and wetland) is likely an important factor.

6.3 Rocky Mountain Bighorn Sheep

Arizona and Nevada have constructed several wildlife overpasses and underpasses for desert bighorn sheep and monitoring studies conducted have shown a strong preference for overpasses (Gagnon et al. 2017). However, desert bighorn sheep are quite different from Rocky Mountain bighorn sheep in their tolerance and response to human disturbance, traffic, and use of WCS.

Over a long-term 17-year monitoring period in Canada, 4,999 successful crossing of WCSs built along the Trans-Canada Highway Twinning project were reported (Clevenger and Barrueto 2014). Phases 1 and 2 had the most frequent (4,958), and Phase 3A had another 41 successful crossings; no success or repel rates were calculated. Rocky Mountain bighorn sheep in this Study only used wildlife crossing underpasses consisting of large culverts, open span, and creek bridges for all documented crossings.

In Colorado, bighorn sheep used WCSs 30 times out of 37 documented approaches throughout a 5-year monitoring study with overpasses being used 18 times (100% success rate) and underpasses 12 times (63% success rate) (Kintsch et al. 2021).

In Montana, Sturm (pers. comm. 2017) used camera traps to document use of three-sided bridges (12 feet high by 20 feet wide by 45 feet long) built east of Lincoln, Montana, by all age classes of Rocky Mountain bighorn sheep. In addition, passage under a very high and wide bridge over the Thompson River and an underpass built for Rocky Mountain bighorn sheep under Montana Highway 200 east of Thompson Falls, Montana, was documented (Weigand, pers. comm. 2022). The underpass (Photo 1) is a pre-stressed concrete slab bridge 49.5 feet long. The bottom of the draw under the bridge is 20 feet across with a shallow depression 1 foot deep for drainage. Maximum clearance height under the bridge is just over 10 feet. The underpass is accompanied by 2.2 miles of 8-foot exclusion fence.

Photo 1. Underpass built for Rocky Mountain bighorn sheep, Hwy 200 East of Thompson Falls, MT.
Source: Joe Weigand, Montana Department of Transportation (MDT)

Montana Department of Transportation (MDT) conducted trail camera monitoring pre and post-construction (Weigand, pers. comm. 2022). White-tailed deer were regularly using the underpass within a few days of completed construction. Bighorn sheep and elk were using the underpass within a month. All three species, plus turkeys, now freely and regularly move back and forth under the bridge. Other species documented using the underpass include black bear, mountain lion, coyote and mule deer. All of these species are also documented to frequently move back and forth under the new 2016 Thompson River bridge. When the exclusion fence and underpass were constructed, Crosstek Zapcrete electrified wildlife deterrent mats were installed at each end of the project fence ends to deter wildlife from entering the fenced road corridor. It has been a learning experience for MDT, but the Zapcrete appears to be functioning as intended. Formal research and evaluation of the Zapcrete efficacy is underway.

Photo 2. Bighorn sheep displaying rutting activity at bridged underpass East of Thompson Falls, Montana

Source: Joe Weigand, MDT

Since completion of the project, Weigand is unaware of any bighorn sheep, or other wildlife, being hit by a vehicle along this stretch. Images of bighorn sheep hanging out at the entrance of each side of the underpass bridge have been captured, and the sheep have been exhibiting rutting activity at and under the new underpass (Photo 2). The bighorn sheep appear to be indifferent to vehicles passing over the bridge (Weigand, pers. comm. 2022).

Photo 3: Herd of bighorn sheep indifferent to vehicular traffic on bridged underpass East of Thompson Falls, MT.

Source: Joe Weigand, MDT

6.4 Pronghorn

Pronghorn are perhaps one of the more difficult large mammals for which to design functional wildlife crossings for in North America. In a review of pronghorn movements near roads, Sawyer and Rudd (2005) concluded that either very high and wide bridges or overpasses are suitable structures for pronghorn passage. Little research has been conducted on the crossing features influencing pronghorn passage. US 30 in Nugget Canyon in Wyoming is one of the few states where pronghorn have been documented using crossing structures (Sawyer and LeBeau 2011). In this herd, pronghorn appear to have learned to use 10-foot-high by 20-foot-wide by 60-foot-long reinforced concrete box culverts by following mule deer through the structure. In Colorado, Kintsch et.al (2021) documented use of underpasses (14 feet high by 42 feet wide by 66 feet long) and overpasses (100 feet wide by 66 feet long) by pronghorn along SH 9 with a remarkable success rate of 99%. Pronghorn appeared to have preference for underpasses versus overpasses, and habituation increased over time. The authors also noted that the majority of pronghorn passages were males (79%) making solo movements or in pairs at underpass structures.

Recently, the Wyoming Department of Transportation completed a project in western Wyoming where 12 miles of game fencing, six simple span bridge underpasses (approximately 66 feet wide by 42 feet long by 13 feet high), and two overpasses (150 feet wide by 400 feet long) were constructed to reduce WVCs and allow large herds of migratory pronghorn and mule deer to safely cross US 191, an increasingly popular two-lane highway that leads to Grand Teton and Yellowstone National Parks (Sawyer and Rogers 2015). Although the overpasses were constructed 7 miles apart, each had an underpass located within 0.5 mile. Overall, 90% of pronghorn traveled over the highway (n = 22,710) via the overpasses and only 10% moved under (n = 2,546). With respect to roads, several authors have noted the serious barrier effect of various types of highway right-of-way fencing relative to pronghorn movement and distribution (Sheldon and Lindzey 2004; Jones et al. 2019; Xu et al. 2021).

6.5 Other Variables Influencing Wildlife Crossing Structure Use

Other variables that can affect use of WCSs by wildlife have been identified by various authors (Cramer 2012; Clevenger and Waltho 2005; Clevenger et al. 2009; Denneboom et al. 2021; Dodd et al. 2007; Huijser et al. 2016; Riginos et al. 2018; Van der Grift et al. 2013). While applying lessons learned from various studies to a potential project may be challenging, by carefully analyzing the studies' target species, movement types, location and relevant habitat, road structure, traffic volumes, and other factors where a mitigation project was built is important and would aid CDOT in development of mitigation designs. Long-term monitoring studies such as those conducted by Clevenger et.al.(2009), Kintsch et.al (2021), Dodd et.al (2007) and Eco-Kare Intl. (2020) have yielded a wealth of information that must be taken into context relative to each of their respective study areas. Lessons learned from these studies can be used and applied when and where appropriate to aid in design and decision making for mitigation projects. For example, Clevenger and Waltho (2005), Cramer (2015), and Denneboom et.al (2021) have put forth that ungulate use of overpasses can be negatively affected by shrub and tree cover at the entrances of overpasses. For mule deer, use of underpasses has been positively correlated with structural vegetation near the approaches. Clevenger and Waltho (2005) found that structural attributes dominate species performance indices. However, they also found that human activity in or near WCSs can negatively affect wildlife usage, particularly for carnivores. Similarly, cattle presence at a WCS was found to negatively affect wildlife use of a crossing structure (Loberger et al. 2021).

Clevenger and Waltho (2005) and Cramer (2015) provide good discussions regarding wildlife usage related to guild levels. For example, at the guild level, structural and landscape factors were equally important in explaining carnivore passage, whereas structural attributes were the most dominant features affecting ungulate passage (Clevenger and Waltho 2005). Consistent with our findings in this Study, shorter length of underpasses in addition to openness (width and relative height) has a stronger correlation to successful passage for elk and mule deer. More constricted crossing structures (that is, longer in length, low and narrow) best explained passage by black bears and mountain lions (Clevenger and Waltho 2005).

Mitigation strategies that paired WCS with longer stretches of wildlife exclusion fencing approximately 3 miles) were found to have a much stronger effect in reducing WVCs by approximately 80% (Huijser et al. 2016). Isolated crossing structures with shorter sections of wing fencing (less than approximately 3 miles) was more variable in its affect reducing WVCs but averaged approximately 52%. With isolated crossing structures paired with short wing fencing less than approximately 3 miles, consideration should be given to fence end treatments so that WVC problems are not moved from one spot to another close to the fence ends. A recent study in Virginia found that the addition of 1 mile of wildlife fencing (0.5 mile of fence in both directions from underpass) to certain existing isolated underpasses can be a highly cost-effective means of increasing driver safety and enhancing habitat connectivity for wildlife (Donaldson and

Elliot 2020). After fencing installation, deer vehicle collisions (DVCs) were reduced by 92% on average (96.5% and 88% at the box culvert and bridge underpass, respectively). Deer crossings increased 410% at the box culvert and 71% at the bridge underpass. Use of the culvert and bridge underpasses by other mammals increased 81% and 165%, respectively. DVCs did not increase at the fence ends, but high deer activity was noted where fence ends did not tie into a feature, such as right-of-way fencing.

Another issue relative to fencing and WCSs is that any deterrent to movement including wildlife-friendly fencing directly in front of WCS openings can negatively affect wildlife use (Cramer and Hamlin 2021; Loberger et al. 2021).

Structures placed too closely together may influence usage of structure type whereas isolated structures within higher quality habitat may actually see higher use than a structure with similar dimensions closer to other crossing structures (Clevenger and Waltho 2005). Structures paired too closely together may also negatively affect the benefit-cost analysis and the ability of those structures to pay for themselves over their lifespan in mitigation benefits through reduction of WVCs.

Maintaining wildlife connectivity across roads through tested wildlife crossing designs as presented by Cramer (2015) and the *Wildlife Crossing Structure Handbook Design and Evaluation in North America*, (Clevenger and Huijser 2011), give a good synthesis covering multiple studies of wildlife use of crossing structures relative to individual species and/or guilds in conjunction with design considerations and recommendations.

By no means comprehensive, a list of other factors that have been identified as affecting wildlife usage of crossing structures includes, but is not limited to, the following:

- Structural variables
- Wildlife exclusion fencing
- Spacing between structures
- Human use
- Land use and development
- Habitat quality and heterogeneity relative to season of use by wildlife around WCS

- Vegetation near WCS
  - Ungulate use of underpasses had a positive correlation with increased distance to forest cover in winter range
  - Proximity to riparian meadows positively correlated with elk use of underpasses in drier environments
- Traffic volume
- Noise

Other research or documents identified herein provide a list for CDOT biologists and other interdisciplinary team members to consider and work from as they work to identify relevant WCS sizing and other factors for a given mitigation projects that could affect wildlife usage of planned mitigation measures.

7. Recommendations

WCSs are gaining increasing attention by transportation agencies as well as various state governments and wildlife agencies for their ability to allow wildlife movement across roadways and improve safety for the traveling public by reducing wildlife-vehicle collisions. One of the primary challenges facing transportation agencies is designing and building successful, cost-effective wildlife crossing systems with limited funding. The project team suggests the following recommendations.

Identify the priority locations for mitigation

A good first step to addressing these challenges is identifying the priority locations for mitigation. CDOT has taken the initiative by recognizing this need and working collaboratively with the CPW to develop the *Western Slope Wildlife Prioritization Study* in 2019 and the soon-to-be-completed *Eastern Slope and Plains Wildlife Prioritization Study*. These studies will provide Colorado a statewide wildlife prioritization that incorporates biological criteria for identified target species and safety criteria.

Develop systematic monitoring protocol for mitigation projects

Underpinning research is still needed to identify best practices and ensure funds are allocated in a cost-effective manner that maximizes (to the extent practical) ecological and societal benefits (Denneboom et al. 2021). In a systematic review of studies around the world that assessed factors affecting usage of WCS by wildlife, most studies in their review did not measure approaches to crossing structures (71.5% of the studies reviewed), and this can explain the inconsistencies found in the literature regarding the effects of structural and environmental attributes (Denneboom et al. 2021). Kintsch et.al. (2021) and Cramer et.al. (2021, draft New Mexico Wildlife Action Plan, Chapter 7.2) provide good examples for guidelines CDOT might consider in developing systematic monitoring protocol for mitigation projects in Colorado.

Define success for any given mitigation project

WCSs and their associated features (fencing, escape ramps, wildlife-guards) must be designed to accommodate site-specific conditions determined by the target specie(s) or for multi-species design guild preferences, terrain, landscape considerations, roadway footprint and associated infrastructure, and other variables (Kintsch and Basting 2021). However, CDOT must decide how they will define success for any given mitigation project. The project team suggests the following stepwise progression early on during project planning and development:

First, identify and clearly articulate the mitigation objectives that a project is attempting to achieve. Typically, most wildlife mitigation projects implemented by a department of transportation are attempting to address safety of the traveling public through a reduction in WVCs. Further, as recognized herein, governments at the federal, state, tribal, and local scales are recognizing the importance of maintaining wildlife migration and movement corridors and connecting crucial wildlife habitats. Therefore, a second objective paired with safety is often maintaining habitat connectivity.

Once broader mitigation objectives have been established, transportation and respective state fish and game staff must work to identify target species and the scale and type of movement that is to be addressed. Identify whether the project is addressing the following:

- Within home range movements by resident populations
- Within seasonal winter or summer range movements
- Critical seasonal migration movements (spring and fall)
- Dispersal movements (infrequent movements by members of a population to access new habitat and/or establish new territories within a region)

Once mitigation success criteria are defined, identify how best to measure or determine success. Using data-driven analysis and research regarding target species and factors affecting successful wildlife use of crossing structures, determine what level or range of successful crossings by wildlife would be desired as a percentage basis of successful crossing rates relative to visitation/parallel and repel rates. The success rate does not have to be a hard singular number but should be a range. Recognize scale when assessing connectivity, it is important to determine if a localized issue or a larger landscape issue is being addressed. In addition to defining success relative to successful wildlife crossings, the level of reductions in WVCs that a department of transportation would accept must also be clearly identified. This is best accomplished by an interdisciplinary team of biologists and engineers.

Determine wildlife crossing sizing

To determine wildlife crossing sizing, we recommend pairing data-driven research (such as presented herein) with benefit-cost analysis to define success criteria more comprehensively. Ultimately, pairing the two processes would help tighten success criteria and aid in development of cost-effective mitigation strategies that can work within identified budget constraints. A useful benefit-cost analysis tool to specifically assess wildlife mitigation projects has already been developed by CDOT and their research team for the Western Slope and Eastern Slope and Plains wildlife prioritization studies identified earlier in this document. The benefit-cost analysis tool in combination with this and other relevant research for WCS sizing would provide CDOT with a powerful set of tools for development of effective wildlife crossing sizing and mitigation projects from the biological, engineering, safety and fiscal budgetary aspects as well.

8. Conclusion

In conclusion, success rates for mule deer use of underpasses (culverts and bridges) is most strongly influenced by structure length and width. Given this, the project team was able to generate a tabular summary of predicted success rates for underpasses given length and width dimensions. Mule deer do not show any preference between bridges or culverts. Conversely, elk prefer bridges to culverts. The study team did not have adequate data to determine the strongest drivers of success rates relative to bridge or culvert underpass size dimensions for elk. Based on the modeling and statistical analysis with the database, the success rate could be the same for mule deer and elk for a combination of underpass structure dimensions.

The team attempted to determine if mule deer or elk exhibited a preference for overpasses as compared to underpasses and if so, the range of dimensions (length, width, and height) correlated to success rate. However, the data for overpasses used by mule deer and elk to evaluate this scenario were insufficient.

Currently there is not enough monitoring data available to perform separate statistical analysis to determine predicted success rates for any given structural types or dimensions for moose, pronghorn, Rocky Mountain bighorn sheep, or Canada lynx.

The team could not identify a single point of diminishing return where incremental costs to increase structure size outweighed predicted increase in success rate. Using the results of Model 4 predicted success rates for mule deer, the project team was able to demonstrate an example where once a desired success rate or range of success rates (for example, 60% to 75%) is identified, a predicted range of structural dimensions can be identified that may achieve that success rate. Evaluation of biological, engineering, and cost constraints of a project can be worked through to balance project needs and achieve desired outcomes.

Based on the literature review and modeling, the project team recommends using the Eastern Slope and Plains and Western Slope wildlife prioritization studies to identify priority locations to perform wildlife mitigation. In addition, there is a need for developing a systematic monitoring protocol for wildlife mitigation projects—in particular, those projects addressing species such as elk, moose, pronghorn, Rocky Mountain bighorn sheep, and Canada lynx where success and repel rates are determined. This additional data over time will allow further modeling and analysis to determine predicted optimal sizing for WCSs for these species. A key recommendation is a clearly defining success for mitigation projects by defining a range of expected wildlife crossing success rates and expected reductions in wildlife-vehicle collisions. This can best be accomplished by developing interdisciplinary design teams of biologists and engineers.

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Appendix A
Published and Unpublished Data Used in Statistical Modeling

Appendix A – Studies Used

Title	Roadway(s)	State/Province	Author
Nevada Crossing Projects[1]	United States of America (USA) Parkway, United States Route (US) 93, State Route (SR) 160, Interstate- (I) 580	Nevada	Nova Simpson-Proctor
Washington Wildlife Structure Use[1]	SR 522, SR 109	Washington	Glen Kalisz
Banff Wildlife Crossings Project: Integrating Science and Education in Restoring Population Connectivity Across Transportation Corridors	Trans Canadian Highway	Alberta (CA)	Anthony P. Clevenger, Adam T. Ford, Michael A. Sawaya
Washington I-90 Snoqualmie Deer and Elk Detections[1]	I-90	Washington	Josh Zylstra
Evaluation of Measures to Minimize Wildlife-Vehicle Collisions and Maintain Permeability Across Highways	SR 260	Arizona	Norris L. Dodd, Jeffrey W. Gagnon, Susan Boe, Amanda Manzo, Raymond E. Schweinsburg
State Highway 9 Wildlife Crossings Monitoring	SR 9	Colorado	Julia Kintsch, Patricia Cramer, Paige Singer, Michelle Cowardin, Joy Phelan
Pronghorn and Mule Deer Use of Underpasses and Overpasses Along US Highway 191, Wyoming	US 191	Wyoming	Hall Sawyer, Patrick Rodgers
Evaluation of Mule Deer Crossing Structures in Nugget Canyon, Wyoming	US 35	Wyoming	Hall Sawyer, Chad LeBeau
Determining Wildlife Use of Wildlife Crossing Structures Under Different Scenarios	US 6, I-70, US 89, US 191, I-15, I-80, US 189	Utah	Patricia Cramer
Effectiveness of Wildlife Crossing Structures to Minimize Traffic Collisions with Mule Deer and Other wildlife in Nevada	US 93	Nevada	Kelley M. Stewart
Behavioral Response of Mule Deer to a Highway Underpass	I-70	Colorado	Dale F. Reed, Thomas N. Woodard, Thomas M. Pojar
US 160 Dry Creek Wildlife Study	US 160	Colorado	Patricia Cramer, Robert Hamlin
U.S. Highway 89 Kanab-Paunsaugunt Wildlifecrossing and Existing Structures Research	US 89	Utah	Patricia Cramer, Robert Hamlin
I-25 South Gap Project[1]	I-25	Colorado	CDOT
Richmond Hills Underpass[1]	US 285	Colorado	CDOT
Shaffers Crossing[1]	US 285	Colorado	CDOT

[1] unpublished data

Appendix B
Model 1 Statistical Analysis of Weighted Average Success Rate for all Species and Structural Dimensions for all Underpass Types

Model 1 - underpasses, structure dimensions, weighted average success rate

Best Fit Model: SuccessRate = 185.412 - 32.687*ln(Length) + 10.736*ln(Width)

SUMMARY OUTPUT (81 Observations)

	SuccessRate	Length	Width	Height
Minimum	-	38	6	6
1st Quartile	50	70	19	10
Median	69	105	24	12
Mean	65	138	46	14
3rd Quartile	88	185	38	15
Maximum	100	558	900	38

SKEWNESS & KURTOSIS (LOG, SQUARE ROOT, CUBED)

	SuccessRate	Length	Width	Height
Skew, no adj	-0.7838	1.889	7.4979	1.9071
Kurtosis, no adj	2.3841	8.9457	63.0092	6.5568
Skew, log	na	0.233	1.41	0.925
Kurtosis, log	na	2.344	6.532	3.564
Skew, sqrt	-1.308	0.886	4.418	1.416
Kurtosis, sqrt	3.885	4.021	29.119	4.792
Skew, cube	-1.816	0.638	3.226	1.251
Kurtosis, cube	6.712	3.21	18.314	4.32

RESULTS: apply log transformation to Length, Width, and Height

JARQUE-BERA NORMALITY TEST (per transformation above)

	SuccessRate	Length	Width	Height
JB	9.57	2.18	68.92	12.62
p-value	8.34E-03	0.3353	1.11E-15	0.0018
	not normal	*normal*	*not normal*	*not normal*

LM VARIABLE ANALYSIS:

	Estimate	Std Error	t value	Pr(>|t|)	
(Intercept)	168.516	24.895	6.769	2.27E-09	sig to 0
Length	-32.857	4.086	-8.042	8.43E-12	sig to 0
Width	6.948	3.818	1.82	0.0727	sig to 0.1
Height	11.94	7.97	1.498	0.1382	

Residential standard error	20.43	77 df
Multiple R-squared	0.5203	
Adjusted R-squared	0.5016	
F-statistic	27.84	3 and 77 df
p-value	2.70E-12	

	Length	Width	Height	
Var Inflation Factor (Multicollinearity)	1.003	1.786	1.782	***<5, low collinearity***
Importation of Variables	**8.04**	1.82	1.498	

ANOVA LM model

			Residuals	
Df	1	1	1	77
Sum Sq	28030	5881	936	32132
Mean Sq	28030	5881	936	417
F value	67.17	14.09	2.24	
Pr(>F)	4.27E-12	0.0003359	0.1382171	

BEST FIT MODEL (glmulti analysis): SuccessRate ~ 1 + Length + Height

Evidence 0.3931

Worst IC 778.16

2 models to reach 95% of evidence weight

3 models within 2 IC units

model	aicc	weights
SuccessRate ~ 1 + Length + Width + Height	**725.30**	0.393
SuccessRate ~ 1 + Length + Width	**725.36**	0.383
SuccessRate ~ 1 + Length + Height	**726.44**	0.223

FINAL LM COEFFICIENTS (SuccessRate ~ 1 + Length + Height)

	Estimate	Std Error	t value	Pr(>|t|)	
Intercept	185.412	22.369	8.289	2.59E-12	sig 0
Length	-32.687	4.116	-7.941	1.226E-11	sig 0
Width	10.736	2.883	3.724	0.000368	sig 0
Residential standa	20.59	78 df			
Multiple R-square	0.5063				
Adjusted R-square	0.4936				
F-statistic	39.99	2 and 78 df			
p-value	1.11E-12				

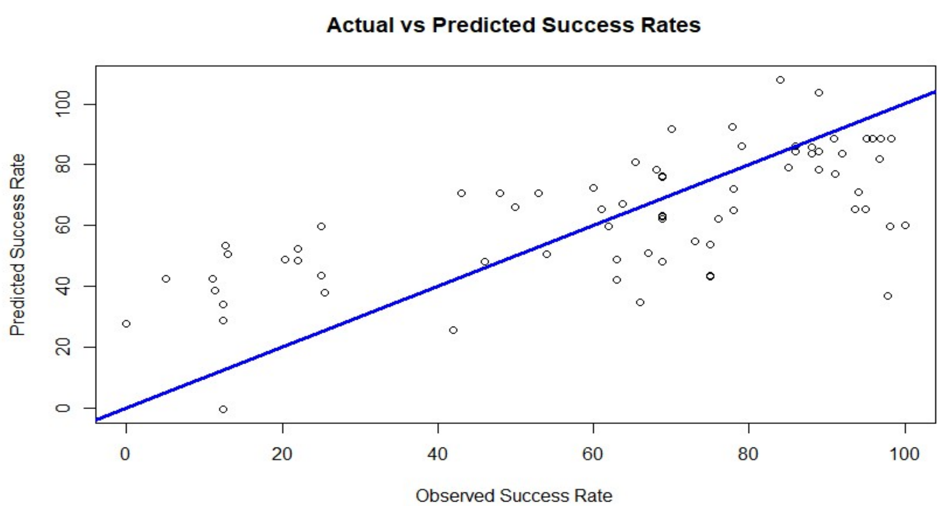
PSEUDO R SQUARED

McFadden	0.221553
Cox and Snell (ML	0.919437
Nagelkerke (Craig	0.919448

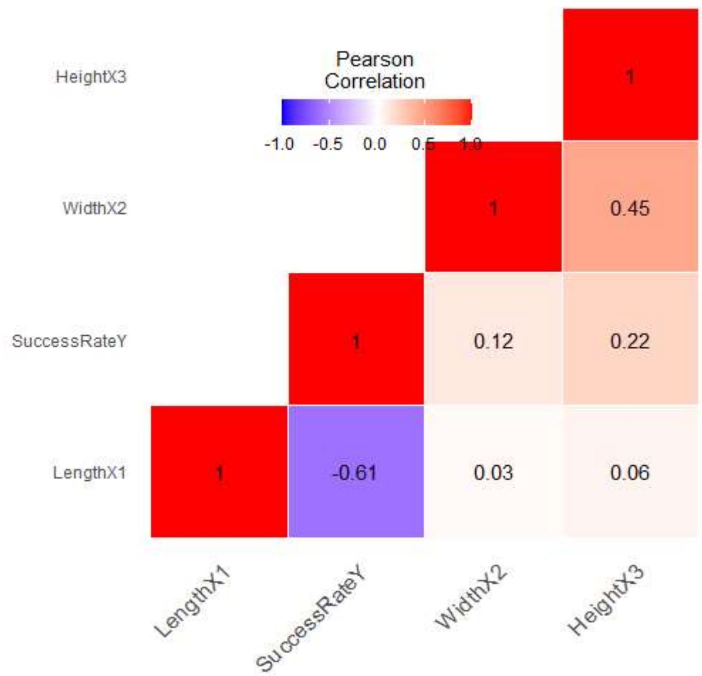
ANOVA Best Fit model

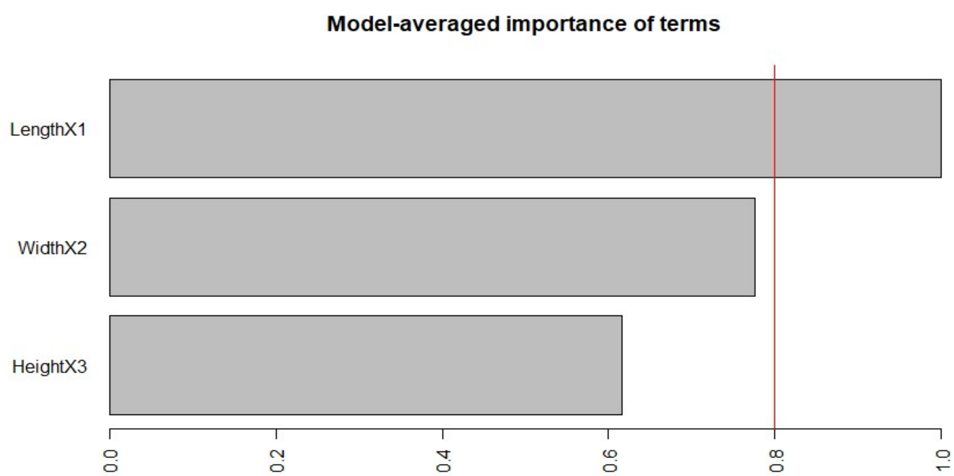
	Length	Width	Residuals
Df	1	1	78
Sum Sq	28030	5881	33069
Mean Sq	28030	5881	424
F value	66.116	13.871	
Pr(>F)	5.241E-12	0.0003683	

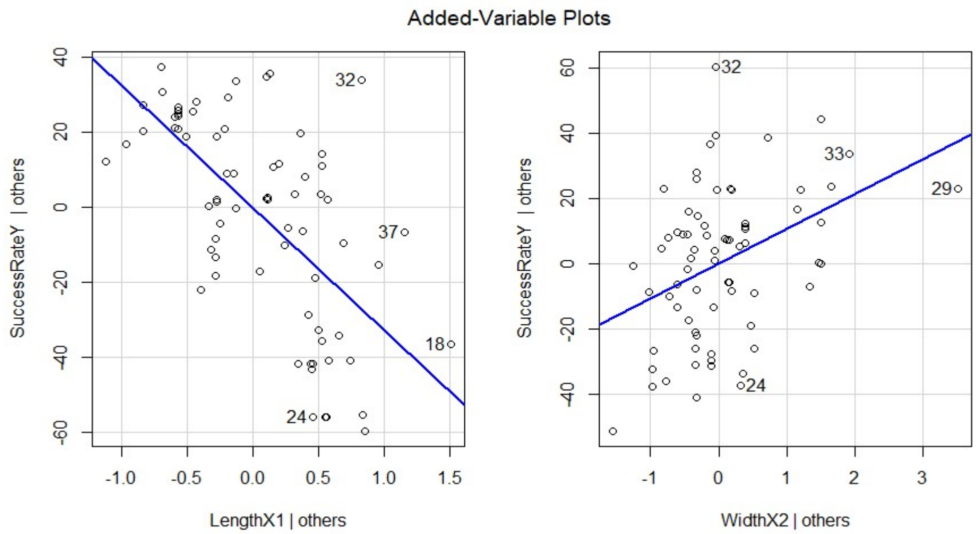
y = [(185.412) - (32.687)*ln(Length) + (10.736)*ln(Width)]

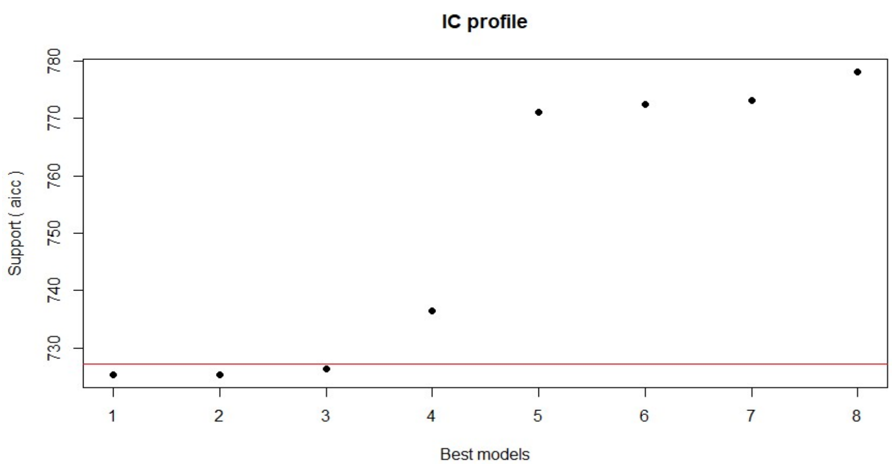


CORRELATION (PEARSON)

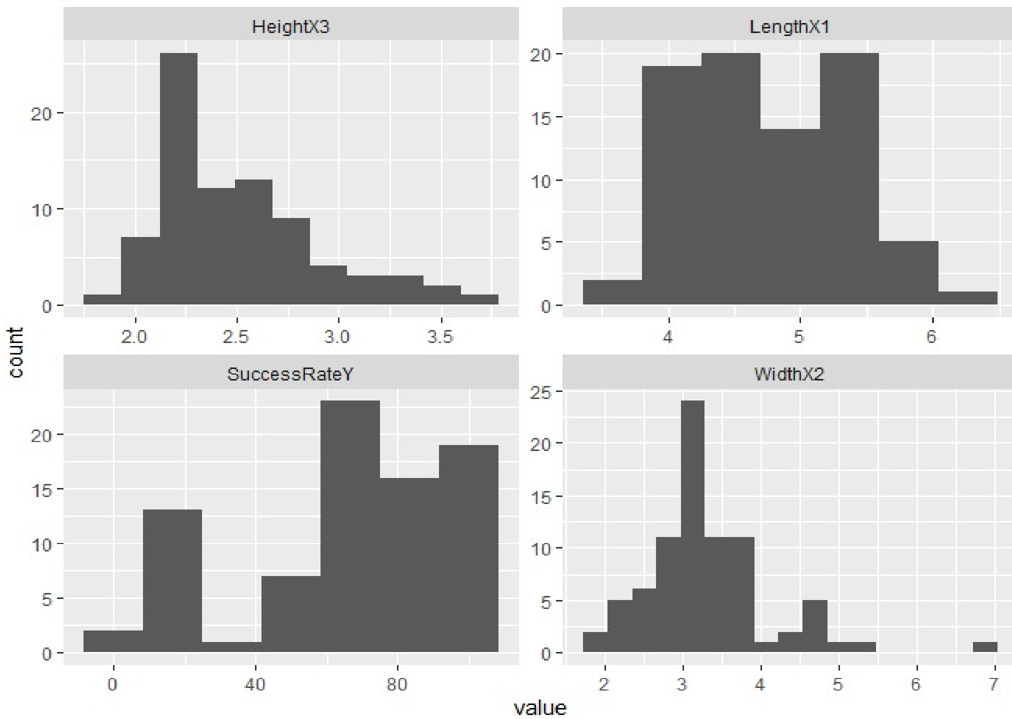


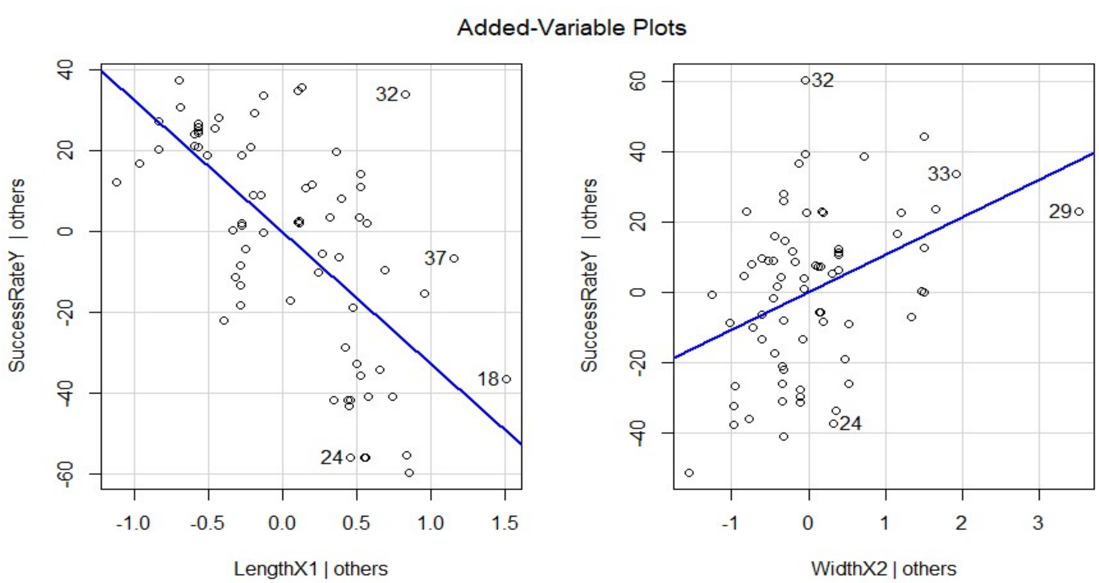


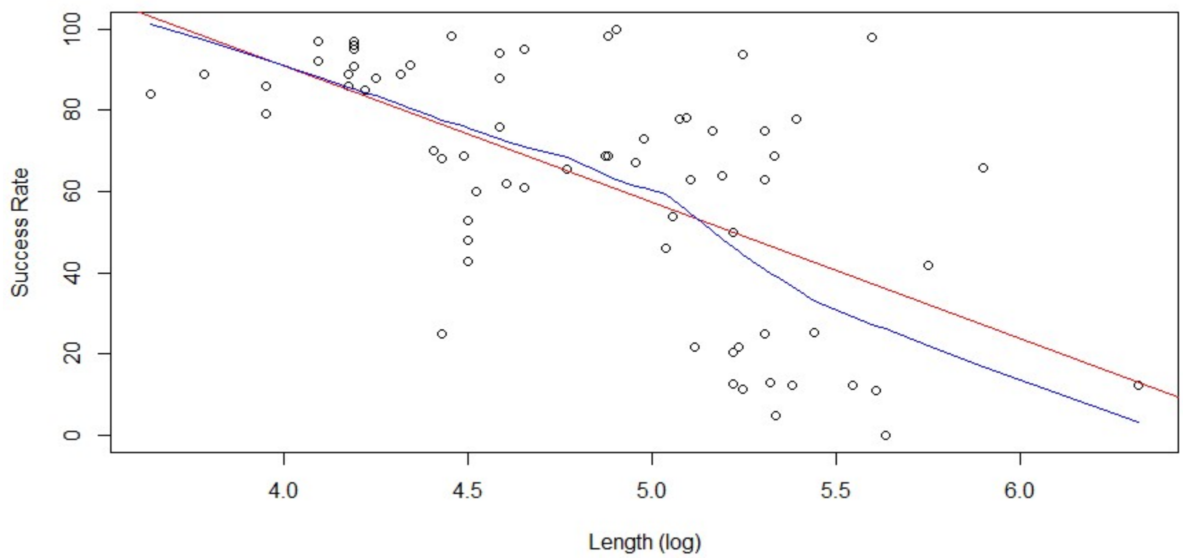

Added-Variable Plots
SuccessRateY | others
LengthX1 | others
WidthX2 | others
32
37
18
24
33
29

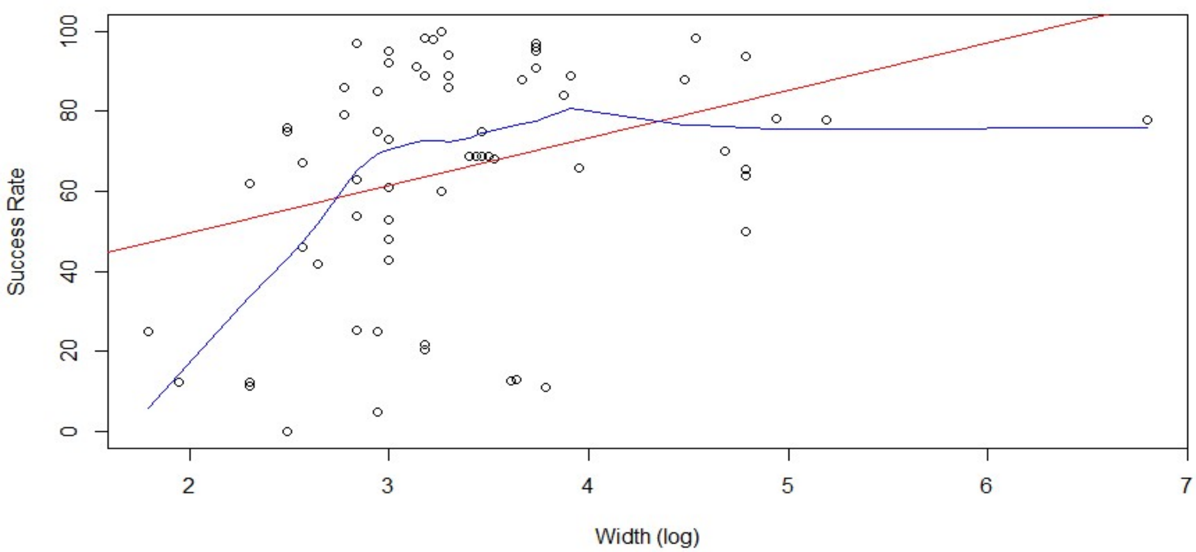

IC profile
Support (aicc)
Best models

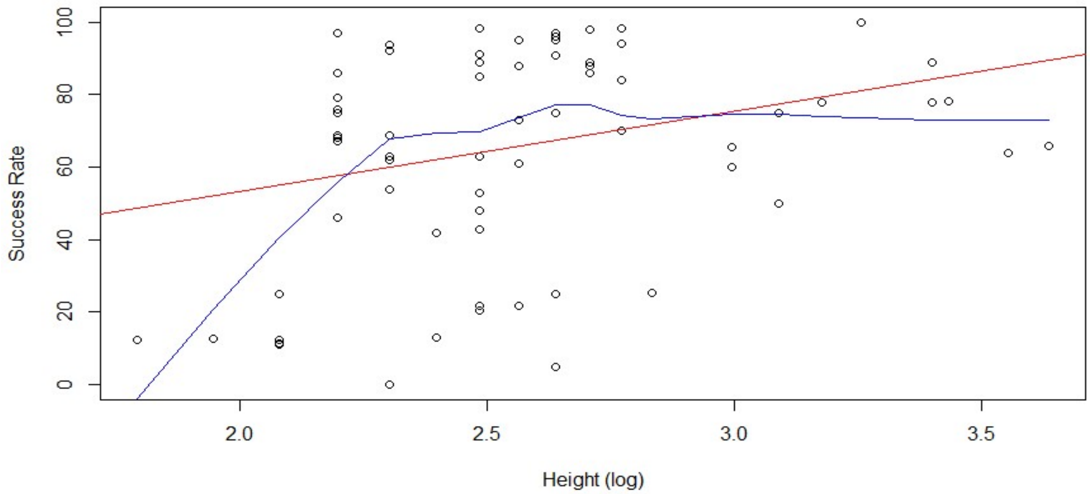
PLOTS: VARIABLE TO SUCCESS RATES






Success Rate
Length (log)
0
20
40
60
80
100
4.0
4.5
5.0
5.5
6.0


Success Rate
Width (log)
0
20
40
60
80
100
2
3
4
5
6
7



	Y	X1	X2	X3
Record_ID	Average Success Rate	Structure_ Length_ft	Structure_ Width_ft	Structure_ Height_ft
110	53	90	20	12
111	48	90	20	12
113	43	90	20	12
115	73	145	20	13
117	61	105	20	13
118	95	105	20	13
135	98	132	24	12
136	97	60	17	9
137	62	207	32	9
138	19	273	44	8
139	44	315	14	11
140	62	131	32	10
141	62	131	31	10
142	62	89	33	10
143	62	89	32	9
144	62	84	34	9
146	62	132	30	10
149	12	558	7	6
150	11	205	38	11
151	22	167	24	12
152	12	217	10	8
153	12	217	10	8
154	12	256	10	8
156	11	185	37	7
157	22	188	24	13
158	12	190	10	8
159	22	185	24	12
160	69	118	120	20
161	84	160	900	30
162	47	190	120	10
164	39	163	140	31
166	50	270	25	15
167	77	220	180	24
168	64	180	120	35

	Y	X1	X2	X3
Record_ID	Average Success Rate	Structure_ Length_ft	Structure_ Width_ft	Structure_ Height_ft
169	49	185	120	22
187	75	175	32	22
188	66	365	52	38
204	82	66	42	14
206	62	66	42	14
207	79	66	42	14
208	90	66	42	14
210	97	66	42	14
219	92	60	20	10
220	92	60	20	10
221	92	60	20	10
222	92	60	20	10
223	92	60	20	10
224	92	60	20	10
225	92	60	20	10
226	98	86	93	16
227	70	82	108	16
228	94	98	27	16
229	88	98	88	15
232	84	38	48	16
233	25	231	17	17
234	63	202	17	12
235	76	98	12	9
236	75	202	19	14
237	25	202	19	14
238	5	208	19	14
241	54	157	17	10
242	63	165	17	10
243	46	154	13	9
244	67	142	13	9
245	89	65	27	15
246	86	65	27	15
248	75	175	12	9
249	0	280	12	10
250	100	135	26	26
257	60	92	26	20
259	60	92	26	20
260	60	92	26	20
262	62	100	10	10
263	88	70	39	13
264	89	44	50	30
265	25	84	6	8
266	86	52	16	9
267	79	52	16	9
268	85	68	19	12
269	91	77	23	12
270	89	75	24	12

Appendix C
Model 2 Statistical Analysis of Predicted Response to Underpass Structures with Fixed Dimensions by Mule Deer and Elk

Model 2 - structure dimensions, species success rate

Best Fit Model: SuccessRate for deer and elk is not impacted by species

SuccessRate = 161.247 - (33.378*ln(length)) + (5.721*ln(width)) + (16.116*ln(height))

SUMMARY OUTPUT (106 Observations)

	SuccessRate	Length	Width	Height
Minimum	-	38	6	6
1st Quartile	33	78	19	9
Median	66	132	26	12
Mean	60	149	54	14
3rd Quartile	88	190	42	15
Maximum	100	558	900	38

SKEWNESS & KURTOSIS (LOG, SQUARE ROOT, CUBED)

	SuccessRate	Length	Width	Height
Skew, no adj	-0.455	1.866	6.217	1.820
Kurtosis, no adj	1.872	8.678	42.796	6.009
Skew, log	na	0.128	1.306	0.895
Kurtosis, log	na	2.332	5.982	3.350
Skew, sqrt	-0.906	0.821	4.021	1.360
Kurtosis, sqrt	2.757	4.016	23.061	4.445
Skew, cube	-1.299	0.556	3.028	1.205
Kurtosis, cube	4.551	3.204	15.516	4.025
RESULTS: apply log transformation to Length, Width, and Height				

JARQUE-BERA NORMALITY TEST (per transformation above)

null hypothesis: distribution is normal after transformation

	SuccessRate	Length	Width	Height
JB	9.27	2.2578	69.41	14.693
p-value	9.70E-03	0.3234	8.82E-16	0.0006
	not normal	*normal*	*not normal*	*not normal*

Initial LM VARIABLE ANALYSIS:

	Estimate	Std Error	t value	Pr(>|t|)	
(Intercept)	153.802	23.527	6.537	2.59E-09	sig to 0
Length	-32.495	3.64	-8.926	2.07E-14	sig to 0
Width	6.28	3.268	1.922	0.0575	sig to 0.05
Height	15.437	7.012	2.201	0.03	sig to 0.01
Species: Deer	4.154	4.628	0.897	0.3716	

Residential standard error	20.35	101 df
Multiple R-squared	0.564	
Adjusted R-squared	0.567	
F-statistic	32.66	4 and 101 df
p-value	2.20E-16	

	Length	Width	Height	Species	
Var Inflation Factor (Multicollinearity)	1.089	2.068	2.016	1.113	***<5, low collinearity***
Importation of Variables	**8.93**	1.92	2.2	0.9	

BEST FIT MODEL (glmulti analysis): SuccessRate ~ 1 + Length + Width + Height

Evidence 0.37899

Worst IC 1026

4 models to reach 95% of evidence weight

3 models within 2 IC units

model	aicc	weights
SuccessRate ~ 1 + Length + Width + Height	**945.87**	0.37899
SuccessRate ~ 1 + Length + Width	946.93	0.2235
SuccessRate ~ 1 + Length + Height	947.28	0.1876

	X1	X2	X3	Y
Record_ID	Structure_Length_ft	Structure_Width_ft	Structure_Height_ft	Deer_Success_Rate
110	90	20	12	53
111	90	20	12	48
113	90	20	12	43
135	132	24	12	98.13
136	60	17	9	96.81
137	207	32	9	50
138	273	44	8	30
139	315	14	11	43
140	131	32	10	50
141	131	31	10	50
142	89	33	10	50
143	89	32	9	50
144	84	34	9	50
146	132	30	10	50
149	558	7	6	13
150	205	38	11	15
151	167	24	12	20
152	217	10	8	13
153	217	10	8	13
154	256	10	8	13
156	185	37	7	15
157	188	24	13	20
158	190	10	8	13
159	185	24	12	20
160	118	120	20	65
161	160	900	30	77
162	190	120	10	94

	X1	X2	X3	Y
Record_ID	Structure_Length_ft	Structure_Width_ft	Structure_Height_ft	Deer_Success_Rate
164	163	140	31	78
166	270	25	15	100
167	220	180	24	82
168	180	120	35	64
169	185	120	22	53
204	66	42	14	91
206	66	42	14	97
207	66	42	14	96
208	66	42	14	96
210	66	42	14	95
219	60	20	10	92
220	60	20	10	92
221	60	20	10	92
222	60	20	10	92
223	60	20	10	92
224	60	20	10	92
225	60	20	10	92
226	86	93	16	98.3
227	82	108	16	70.1
228	98	27	16	94
229	98	88	15	88
232	38	48	16	84
233	231	17	17	25.4
234	202	17	12	63
235	98	12	9	76
236	202	19	14	75
237	202	19	14	25
238	208	19	14	5
241	157	17	10	54
242	165	17	10	63
243	154	13	9	46
244	142	13	9	67
245	65	27	15	89
246	65	27	15	86
248	175	12	9	75
249	280	12	10	0
250	135	26	26	100
257	92	26	20	60
259	92	26	20	60
260	92	26	20	60
262	100	10	10	62
263	70	39	13	88
264	44	50	30	89
265	84	6	8	25
266	52	16	9	86
267	52	16	9	79

	X1	X2	X3	Y
Record_ID	Structure_Length_ft	Structure_Width_ft	Structure_Height_ft	Deer_Success_Rate
268	68	19	12	85
269	77	23	12	91
270	75	24	12	89

	X1	X2	X3	Y
Record_ID	Structure_Length_ft	Structure_Width_ft	Structure_Height_ft	Elk_Success_Rate
137	207	32	9	74
138	273	44	8	8
139	315	14	11	45
140	131	32	10	74
141	131	31	10	74
142	89	33	10	74
143	89	32	9	74
144	84	34	9	74
146	132	30	10	74
149	558	7	6	11
150	205	38	11	7
151	167	24	12	24
152	217	10	8	11
153	217	10	8	11
154	256	10	8	11
156	185	37	7	7
157	188	24	13	24
158	190	10	8	11
159	185	24	12	24
160	118	120	20	72
161	160	900	30	91
167	220	180	24	72
168	180	120	35	63
169	185	120	22	45
187	175	32	22	75
188	365	52	38	66
204	66	42	14	55
207	66	42	14	84
208	66	42	14	78
210	66	42	14	99

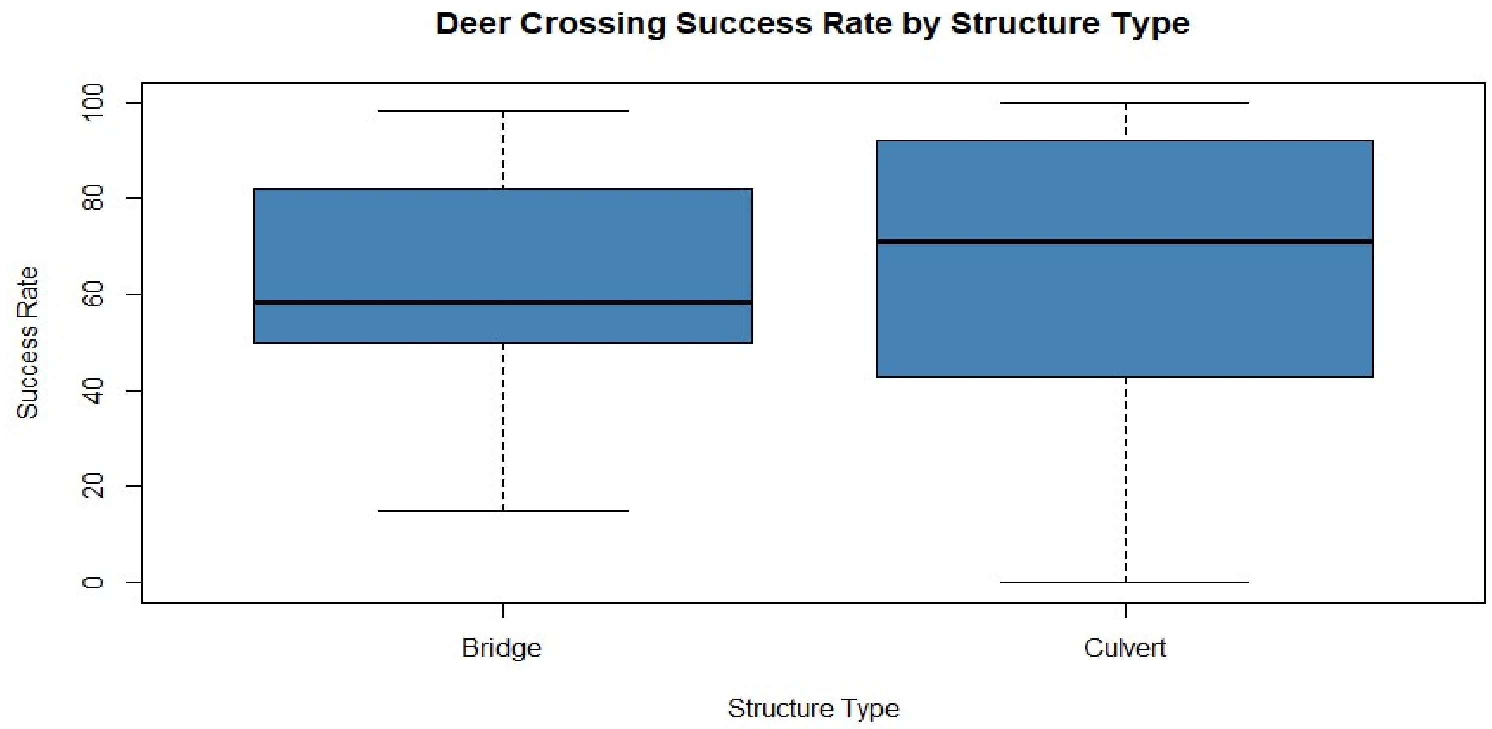
Appendix D
Model 4 Statistical Analysis of Predicted Success Rates and Structural Dimensions for Mule Deer; Underpass Structure Preference for Elk

Analyze Deer Reaction to Various Scenarios

Summary Data (78 Observations)

1) Deer to Structure Type: Conclusion is no significant difference between structure types

StructureType	mean	sd
1 Bridge	61.50	29.10
2 Culvert	63.60	29.10



ONE WAY ANOVA

Model Summary	Df	Sum Sq	Mean Sq	F Value	Pr(>F)	
StructureType	1	74	73.6	0.086	0.771	greater than .05, accept Hyp that
Residuals	76	65324	859.5			all groups are equal

Tukey HSD between structure types

Type	diff	lwr	upr	p adj	
Culvert-Bridge	2.158	-12.534	16.851	0.7706	significant difference if p adj < .05

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Deer to Underpass Size: Best Fit Model for Deer

SuccessRate = 188.528 - (33.663*ln(length)) + (10.428*ln(width))

Data Summary (76 Observations)

	SuccessRate	Length	Width	Height
Minimum	0.00	38.00	6.00	6.00
1st Quar	47.50	67.50	17.00	10.00
Median	66.00	99.00	24.00	12.00
Mean	63.25	135.50	46.89	13.29
3rd Quar	91.00	185.80	38.25	15.00
Maximum	100.00	558.00	900.00	35.00

SKEWNESS & KURTOSIS (LOG, SQUARE ROOT, CUBED)

	SuccessRate	Length	Width	Height
Skew, no adj	-0.537	1.958	7.262	1.830
Kurtosis, no adj	2.019	9.781	59.140	6.219
Skew, log	na	0.240	1.383	0.892
Kurtosis, log	na	2.294	6.286	3.497
Skew, sqrt	-1.107	0.887	4.299	1.362
Kurtosis, sqrt	3.572	4.115	27.562	4.624
Skew, cube	-1.687	0.636	3.148	1.205
Kurtosis, cube	6.624	3.222	17.423	4.192
RESULTS: Do not apply transformation to SuccessRate;				

JARQUE-BERA NORMALITY TEST (per transformation above)

	SuccessRate	Length	Width	Height
JB	6.69	2.303	58.42	10.874
p-value	3.52E-02	0.31161	2.063E-13	0.0044
	not normal	*normal*	*not normal*	*not normal*

LINEAR REGRESSION (LM) VARIABLE ANALYSIS:

	Estimate	Std Error	t value	Pr(>|t|)	
(Intercept)	170.343	27.593	6.173	3.55E-08	sig to 0.001
Length	-33.24	4.271	-7.784	3.89E-11	sig to 0.001
Width	7.147	3.975	1.798	0.0764	sig to 0.1
Height	10.772	8.89	1.212	0.2296	

Residential standard e	20.6	72 df
Multiple R-squared	0.5308	
Adjusted R-squared	0.5112	
F-statistic	27.15	3 and 72 df
p-value	7.45E-12	

	Length	Width	Height	
Var Inflation Factor (Multicollinearity)	1.012	1.877	1.889	***<5, low collinearity***
Importation of Variables	**7.78**	1.798	1.212	

ANOVA LM model

	Length	Width	Height	Residuals
Df	1	1	1	72
Sum Sq	28480.9	5451.8	622.9	30548
Mean Sq	28480.9	5451.8	622.9	424
F value	67.1274	12.8494	1.4681	
Pr(>F)	**6.68E-12**	**0.0006109**	0.2296	

BEST FIT MODEL (glmulti analysis): SuccessRate ~ 1 + Length + Width

Evidence 0.477

Worst IC 733.07

2 models to reach 95% of evidence weight

3 models within 2 IC units

model	aicc	weights
Deer_SuccessRate ~ 1 + Length + Width	**681.50**	0.477
Deer_SuccessRate ~ 1 + Length + Width + Height	**682.2569**	0.3263
Deer_SuccessRate ~ 1 + Length + Height	**683.3015**	0.1935

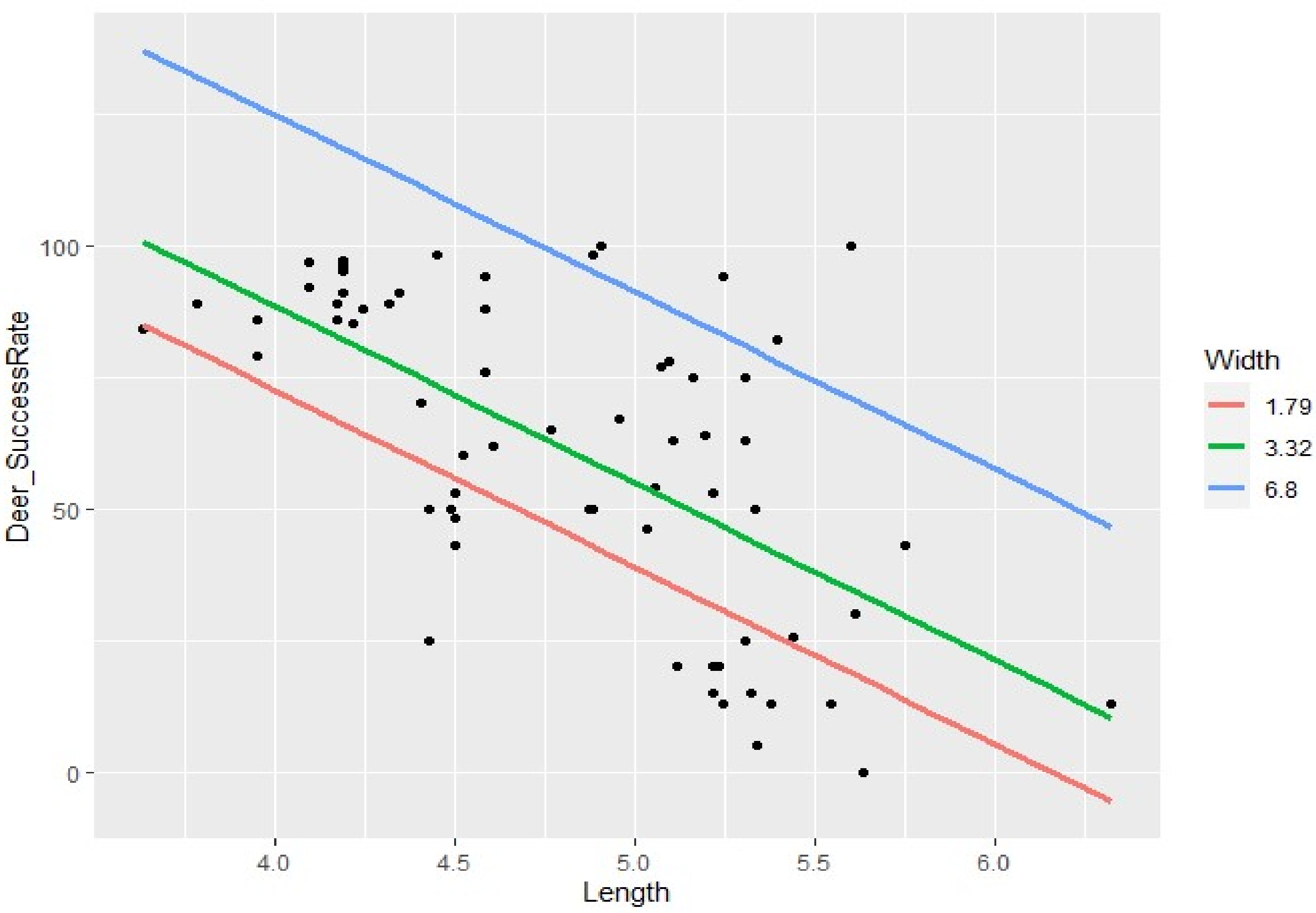
y = 188.528 - (33.663*ln(length)) + (10.428*ln(width))

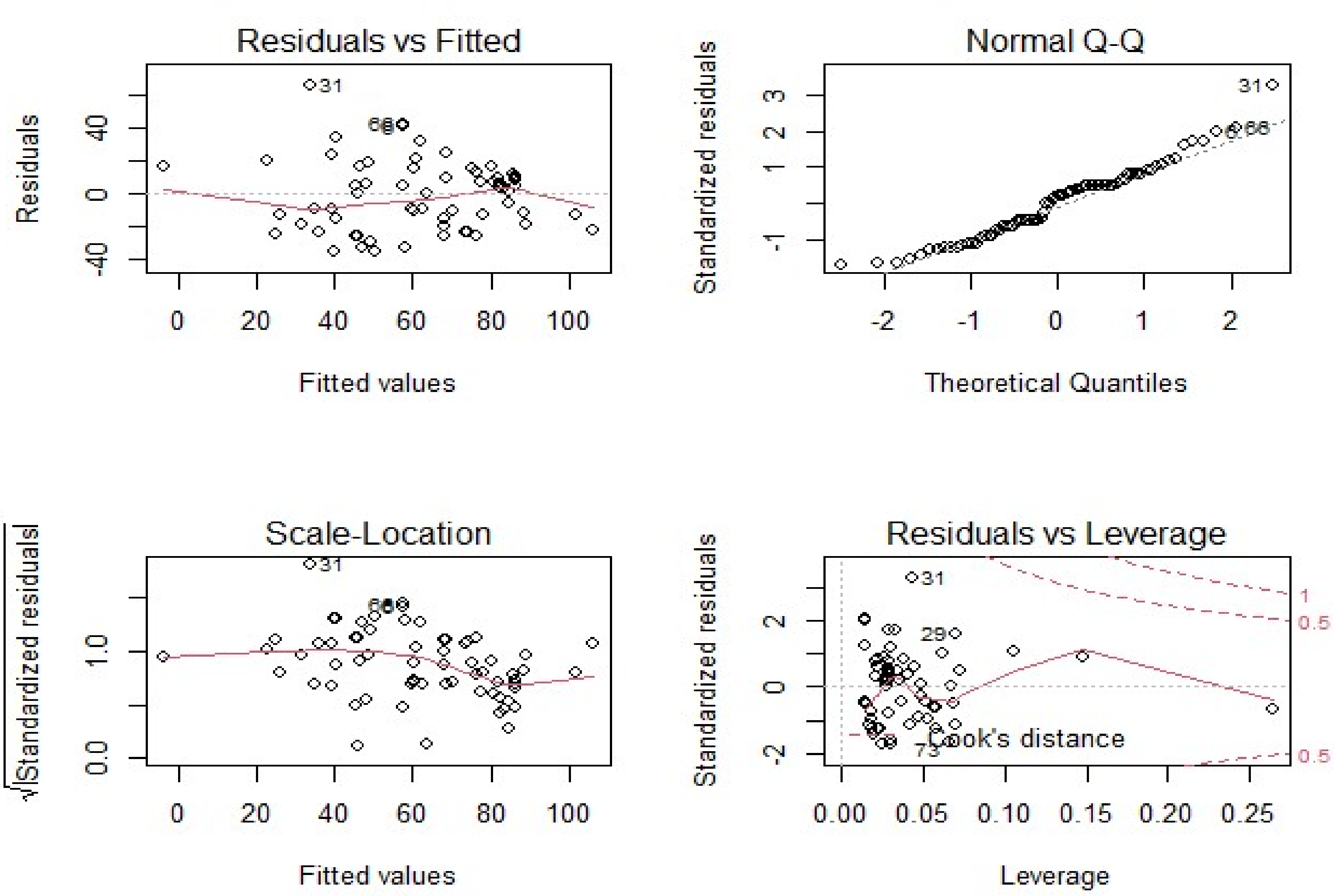
LINEAR REGRESSION (LM) VARIABLE ANALYSIS: Best Fit with Length and Width

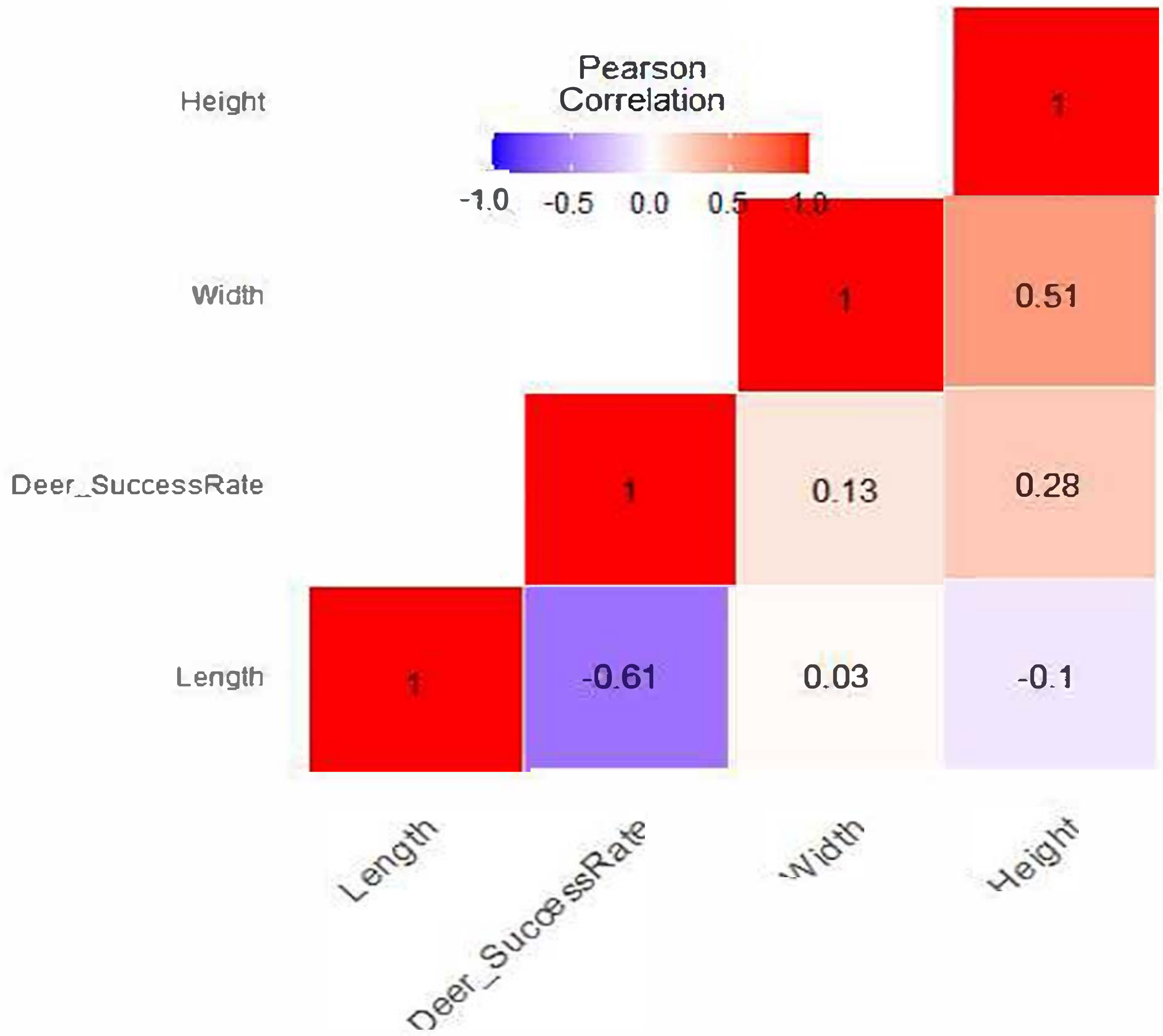
	Estimate	Std Error	t value	Pr(>|t|)	
Intercept	188.528	23.228	8.116	8.51E-12	sig to 0
Length	-33.663	4.27	-7.884	2.33E-11	sig to 0
Width	10.428	2.918	3.573	0.000629	sig to 0
Residential standard e	20.66	73 df			
Multiple R-squared	0.5212				
Adjusted R-squared	0.5081				
F-statistic	39.73	2 and 73 df			
p-value	2.12E-12		GOOD MODEL FIT		

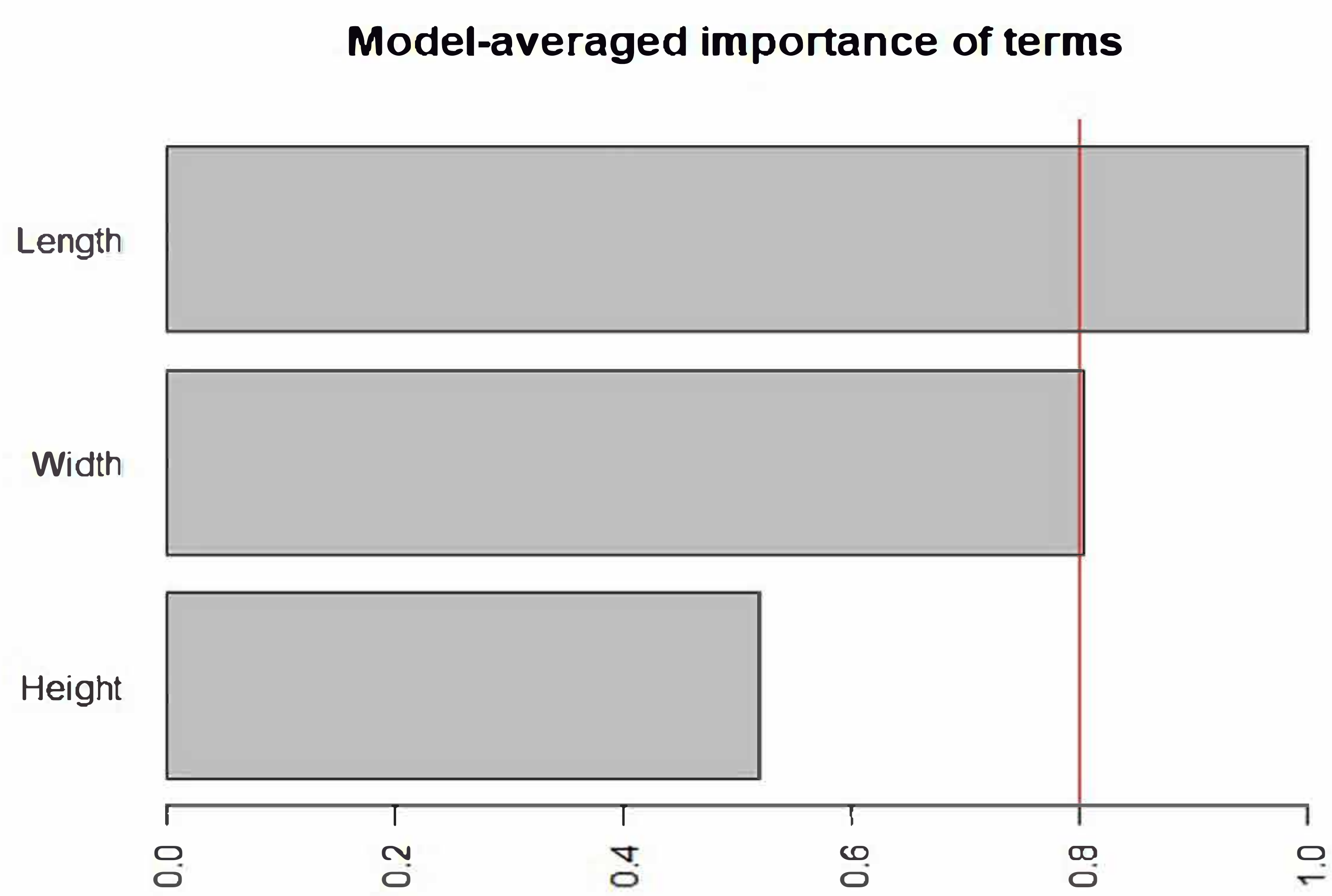
PSEUDO R SQUARED

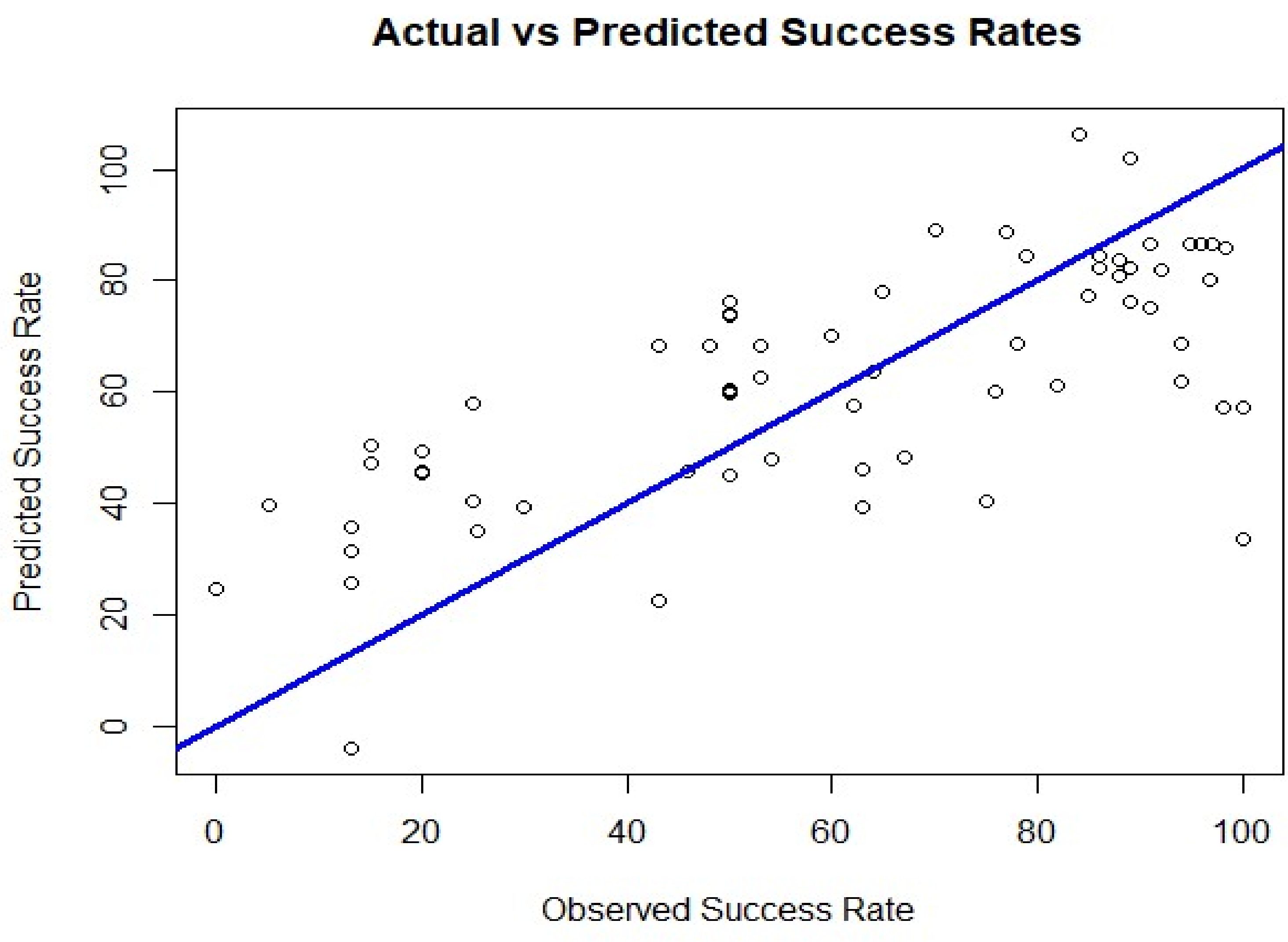
McFadden	0.2182
Cox and Snell (ML)	0.9155
Nagelkerke (Craig & Ul	0.9155

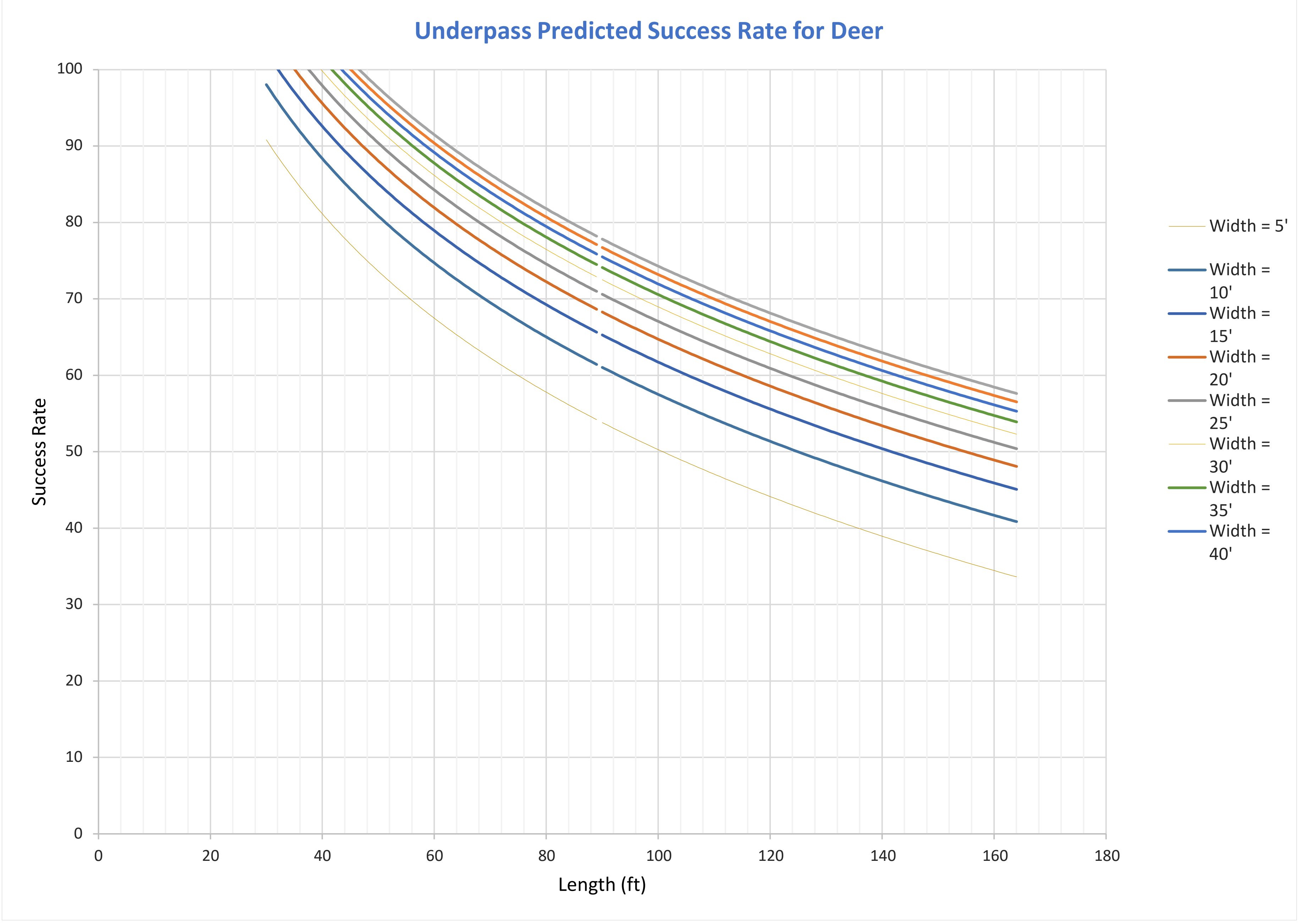





Pearson
Correlation
-1.0
-0.5
0.0
0.5
1.0
Height
Width
Deer_SuccessRate
Length
1
0.51
0.13
0.28
-0.61
0.03
-0.1
Length
Deer_SuccessRate
Width
Height


Model-averaged importance of terms
Length
Width
Height
0.0
0.2
0.4
0.6
0.8
1.0


Actual vs Predicted Success Rates
Predicted Success Rate
0
20
40
60
80
100
Observed Success Rate


Underpass Predicted Success Rate for Deer
Success Rate
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
Length (ft)
Width = 5'
Width = 10'
Width = 15'
Width = 20'
Width = 25'
Width = 30'
Width = 35'
Width = 40'

formula: Deer_SuccessRate = 188.528 - (33.663*ln(length)) + (10.428*ln(width))

Length/Width	5	10	15	20	25	30	35	40	45	50
30	90.81671	98.04485	102.273	105.273	107.5999	109.5012	111.1087	112.5011	113.7294	114.8281
31	89.71291	96.94105	101.1692	104.1692	106.4961	108.3974	110.0049	111.3973	112.6256	113.7243
32	88.64415	95.87229	100.1005	103.1004	105.4274	107.3286	108.9361	110.3286	111.5568	112.6555
33	87.60828	94.83642	99.06461	102.0646	104.3915	106.2928	107.9002	109.2927	110.5209	111.6196
34	86.60334	93.83148	98.05967	101.0596	103.3866	105.2878	106.8953	108.2878	109.516	110.6147
35	85.62754	92.85568	97.08387	100.0838	102.4108	104.312	105.9195	107.312	108.5402	109.6389
36	84.67922	91.90736	96.13555	99.1355	101.4624	103.3637	104.9712	106.3636	107.5919	108.6906
37	83.75689	90.98503	95.21322	98.21317	100.5401	102.4414	104.0488	105.4413	106.6695	107.7682
38	82.85916	90.08729	94.31548	97.31543	99.64237	101.5436	103.1511	104.5436	105.7718	106.8705
39	81.98474	89.21288	93.44107	96.44102	98.76796	100.6692	102.2767	103.6692	104.8974	105.9961
40	81.13247	88.36061	92.5888	95.58875	97.91569	99.81694	101.4244	102.8169	104.0451	105.1438
41	80.30124	87.52938	91.75757	94.75752	97.08446	98.98571	100.5932	101.9857	103.2139	104.3126
42	79.49005	86.71818	90.94638	93.94632	96.27326	98.17451	99.782	101.1745	102.4027	103.5014
43	78.69794	85.92608	90.15427	93.15422	95.48116	97.38241	98.98989	100.3824	101.6106	102.7093
44	77.92404	85.15218	89.38037	92.38032	94.70726	96.60851	98.21599	99.60846	100.8367	101.9354
45	77.16754	84.39568	88.62387	91.62382	93.95076	95.85201	97.45949	98.85196	100.0802	101.1789
46	76.42766	83.6558	87.88399	90.88394	93.21088	95.11213	96.71961	98.11208	99.34032	100.439
47	75.7037	82.93184	87.16003	90.15998	92.48692	94.38817	95.99565	97.38812	98.61636	99.71506
48	74.99498	82.22312	86.45131	89.45126	91.7782	93.67945	95.28693	96.6794	97.90764	99.00634
49	74.30087	81.52901	85.7572	88.75715	91.08409	92.98534	94.59282	95.98529	97.21353	98.31223
50	73.62079	80.84893	85.07712	88.07707	90.40401	92.30526	93.91274	95.3052	96.53345	97.63215
51	72.95417	80.18231	84.4105	87.41045	89.73739	91.63864	93.24612	94.63859	95.86683	96.96553
52	72.3005	79.52864	83.75683	86.75678	89.08372	90.98497	92.59245	93.98492	95.21316	96.31186
53	71.65928	78.88742	83.11561	86.11556	88.4425	90.34375	91.95123	93.3437	94.57194	95.67064
54	71.03005	78.25819	82.48638	85.48633	87.81327	89.71452	91.322	92.71446	93.94271	95.04141
55	70.41236	77.6405	81.86869	84.86864	87.19558	89.09683	90.70431	92.09678	93.32502	94.42372
56	69.8058	77.03394	81.26213	84.26208	86.58902	88.49027	90.09776	91.49022	92.71846	93.81716
57	69.20998	76.43812	80.66631	83.66626	85.9932	87.89445	89.50193	90.8944	92.12264	93.22134
58	68.62453	75.85266	80.08085	83.0808	85.40774	87.30899	88.91648	90.30894	91.53718	92.63588
59	68.04908	75.27721	79.5054	82.50535	84.83229	86.73354	88.34103	89.73349	90.96173	92.06043
60	67.4833	74.71144	78.93963	81.93958	84.26652	86.16777	87.77525	89.16771	90.39596	91.49465
61	66.92687	74.15501	78.3832	81.38315	83.71009	85.61134	87.21882	88.61129	89.83953	90.93823
62	66.37949	73.60763	77.83582	80.83577	83.16271	85.06396	86.67144	88.06391	89.29215	90.39085
63	65.84087	73.06901	77.2972	80.29715	82.62409	84.52534	86.13283	87.52529	88.75353	89.85223
64	65.31074	72.53888	76.76707	79.76701	82.09396	83.99521	85.60269	86.99515	88.2234	89.32209
65	64.78882	72.01696	76.24515	79.2451	81.57204	83.47329	85.08077	86.47324	87.70148	88.80018
66	64.27487	71.50301	75.7312	78.73115	81.05809	82.95934	84.56682	85.95929	87.18753	88.28623
67	63.76865	70.99679	75.22498	78.22493	80.55187	82.45312	84.0606	85.45307	86.68131	87.78001
68	63.26993	70.49807	74.72626	77.72621	80.05315	81.9544	83.56188	84.95435	86.18259	87.28129
69	62.77849	70.00663	74.23482	77.23477	79.56171	81.46296	83.07044	84.46291	85.69115	86.78985
70	62.29412	69.52226	73.75045	76.7504	79.07734	80.97859	82.58607	83.97854	85.20678	86.30548
71	61.81663	69.04476	73.27295	76.2729	78.59984	80.50109	82.10858	83.50104	84.72928	85.82798
72	61.34581	68.57395	72.80214	75.80208	78.12903	80.03027	81.63776	83.03022	84.25846	85.35716
73	60.88148	68.10962	72.33781	75.33776	77.6647	79.56595	81.17343	82.5659	83.79414	84.89284
74	60.42348	67.65161	71.8798	74.87975	77.20669	79.10794	80.71543	82.10789	83.33613	84.43483
75	59.97162	67.19975	71.42795	74.42789	76.75483	78.65608	80.26357	81.65603	82.88427	83.98297
76	59.52574	66.75388	70.98207	73.98202	76.30896	78.21021	79.81769	81.21016	82.4384	83.5371
77	59.0857	66.31384	70.54203	73.54197	75.86892	77.77016	79.37765	80.77011	81.99835	83.09705
78	58.65133	65.87947	70.10766	73.10761	75.43455	77.3358	78.94328	80.33575	81.56399	82.66269
79	58.2225	65.45063	69.67882	72.67877	75.00571	76.90696	78.51445	79.90691	81.13515	82.23385
80	57.79906	65.02719	69.25538	72.25533	74.58227	76.48352	78.09101	79.48347	80.71171	81.81041
81	57.38088	64.60902	68.83721	71.83715	74.1641	76.06534	77.67283	79.06529	80.29353	81.39223
82	56.96783	64.19597	68.42416	71.42411	73.75105	75.6523	77.25978	78.65224	79.88049	80.97919
83	56.55979	63.78793	68.01612	71.01606	73.34301	75.24425	76.85174	78.2442	79.47245	80.57114
84	56.15663	63.38477	67.61296	70.61291	72.93985	74.8411	76.44858	77.84105	79.06929	80.16799
85	55.75825	62.98639	67.21458	70.21453	72.54147	74.44272	76.0502	77.44267	78.67091	79.76961
86	55.36453	62.59266	66.82085	69.8208	72.14774	74.04899	75.65648	77.04894	78.27718	79.37588
87	54.97535	62.20349	66.43168	69.43163	71.75857	73.65982	75.2673	76.65977	77.88801	78.98671
88	54.59063	61.81877	66.04696	69.04691	71.37385	73.2751	74.88258	76.27505	77.50329	78.60199
89	54.21025	61.43839	65.66658	68.66653	70.99347	72.89472	74.5022	75.89467	77.12291	78.22161

90	53.83413	61.06226	65.29045	68.2904	70.61734	72.51859	74.12608	75.51854	76.74678	77.84548
91	53.46215	60.69029	64.91848	67.91843	70.24537	72.14662	73.75411	75.14657	76.37481	77.47351
92	53.09425	60.32239	64.55058	67.55053	69.87747	71.77872	73.3862	74.77867	76.00691	77.10561
93	52.73032	59.95846	64.18665	67.1866	69.51354	71.41479	73.02227	74.41474	75.64298	76.74168
94	52.37029	59.59843	63.82662	66.82656	69.1535	71.05475	72.66224	74.0547	75.28294	76.38164
95	52.01406	59.2422	63.47039	66.47034	68.79728	70.69853	72.30601	73.69848	74.92672	76.02542
96	51.66157	58.8897	63.11789	66.11784	68.44478	70.34603	71.95352	73.34598	74.57422	75.67292
97	51.31272	58.54086	62.76905	65.769	68.09594	69.99719	71.60467	72.99714	74.22538	75.32408
98	50.96746	58.1956	62.42379	65.42374	67.75068	69.65193	71.25941	72.65187	73.88012	74.97882
99	50.6257	57.85384	62.08203	65.08198	67.40892	69.31017	70.91765	72.31012	73.53836	74.63706
100	50.28737	57.51551	61.7437	64.74365	67.07059	68.97184	70.57933	71.97179	73.20003	74.29873
101	49.95242	57.18056	61.40875	64.40869	66.73564	68.63688	70.24437	71.63683	72.86507	73.96377
102	49.62076	56.8489	61.07709	64.07704	66.40398	68.30523	69.91271	71.30518	72.53342	73.63212
103	49.29234	56.52048	60.74867	63.74861	66.07556	67.9768	69.58429	70.97675	72.20499	73.30369
104	48.96709	56.19523	60.42342	63.42337	65.75031	67.65156	69.25904	70.6515	71.87975	72.97845
105	48.64495	55.87309	60.10128	63.10123	65.42817	67.32942	68.9369	70.32937	71.55761	72.65631
106	48.32587	55.55401	59.7822	62.78215	65.10909	67.01034	68.61782	70.01028	71.23853	72.33723
107	48.00978	55.23792	59.46611	62.46606	64.793	66.69425	68.30173	69.6942	70.92244	72.02114
108	47.69664	54.92477	59.15296	62.15291	64.47985	66.3811	67.98859	69.38105	70.60929	71.70799
109	47.38637	54.61451	58.8427	61.84265	64.16959	66.07084	67.67833	69.07079	70.29903	71.39773
110	47.07895	54.30709	58.53528	61.53523	63.86217	65.76342	67.3709	68.76336	69.99161	71.09031
111	46.7743	54.00244	58.23063	61.23058	63.55752	65.45877	67.06625	68.45872	69.68696	70.78566
112	46.47239	53.70053	57.92872	60.92867	63.25561	65.15686	66.76434	68.15681	69.38505	70.48375
113	46.17316	53.4013	57.62949	60.62944	62.95638	64.85763	66.46511	67.85758	69.08582	70.18452
114	45.87657	53.10471	57.3329	60.33285	62.65979	64.56104	66.16852	67.56099	68.78923	69.88793
115	45.58257	52.81071	57.0389	60.03885	62.36579	64.26704	65.87452	67.26698	68.49523	69.59393
116	45.29111	52.51925	56.74744	59.74739	62.07433	63.97558	65.58306	66.97553	68.20377	69.30247
117	45.00216	52.2303	56.45849	59.45843	61.78538	63.68663	65.29411	66.68657	67.91482	69.01351
118	44.71566	51.9438	56.17199	59.17194	61.49888	63.40013	65.00761	66.40008	67.62832	68.72702
119	44.43158	51.65972	55.88791	58.88786	61.2148	63.11605	64.72354	66.116	67.34424	68.44294
120	44.14988	51.37802	55.60621	58.60616	60.9331	62.83435	64.44184	65.8343	67.06254	68.16124
121	43.87052	51.09866	55.32685	58.3268	60.65374	62.55499	64.16247	65.55494	66.78318	67.88188
122	43.59346	50.8216	55.04979	58.04974	60.37668	62.27793	63.88541	65.27787	66.50612	67.60482
123	43.31866	50.5468	54.77499	57.77493	60.10188	62.00312	63.61061	65.00307	66.23131	67.33001
124	43.04608	50.27422	54.50241	57.50236	59.8293	61.73055	63.33803	64.7305	65.95874	67.05744
125	42.77569	50.00383	54.23202	57.23197	59.55891	61.46016	63.06764	64.46011	65.68835	66.78705
126	42.50746	49.7356	53.96379	56.96374	59.29068	61.19193	62.79941	64.19188	65.42012	66.51882
127	42.24135	49.46949	53.69768	56.69763	59.02457	60.92582	62.5333	63.92577	65.15401	66.25271
128	41.97732	49.20546	53.43365	56.4336	58.76054	60.66179	62.26927	63.66174	64.88998	65.98868
129	41.71535	48.94349	53.17168	56.17163	58.49857	60.39982	62.0073	63.39977	64.62801	65.72671
130	41.45541	48.68355	52.91174	55.91168	58.23862	60.13987	61.74736	63.13982	64.36806	65.46676
131	41.19745	48.42559	52.65378	55.65373	57.98067	59.88192	61.4894	62.88187	64.11011	65.20881
132	40.94146	48.1696	52.39779	55.39774	57.72468	59.62593	61.23341	62.62587	63.85412	64.95281
133	40.6874	47.91553	52.14372	55.14367	57.47061	59.37186	60.97935	62.37181	63.60005	64.69875
134	40.43524	47.66338	51.89157	54.89151	57.21846	59.11971	60.72719	62.11965	63.3479	64.44659
135	40.18495	47.41309	51.64128	54.64123	56.96817	58.86942	60.4769	61.86937	63.09761	64.19631
136	39.93652	47.16466	51.39285	54.39279	56.71974	58.62098	60.22847	61.62093	62.84918	63.94787
137	39.6899	46.91804	51.14623	54.14618	56.47312	58.37437	59.98185	61.37432	62.60256	63.70126
138	39.44508	46.67322	50.90141	53.90136	56.2283	58.12955	59.73703	61.12949	62.35774	63.45644
139	39.20202	46.43016	50.65835	53.6583	55.98524	57.88649	59.49397	60.88644	62.11468	63.21338
140	38.96071	46.18885	50.41704	53.41699	55.74393	57.64518	59.25266	60.64513	61.87337	62.97207
141	38.72111	45.94925	50.17744	53.17739	55.50433	57.40558	59.01307	60.40553	61.63377	62.73247
142	38.48321	45.71135	49.93954	52.93949	55.26643	57.16768	58.77516	60.16763	61.39587	62.49457
143	38.24698	45.47512	49.70331	52.70326	55.0302	56.93145	58.53893	59.9314	61.15964	62.25834
144	38.01239	45.24053	49.46872	52.46867	54.79561	56.69686	58.30434	59.69681	60.92505	62.02375
145	37.77943	45.00757	49.23576	52.23571	54.56265	56.4639	58.07138	59.46385	60.69209	61.79079
146	37.54807	44.77621	49.0044	52.00435	54.33129	56.23254	57.84002	59.23249	60.46073	61.55943
147	37.31829	44.54643	48.77462	51.77456	54.1015	56.00275	57.61024	59.0027	60.23094	61.32964
148	37.09006	44.3182	48.54639	51.54634	53.87328	55.77453	57.38201	58.77448	60.00272	61.10142
149	36.86337	44.09151	48.3197	51.31965	53.64659	55.54784	57.15533	58.54779	59.77603	60.87473
150	36.6382	43.86634	48.09453	51.09448	53.42142	55.32267	56.93015	58.32262	59.55086	60.64956
151	36.41453	43.64267	47.87086	50.87081	53.19775	55.099	56.70648	58.09894	59.32719	60.42588
152	36.19233	43.42047	47.64866	50.64861	52.97555	54.8768	56.48428	57.87674	59.10499	60.20369
153	35.97159	43.19973	47.42792	50.42786	52.75481	54.65605	56.26354	57.656	58.88424	59.98294
154	35.75228	42.98042	47.20861	50.20856	52.5355	54.43675	56.04423	57.4367	58.66494	59.76364
155	35.5344	42.76254	46.99073	49.99068	52.31762	54.21887	55.82635	57.21882	58.44706	59.54576
156	35.31792	42.54605	46.77424	49.77419	52.10113	54.00238	55.60987	57.00233	58.23057	59.32927
157	35.10282	42.33095	46.55914	49.55909	51.88603	53.78728	55.39477	56.78723	58.01547	59.11417
158	34.88908	42.11722	46.34541	49.34536	51.6723	53.57355	55.18103	56.5735	57.80174	58.90044
159	34.6767	41.90484	46.13303	49.13297	51.45991	53.36116	54.96865	56.36111	57.58935	58.68805
160	34.46564	41.69378	45.92197	48.92192	51.24886	53.15011	54.75759	56.15006	57.3783	58.477
161	34.2559	41.48404	45.71223	48.71218	51.03912	52.94037	54.54785	55.94032	57.16856	58.26726
162	34.04746	41.2756	45.50379	48.50374	50.83068	52.73193	54.33941	55.73188	56.96012	58.05882
163	33.84031	41.06844	45.29663	48.29658	50.62352	52.52477	54.13226	55.52472	56.75296	57.85166
164	33.63441	40.86255	45.09074	48.09069	50.41763	52.31888	53.92637	55.31883	56.54707	57.64577

55	60	65	70	75	80	85	90	95	100
115.822	116.7293	117.564	118.3368	119.0563	119.7293	120.3615	120.9575	121.5213	122.0562
114.7182	115.6255	116.4602	117.233	117.9525	118.6255	119.2577	119.8537	120.4175	120.9524
113.6494	114.5568	115.3914	116.1642	116.8837	117.5567	118.1889	118.7849	119.3488	119.8836
112.6135	113.5209	114.3556	115.1284	115.8478	116.5208	117.153	117.7491	118.3129	118.8478
111.6086	112.516	113.3506	114.1234	114.8429	115.5159	116.1481	116.7441	117.308	117.8428
110.6328	111.5401	112.3748	113.1476	113.8671	114.5401	115.1723	115.7683	116.3321	116.867
109.6845	110.5918	111.4265	112.1993	112.9188	113.5918	114.224	114.82	115.3838	115.9187
108.7621	109.6695	110.5042	111.277	111.9964	112.6694	113.3016	113.8977	114.4615	114.9964
107.8644	108.7718	109.6064	110.3792	111.0987	111.7717	112.4039	113	113.5638	114.0987
106.99	107.8973	108.732	109.5048	110.2243	110.8973	111.5295	112.1255	112.6894	113.2242
106.1377	107.0451	107.8798	108.6526	109.372	110.045	110.6772	111.2733	111.8371	112.372
105.3065	106.2138	107.0485	107.8213	108.5408	109.2138	109.846	110.442	111.0059	111.5407
104.4953	105.4027	106.2373	107.0101	107.7296	108.4026	109.0348	109.6308	110.1947	110.7295
103.7032	104.6105	105.4452	106.218	106.9375	107.6105	108.2427	108.8387	109.4025	109.9374
102.9293	103.8366	104.6713	105.4441	106.1636	106.8366	107.4688	108.0648	108.6287	109.1635
102.1728	103.0801	103.9148	104.6876	105.4071	106.0801	106.7123	107.3083	107.8721	108.407
101.4329	102.3403	103.175	103.9478	104.6672	105.3402	105.9724	106.5685	107.1323	107.6672
100.709	101.6163	102.451	103.2238	103.9432	104.6163	105.2484	105.8445	106.4083	106.9432
100.0002	100.9076	101.7423	102.5151	103.2345	103.9075	104.5397	105.1358	105.6996	106.2345
99.30612	100.2135	101.0482	101.821	102.5404	103.2134	103.8456	104.4417	105.0055	105.5404
98.62604	99.53339	100.3681	101.1409	101.8603	102.5333	103.1655	103.7616	104.3254	104.8603
97.95942	98.86678	99.70146	100.4743	101.1937	101.8667	102.4989	103.095	103.6588	104.1937
97.30575	98.21311	99.04779	99.82059	100.54	101.2131	101.8453	102.4413	103.0051	103.54
96.66453	97.57189	98.40657	99.17937	99.89883	100.5718	101.204	101.8001	102.3639	102.8988
96.0353	96.94266	97.77734	98.55014	99.2696	99.9426	100.5748	101.1708	101.7347	102.2695
95.41761	96.32497	97.15965	97.93245	98.65191	99.32492	99.95711	100.5532	101.117	101.6519
94.81106	95.71841	96.5531	97.32589	98.04535	98.71836	99.35055	99.9466	100.5104	101.0453
94.21524	95.12259	95.95728	96.73007	97.44953	98.12254	98.75473	99.35078	99.91459	100.4495
93.62978	94.53713	95.37182	96.14462	96.86407	97.53708	98.16927	98.76532	99.32914	99.86402
93.05433	93.96168	94.79637	95.56917	96.28862	96.96163	97.59382	98.18987	98.75369	99.28857
92.48855	93.3959	94.23059	95.00339	95.72285	96.39585	97.02805	97.62409	98.18791	98.72279
91.93212	92.83948	93.67416	94.44696	95.16642	95.83943	96.47162	97.06767	97.63148	98.16637
91.38475	92.2921	93.12679	93.89958	94.61904	95.29205	95.92424	96.52029	97.0841	97.61899
90.84613	91.75348	92.58817	93.36096	94.08042	94.75343	95.38562	95.98167	96.54548	97.08037
90.31599	91.22334	92.05803	92.83083	93.55028	94.22329	94.85549	95.45153	96.01535	96.55023
89.79407	90.70143	91.53611	92.30891	93.02837	93.70138	94.33357	94.92962	95.49343	96.02832
89.28012	90.18748	91.02216	91.79496	92.51442	93.18743	93.81962	94.41567	94.97948	95.51437
88.7739	89.68126	90.51594	91.28874	92.0082	92.68121	93.3134	93.90945	94.47326	95.00815
88.27518	89.18254	90.01722	90.79002	91.50948	92.18249	92.81468	93.41073	93.97454	94.50943
87.78374	88.6911	89.52578	90.29858	91.01804	91.69105	92.32324	92.91929	93.4831	94.01799
87.29938	88.20673	89.04142	89.81421	90.53367	91.20668	91.83887	92.43492	92.99873	93.53362
86.82188	87.72923	88.56392	89.33672	90.05617	90.72918	91.36137	91.95742	92.52124	93.05612
86.35106	87.25841	88.0931	88.8659	89.58535	90.25836	90.89056	91.4866	92.05042	92.5853
85.88673	86.79409	87.62877	88.40157	89.12103	89.79404	90.42623	91.02228	91.58609	92.12098
85.42873	86.33608	87.17077	87.94357	88.66302	89.33603	89.96822	90.56427	91.12808	91.66297
84.97687	85.88422	86.71891	87.49171	88.21116	88.88417	89.51636	90.11241	90.67623	91.21111
84.53099	85.43835	86.27303	87.04583	87.76529	88.4383	89.07049	89.66654	90.23035	90.76524
84.09095	84.9983	85.83299	86.60579	87.32524	87.99825	88.63045	89.22649	89.79031	90.32519
83.65658	84.56394	85.39862	86.17142	86.89088	87.56388	88.19608	88.79213	89.35594	89.89083
83.22775	84.1351	84.96979	85.74259	86.46204	87.13505	87.76724	88.36329	88.92711	89.46199
82.80431	83.71166	84.54635	85.31915	86.0386	86.71161	87.3438	87.93985	88.50367	89.03855
82.38613	83.29348	84.12817	84.90097	85.62042	86.29343	86.92563	87.52167	88.08549	88.62037
81.97308	82.88044	83.71512	84.48792	85.20738	85.88038	86.51258	87.10863	87.67244	88.20732
81.56504	82.47239	83.30708	84.07988	84.79933	85.47234	86.10454	86.70058	87.2644	87.79928
81.16188	82.06924	82.90392	83.67672	84.39618	85.06919	85.70138	86.29743	86.86124	87.39613
80.7635	81.67086	82.50554	83.27834	83.9978	84.6708	85.303	85.89905	86.46286	86.99775
80.36978	81.27713	82.11182	82.88462	83.60407	84.27708	84.90927	85.50532	86.06914	86.60402
79.98061	80.88796	81.72265	82.49544	83.2149	83.88791	84.5201	85.11615	85.67996	86.21485
79.59588	80.50324	81.33792	82.11072	82.83018	83.50318	84.13538	84.73143	85.29524	85.83013
79.2155	80.12286	80.95754	81.73034	82.4498	83.12281	83.755	84.35105	84.91486	85.44975

78.83938	79.74673	80.58142	81.35422	82.07367	82.74668	83.37887	83.97492	84.53874	85.07362
78.46741	79.37476	80.20945	80.98224	81.7017	82.37471	83.0069	83.60295	84.16676	84.70165
78.0995	79.00686	79.84154	80.61434	81.3338	82.0068	82.639	83.23505	83.79886	84.33375
77.73557	78.64293	79.47761	80.25041	80.96987	81.64288	82.27507	82.87112	83.43493	83.96982
77.37554	78.28289	79.11758	79.89038	80.60983	81.28284	81.91504	82.51108	83.0749	83.60978
77.01931	77.92667	78.76135	79.53415	80.25361	80.92662	81.55881	82.15486	82.71867	83.25356
76.66682	77.57417	78.40886	79.18166	79.90111	80.57412	81.20631	81.80236	82.36618	82.90106
76.31797	77.22533	78.06001	78.83281	79.55227	80.22528	80.85747	81.45352	82.01733	82.55222
75.97271	76.88006	77.71475	78.48755	79.20701	79.88001	80.51221	81.10826	81.67207	82.20695
75.63095	76.53831	77.37299	78.14579	78.86525	79.53825	80.17045	80.7665	81.33031	81.8652
75.29263	76.19998	77.03467	77.80746	78.52692	79.19993	79.83212	80.42817	80.99198	81.52687
74.95767	75.86502	76.69971	77.47251	78.19196	78.86497	79.49717	80.09321	80.65703	81.19191
74.62601	75.53337	76.36805	77.14085	77.86031	78.53331	79.16551	79.76156	80.32537	80.86025
74.29759	75.20494	76.03963	76.81243	77.53188	78.20489	78.83709	79.43313	79.99695	80.53183
73.97234	74.87969	75.71438	76.48718	77.20664	77.87964	78.51184	79.10788	79.6717	80.20658
73.6502	74.55756	75.39224	76.16504	76.8845	77.55751	78.1897	78.78575	79.34956	79.88445
73.33112	74.23847	75.07316	75.84596	76.56542	77.23842	77.87062	78.46667	79.03048	79.56536
73.01503	73.92239	74.75707	75.52987	76.24933	76.92234	77.55453	78.15058	78.71439	79.24928
72.70189	73.60924	74.44393	75.21672	75.93618	76.60919	77.24138	77.83743	78.40124	78.93613
72.39163	73.29898	74.13367	74.90646	75.62592	76.29893	76.93112	77.52717	78.09098	78.62587
72.0842	72.99155	73.82624	74.59904	75.3185	75.9915	76.6237	77.21974	77.78356	78.31844
71.77956	72.68691	73.5216	74.29439	75.01385	75.68686	76.31905	76.9151	77.47891	78.0138
71.47764	72.385	73.21968	73.99248	74.71194	75.38495	76.01714	76.61319	77.177	77.71189
71.17841	72.08577	72.92045	73.69325	74.41271	75.08572	75.71791	76.31396	76.87777	77.41266
70.88182	71.78918	72.62386	73.39666	74.11612	74.78913	75.42132	76.01737	76.58118	77.11607
70.58782	71.49517	72.32986	73.10266	73.82212	74.49512	75.12732	75.72337	76.28718	76.82206
70.29636	71.20372	72.0384	72.8112	73.53066	74.20367	74.83586	75.43191	75.99572	76.53061
70.00741	70.91476	71.74945	72.52225	73.2417	73.91471	74.54691	75.14295	75.70677	76.24165
69.72091	70.62827	71.46295	72.23575	72.95521	73.62822	74.26041	74.85646	75.42027	75.95516
69.43684	70.34419	71.17888	71.95167	72.67113	73.34414	73.97633	74.57238	75.13619	75.67108
69.15514	70.06249	70.89718	71.66997	72.38943	73.06244	73.69463	74.29068	74.85449	75.38938
68.87577	69.78313	70.61781	71.39061	72.11007	72.78308	73.41527	74.01132	74.57513	75.11002
68.59871	69.50606	70.34075	71.11355	71.83301	72.50601	73.13821	73.73425	74.29807	74.83295
68.32391	69.23126	70.06595	70.83875	71.5582	72.23121	72.86341	73.45945	74.02327	74.55815
68.05133	68.95869	69.79337	70.56617	71.28563	71.95864	72.59083	73.18688	73.75069	74.28558
67.78095	68.6883	69.52299	70.29578	71.01524	71.68825	72.32044	72.91649	73.4803	74.01519
67.51271	68.42007	69.25475	70.02755	70.74701	71.42002	72.05221	72.64826	73.21207	73.74696
67.2466	68.15396	68.98864	69.76144	70.4809	71.1539	71.7861	72.38215	72.94596	73.48084
66.98258	67.88993	68.72462	69.49741	70.21687	70.88988	71.52207	72.11812	72.68193	73.21682
66.72061	67.62796	68.46265	69.23544	69.9549	70.62791	71.2601	71.85615	72.41996	72.95485
66.46066	67.36801	68.2027	68.9755	69.69495	70.36796	71.00016	71.5962	72.16002	72.6949
66.2027	67.11006	67.94474	68.71754	69.437	70.11001	70.7422	71.33825	71.90206	72.43695
65.94671	66.85406	67.68875	68.46155	69.181	69.85401	70.48621	71.08225	71.64607	72.18095
65.69265	66.6	67.43469	68.20749	68.92694	69.59995	70.23214	70.82819	71.39201	71.92689
65.44049	66.34784	67.18253	67.95533	68.67478	69.34779	69.97999	70.57603	71.13985	71.67473
65.19021	66.09756	66.93225	67.70504	68.4245	69.09751	69.7297	70.32575	70.88956	71.42445
64.94177	65.84912	66.68381	67.45661	68.17606	68.84907	69.48127	70.07731	70.64113	71.17601
64.69515	65.60251	66.43719	67.20999	67.92945	68.60246	69.23465	69.8307	70.39451	70.9294
64.45033	65.35768	66.19237	66.96517	67.68463	68.35763	68.98983	69.58587	70.14969	70.68457
64.20727	65.11463	65.94931	66.72211	67.44157	68.11458	68.74677	69.34282	69.90663	70.44152
63.96596	64.87332	65.708	66.4808	67.20026	67.87326	68.50546	69.10151	69.66532	70.20021
63.72637	64.63372	65.46841	66.2412	66.96066	67.63367	68.26586	68.86191	69.42572	69.96061
63.48846	64.39582	65.2305	66.0033	66.72276	67.39577	68.02796	68.62401	69.18782	69.72271
63.25223	64.15959	64.99427	65.76707	66.48653	67.15953	67.79173	68.38778	68.95159	69.48648
63.01765	63.925	64.75969	65.53248	66.25194	66.92495	67.55714	68.15319	68.717	69.25189
62.78468	63.69204	64.52672	65.29952	66.01898	66.69199	67.32418	67.92023	68.48404	69.01893
62.55332	63.46068	64.29536	65.06816	65.78762	66.46062	67.09282	67.68887	68.25268	68.78756
62.32354	63.23089	64.06558	64.83838	65.55783	66.23084	66.86304	67.45908	68.0229	68.55778
62.09531	63.00267	63.83735	64.61015	65.32961	66.00262	66.63481	67.23086	67.79467	68.32956
61.86863	62.77598	63.61067	64.38346	65.10292	65.77593	66.40812	67.00417	67.56798	68.10287
61.64345	62.55081	63.38549	64.15829	64.87775	65.55076	66.18295	66.779	67.34281	67.8777
61.41978	62.32713	63.16182	63.93462	64.65407	65.32708	65.95928	66.55532	67.11914	67.65402
61.19758	62.10494	62.93962	63.71242	64.43188	65.10488	65.73708	66.33313	66.89694	67.43182
60.97684	61.88419	62.71888	63.49168	64.21113	64.88414	65.51634	66.11238	66.6762	67.21108
60.75754	61.66489	62.49957	63.27237	63.99183	64.66484	65.29703	65.89308	66.45689	66.99178
60.53965	61.44701	62.28169	63.05449	63.77395	64.44695	65.07915	65.6752	66.23901	66.77389
60.32317	61.23052	62.06521	62.83801	63.55746	64.23047	64.86266	65.45871	66.02253	66.55741
60.10807	61.01542	61.85011	62.62291	63.34236	64.01537	64.64756	65.24361	65.80743	66.34231
59.89433	60.80169	61.63637	62.40917	63.12863	63.80164	64.43383	65.02988	65.59369	66.12858
59.68195	60.5893	61.42399	62.19679	62.91624	63.58925	64.22145	64.81749	65.38131	65.91619
59.47089	60.37825	61.21293	61.98573	62.70519	63.3782	64.01039	64.60644	65.17025	65.70514
59.26116	60.16851	61.0032	61.77599	62.49545	63.16846	63.80065	64.3967	64.96051	65.4954
59.05272	59.96007	60.79476	61.56755	62.28701	62.96002	63.59221	64.18826	64.75207	65.28696
58.84556	59.75291	60.5876	61.3604	62.07985	62.75286	63.38505	63.9811	64.54492	65.0798
58.63967	59.54702	60.38171	61.1545	61.87396	62.54697	63.17916	63.77521	64.33902	64.87391

formula: Deer_SuccessRate = 188.528 - (33.663*ln(length)) + (10.428*ln(width))

Length/Wi(	5	10	15	20	25	30	35	40	45	50
165	33.42978	40.65791	44.88611	47.88605	50.21299	52.11424	53.72173	55.11419	56.34243	57.44113
166	33.22637	40.45451	44.6827	47.68265	50.00959	51.91084	53.51832	54.91079	56.13903	57.23773
167	33.02419	40.25233	44.48052	47.48047	49.80741	51.70866	53.31614	54.70861	55.93685	57.03555
168	32.82322	40.05136	44.27955	47.2795	49.60644	51.50769	53.11517	54.50764	55.73588	56.83458
169	32.62344	39.85158	44.07977	47.07972	49.40666	51.30791	52.91539	54.30785	55.5361	56.6348
170	32.42484	39.65297	43.88116	46.88111	49.20805	51.1093	52.71679	54.10925	55.33749	56.43619
171	32.2274	39.45554	43.68373	46.68368	49.01062	50.91187	52.51935	53.91181	55.14006	56.23876
172	32.03111	39.25925	43.48744	46.48739	48.81433	50.71558	52.32306	53.71553	54.94377	56.04247
173	31.83596	39.0641	43.29229	46.29224	48.61918	50.52043	52.12791	53.52038	54.74862	55.84732
174	31.64194	38.87008	43.09827	46.09822	48.42516	50.32641	51.93389	53.32636	54.5546	55.6533
175	31.44903	38.67717	42.90536	45.90531	48.23225	50.1335	51.74098	53.13344	54.36169	55.46039
176	31.25722	38.48535	42.71354	45.71349	48.04043	49.94168	51.54917	52.94163	54.16987	55.26857
177	31.06649	38.29463	42.52282	45.52277	47.84971	49.75096	51.35844	52.75091	53.97915	55.07785
178	30.87684	38.10498	42.33317	45.33312	47.66006	49.56131	51.16879	52.56126	53.7895	54.8882
179	30.68825	37.91639	42.14458	45.14453	47.47147	49.37272	50.9802	52.37267	53.60091	54.69961
180	30.50071	37.72885	41.95704	44.95699	47.28393	49.18518	50.79266	52.18513	53.41337	54.51207
181	30.31421	37.54235	41.77054	44.77049	47.09743	48.99868	50.60616	51.99863	53.22687	54.32557
182	30.12874	37.35688	41.58507	44.58502	46.91196	48.81321	50.42069	51.81316	53.0414	54.1401
183	29.94429	37.17242	41.40062	44.40056	46.7275	48.62875	50.23624	51.6287	52.85694	53.95564
184	29.76084	36.98897	41.21717	44.21711	46.54405	48.4453	50.05279	51.44525	52.67349	53.77219
185	29.57838	36.80652	41.03471	44.03466	46.3616	48.26285	49.87033	51.2628	52.49104	53.58974
186	29.39691	36.62505	40.85324	43.85319	46.18013	48.08138	49.68886	51.08132	52.30957	53.40827
187	29.21641	36.44455	40.67274	43.67269	45.99963	47.90088	49.50836	50.90083	52.12907	53.22777
188	29.03687	36.26501	40.4932	43.49315	45.82009	47.72134	49.32882	50.72129	51.94953	53.04823
189	28.85829	36.08643	40.31462	43.31457	45.64151	47.54276	49.15024	50.54271	51.77095	52.86965
190	28.68065	35.90879	40.13698	43.13692	45.46387	47.36511	48.9726	50.36506	51.59331	52.692
191	28.50394	35.73208	39.96027	42.96022	45.28716	47.18841	48.79589	50.18835	51.4166	52.5153
192	28.32815	35.55629	39.78448	42.78443	45.11137	47.01262	48.6201	50.01257	51.24081	52.33951
193	28.15328	35.38142	39.60961	42.60956	44.9365	46.83775	48.44523	49.8377	51.06594	52.16464
194	27.97931	35.20745	39.43564	42.43559	44.76253	46.66378	48.27126	49.66373	50.89197	51.99067
195	27.80623	35.03437	39.26256	42.26251	44.58945	46.4907	48.09819	49.49065	50.71889	51.81759
196	27.63404	34.86218	39.09037	42.09032	44.41726	46.31851	47.926	49.31846	50.5467	51.6454
197	27.46273	34.69087	38.91906	41.91901	44.24595	46.1472	47.75468	49.14715	50.37539	51.47409
198	27.29229	34.52042	38.74861	41.74856	44.0755	45.97675	47.58424	48.9767	50.20494	51.30364
199	27.1227	34.35084	38.57903	41.57898	43.90592	45.80717	47.41465	48.80711	50.03536	51.13406
200	26.95396	34.1821	38.41029	41.41024	43.73718	45.63843	47.24591	48.63838	49.86662	50.96532
201	26.78607	34.0142	38.24239	41.24234	43.56928	45.47053	47.07802	48.47048	49.69872	50.79742
202	26.619	33.84714	38.07533	41.07528	43.40222	45.30347	46.91095	48.30342	49.53166	50.63036
203	26.45277	33.6809	37.90909	40.90904	43.23598	45.13723	46.74472	48.13718	49.36542	50.46412
204	26.28735	33.51548	37.74367	40.74362	43.07056	44.97181	46.5793	47.97176	49.2	50.2987
205	26.12273	33.35087	37.57906	40.57901	42.90595	44.8072	46.41468	47.80715	49.03539	50.13409
206	25.95892	33.18706	37.41525	40.4152	42.74214	44.64339	46.25087	47.64334	48.87158	49.97028
207	25.79591	33.02404	37.25223	40.25218	42.57912	44.48037	46.08786	47.48032	48.70856	49.80726
208	25.63367	32.86181	37.09	40.08995	42.41689	44.31814	45.92563	47.31809	48.54633	49.64503
209	25.47222	32.70036	36.92855	39.9285	42.25544	44.15669	45.76417	47.15664	48.38488	49.48358
210	25.31154	32.53968	36.76787	39.76782	42.09476	43.99601	45.60349	46.99595	48.2242	49.3229
211	25.15162	32.37976	36.60795	39.6079	41.93484	43.83609	45.44357	46.83603	48.06428	49.16298
212	24.99245	32.22059	36.44878	39.44873	41.77567	43.67692	45.28441	46.67687	47.90511	49.00381
213	24.83404	32.06218	36.29037	39.29032	41.61726	43.51851	45.12599	46.51846	47.7467	48.8454
214	24.67637	31.90451	36.1327	39.13265	41.45959	43.36084	44.96832	46.36078	47.58903	48.68773
215	24.51943	31.74757	35.97576	38.97571	41.30265	43.2039	44.81138	46.20385	47.43209	48.53079
216	24.36322	31.59136	35.81955	38.8195	41.14644	43.04769	44.65517	46.04764	47.27588	48.37458
217	24.20773	31.43587	35.66406	38.66401	40.99095	42.8922	44.49968	45.89215	47.12039	48.21909
218	24.05296	31.2811	35.50929	38.50924	40.83618	42.73743	44.34491	45.73738	46.96562	48.06432
219	23.8989	31.12704	35.35523	38.35517	40.68212	42.58336	44.19085	45.58331	46.81155	47.91025
220	23.74553	30.97367	35.20186	38.20181	40.52875	42.43	44.03749	45.42995	46.65819	47.75689
221	23.59287	30.82101	35.0492	38.04915	40.37609	42.27734	43.88482	45.27728	46.50553	47.60422
222	23.44089	30.66903	34.89722	37.89717	40.22411	42.12536	43.73284	45.12531	46.35355	47.45225
223	23.2896	30.51773	34.74592	37.74587	40.07281	41.97406	43.58155	44.97401	46.20225	47.30095
224	23.13898	30.36712	34.59531	37.59526	39.9222	41.82345	43.43093	44.82339	46.05164	47.15033

225	22.98903	30.21717	34.44536	37.44531	39.77225	41.6735	43.28098	44.67345	45.90169	47.00039
226	22.83975	30.06789	34.29608	37.29603	39.62297	41.52422	43.1317	44.52417	45.75241	46.85111
227	22.69113	29.91926	34.14746	37.1474	39.47434	41.37559	42.98308	44.37554	45.60378	46.70248
228	22.54316	29.7713	33.99949	36.99943	39.32638	41.22762	42.83511	44.22757	45.45581	46.55451
229	22.39583	29.62397	33.85216	36.85211	39.17905	41.0803	42.68779	44.08025	45.30849	46.40719
230	22.24915	29.47729	33.70548	36.70543	39.03237	40.93362	42.54111	43.93357	45.16181	46.26051
231	22.10311	29.33125	33.55944	36.55939	38.88633	40.78758	42.39506	43.78753	45.01577	46.11447
232	21.9577	29.18584	33.41403	36.41398	38.74092	40.64217	42.24965	43.64211	44.87036	45.96906
233	21.81291	29.04105	33.26924	36.26919	38.59613	40.49738	42.10486	43.49733	44.72557	45.82427
234	21.66874	28.89688	33.12507	36.12502	38.45196	40.35321	41.96069	43.35316	44.5814	45.6801
235	21.52519	28.75333	32.98152	35.98147	38.30841	40.20966	41.81714	43.20961	44.43785	45.53655
236	21.38225	28.61039	32.83858	35.83853	38.16547	40.06672	41.6742	43.06666	44.29491	45.39361
237	21.23991	28.46805	32.69624	35.69619	38.02313	39.92438	41.53186	42.92433	44.15257	45.25127
238	21.09817	28.32631	32.5545	35.55445	37.88139	39.78264	41.39012	42.78259	44.01083	45.10953
239	20.95703	28.18516	32.41335	35.4133	37.74024	39.64149	41.24898	42.64144	43.86968	44.96838
240	20.81647	28.04461	32.2728	35.27275	37.59969	39.50094	41.10842	42.50089	43.72913	44.82783
241	20.6765	27.90464	32.13283	35.13278	37.45972	39.36097	40.96845	42.36092	43.58916	44.68786
242	20.53711	27.76525	31.99344	34.99339	37.32033	39.22158	40.82906	42.22152	43.44977	44.54847
243	20.39829	27.62643	31.85462	34.85457	37.18151	39.08276	40.69024	42.08271	43.31095	44.40965
244	20.26004	27.48818	31.71637	34.71632	37.04326	38.94451	40.552	41.94446	43.1727	44.2714
245	20.12236	27.3505	31.57869	34.57864	36.90558	38.80683	40.41431	41.80678	43.03502	44.13372
246	19.98524	27.21338	31.44157	34.44152	36.76846	38.66971	40.27719	41.66966	42.8979	43.9966
247	19.84868	27.07682	31.30501	34.30496	36.6319	38.53315	40.14063	41.5331	42.76134	43.86004
248	19.71267	26.94081	31.169	34.16894	36.49589	38.39713	40.00462	41.39708	42.62532	43.72402
249	19.5772	26.80534	31.03353	34.03348	36.36042	38.26167	39.86915	41.26162	42.48986	43.58856
250	19.44228	26.67042	30.89861	33.89856	36.2255	38.12675	39.73423	41.1267	42.35494	43.45364
251	19.3079	26.53604	30.76423	33.76417	36.09111	37.99236	39.59985	40.99231	42.22055	43.31925
252	19.17405	26.40219	30.63038	33.63032	35.95727	37.85851	39.466	40.85846	42.08671	43.1854
253	19.04073	26.26887	30.49706	33.49701	35.82395	37.7252	39.33268	40.72514	41.95339	43.05209
254	18.90794	26.13607	30.36426	33.36421	35.69115	37.5924	39.19989	40.59235	41.82059	42.91929
255	18.77566	26.0038	30.23199	33.23194	35.55888	37.46013	39.06761	40.46008	41.68832	42.78702
256	18.64391	25.87205	30.10024	33.10019	35.42713	37.32838	38.93586	40.32833	41.55657	42.65527
257	18.51267	25.74081	29.969	32.96895	35.29589	37.19714	38.80462	40.19709	41.42533	42.52403
258	18.38194	25.61008	29.83827	32.83822	35.16516	37.06641	38.67389	40.06636	41.2946	42.3933
259	18.25172	25.47985	29.70804	32.70799	35.03493	36.93618	38.54367	39.93613	41.16437	42.26307
260	18.12199	25.35013	29.57832	32.57827	34.90521	36.80646	38.41394	39.80641	41.03465	42.13335
261	17.99277	25.22091	29.4491	32.44905	34.77599	36.67724	38.28472	39.67718	40.90543	42.00413
262	17.86404	25.09218	29.32037	32.32032	34.64726	36.54851	38.15599	39.54845	40.7767	41.87539
263	17.7358	24.96394	29.19213	32.19207	34.51902	36.42027	38.02775	39.42021	40.64846	41.74715
264	17.60804	24.83618	29.06437	32.06432	34.39126	36.29251	37.89999	39.29246	40.5207	41.6194
265	17.48077	24.70891	28.9371	31.93705	34.26399	36.16524	37.77272	39.16519	40.39343	41.49213
266	17.35398	24.58212	28.81031	31.81026	34.1372	36.03845	37.64593	39.0384	40.26664	41.36534
267	17.22767	24.45581	28.684	31.68394	34.01089	35.91213	37.51962	38.91208	40.14032	41.23902
268	17.10182	24.32996	28.55815	31.5581	33.88504	35.78629	37.39377	38.78624	40.01448	41.11318
269	16.97645	24.20459	28.43278	31.43273	33.75967	35.66092	37.2684	38.66087	39.88911	40.98781
270	16.85154	24.07968	28.30787	31.30782	33.63476	35.53601	37.14349	38.53596	39.7642	40.8629
271	16.72709	23.95523	28.18342	31.18337	33.51031	35.41156	37.01904	38.41151	39.63975	40.73845
272	16.6031	23.83124	28.05943	31.05938	33.38632	35.28757	36.89505	38.28752	39.51576	40.61446
273	16.47957	23.70771	27.9359	30.93585	33.26279	35.16404	36.77152	38.16399	39.39223	40.49093
274	16.35649	23.58463	27.81282	30.81276	33.13971	35.04095	36.64844	38.0409	39.26914	40.36784
275	16.23385	23.46199	27.69018	30.69013	33.01707	34.91832	36.5258	37.91827	39.14651	40.24521
276	16.11166	23.3398	27.56799	30.56794	32.89488	34.79613	36.40362	37.79608	39.02432	40.12302
277	15.98992	23.21806	27.44625	30.44619	32.77314	34.67438	36.28187	37.67433	38.90258	40.00127
278	15.86861	23.09675	27.32494	30.32489	32.65183	34.55308	36.16056	37.55303	38.78127	39.87997
279	15.74774	22.97588	27.20407	30.20401	32.53095	34.4322	36.03969	37.43215	38.66039	39.75909
280	15.6273	22.85543	27.08363	30.08357	32.41051	34.31176	35.91925	37.31171	38.53995	39.63865
281	15.50729	22.73542	26.96361	29.96356	32.2905	34.19175	35.79924	37.1917	38.41994	39.51864
282	15.3877	22.61584	26.84403	29.84398	32.17092	34.07217	35.67965	37.07212	38.30036	39.39906
283	15.26854	22.49668	26.72487	29.72482	32.05176	33.95301	35.56049	36.95296	38.1812	39.2799
284	15.1498	22.37794	26.60613	29.60608	31.93302	33.83427	35.44175	36.83422	38.06246	39.16116
285	15.03148	22.25961	26.4878	29.48775	31.81469	33.71594	35.32343	36.71589	37.94413	39.04283
286	14.91357	22.14171	26.3699	29.36984	31.69678	33.59803	35.20552	36.59798	37.82622	38.92492
287	14.79607	22.02421	26.2524	29.25235	31.57929	33.48054	35.08802	36.48049	37.70873	38.80743
288	14.67898	21.90712	26.13531	29.13526	31.4622	33.36345	34.97093	36.3634	37.59164	38.69034
289	14.5623	21.79044	26.01863	29.01857	31.34552	33.24676	34.85425	36.24671	37.47495	38.57365
290	14.44602	21.67416	25.90235	28.90229	31.22924	33.13048	34.73797	36.13043	37.35867	38.45737
291	14.33014	21.55828	25.78647	28.78642	31.11336	33.01461	34.62209	36.01455	37.2428	38.34149
292	14.21466	21.44279	25.67098	28.67093	30.99787	32.89912	34.50661	35.89907	37.12731	38.22601
293	14.09957	21.32771	25.5559	28.55585	30.88279	32.78404	34.39152	35.78398	37.01223	38.11093
294	13.98487	21.21301	25.4412	28.44115	30.76809	32.66934	34.27682	35.66929	36.89753	37.99623
295	13.87057	21.09871	25.3269	28.32684	30.65379	32.55503	34.16252	35.55498	36.78323	37.88192
296	13.75665	20.98479	25.21298	28.21293	30.53987	32.44112	34.0486	35.44106	36.66931	37.76801
297	13.64311	20.87125	25.09944	28.09939	30.42633	32.32758	33.93506	35.32753	36.55577	37.65447
298	13.52996	20.7581	24.98629	27.98624	30.31318	32.21443	33.82191	35.21438	36.44262	37.54132
299	13.41719	20.64533	24.87352	27.87346	30.20041	32.10165	33.70914	35.1016	36.32984	37.42854

55	60	65	70	75	80	85	90	95	100
58.43503	59.34238	60.17707	60.94987	61.66932	62.34233	62.97452	63.57057	64.13439	64.66927
58.23163	59.13898	59.97367	60.74646	61.46592	62.13893	62.77112	63.36717	63.93098	64.46587
58.02944	58.9368	59.77148	60.54428	61.26374	61.93675	62.56894	63.16499	63.7288	64.26369
57.82847	58.73583	59.57051	60.34331	61.06277	61.73577	62.36797	62.96402	63.52783	64.06272
57.62869	58.53604	59.37073	60.14353	60.86299	61.53599	62.16819	62.76423	63.32805	63.86293
57.43009	58.33744	59.17213	59.94493	60.66438	61.33739	61.96958	62.56563	63.12945	63.66433
57.23265	58.14	58.97469	59.74749	60.46695	61.13995	61.77215	62.36819	62.93201	63.46689
57.03636	57.94372	58.7784	59.5512	60.27066	60.94367	61.57586	62.17191	62.73572	63.27061
56.84122	57.74857	58.58326	59.35605	60.07551	60.74852	61.38071	61.97676	62.54057	63.07546
56.64719	57.55455	58.38923	59.16203	59.88149	60.5545	61.18669	61.78274	62.34655	62.88144
56.45428	57.36163	58.19632	58.96912	59.68858	60.36158	60.99378	61.58983	62.15364	62.68852
56.26247	57.16982	58.00451	58.77731	59.49676	60.16977	60.80196	61.39801	61.96183	62.49671
56.07174	56.9791	57.81378	58.58658	59.30604	59.97905	60.61124	61.20729	61.7711	62.30599
55.88209	56.78945	57.62413	58.39693	59.11639	59.78939	60.42159	61.01764	61.58145	62.11634
55.6935	56.60086	57.43554	58.20834	58.9278	59.60081	60.233	60.82905	61.39286	61.92775
55.50596	56.41332	57.248	58.0208	58.74026	59.41327	60.04546	60.64151	61.20532	61.74021
55.31946	56.22682	57.0615	57.8343	58.55376	59.22677	59.85896	60.45501	61.01882	61.55371
55.13399	56.04135	56.87603	57.64883	58.36829	59.0413	59.67349	60.26954	60.83335	61.36824
54.94954	55.85689	56.69158	57.46438	58.18383	58.85684	59.48903	60.08508	60.6489	61.18378
54.76609	55.67344	56.50813	57.28093	58.00038	58.67339	59.30558	59.90163	60.46545	61.00033
54.58363	55.49099	56.32567	57.09847	57.81793	58.49094	59.12313	59.71918	60.28299	60.81788
54.40216	55.30951	56.1442	56.917	57.63646	58.30946	58.94166	59.5377	60.10152	60.6364
54.22166	55.12902	55.9637	56.7365	57.45596	58.12896	58.76116	59.35721	59.92102	60.45591
54.04212	54.94948	55.78416	56.55696	57.27642	57.94943	58.58162	59.17767	59.74148	60.27637
53.86354	54.7709	55.60558	56.37838	57.09784	57.77084	58.40304	58.99909	59.5629	60.09778
53.6859	54.59325	55.42794	56.20074	56.92019	57.5932	58.2254	58.82144	59.38526	59.92014
53.50919	54.41654	55.25123	56.02403	56.74349	57.41649	58.04869	58.64473	59.20855	59.74343
53.3334	54.24076	55.07544	55.84824	56.5677	57.24071	57.8729	58.46895	59.03276	59.56765
53.15853	54.06589	54.90057	55.67337	56.39283	57.06583	57.69803	58.29408	58.85789	59.39277
52.98456	53.89192	54.7266	55.4994	56.21886	56.89186	57.52406	58.12011	58.68392	59.21881
52.81149	53.71884	54.55353	55.32632	56.04578	56.71879	57.35098	57.94703	58.51084	59.04573
52.6393	53.54665	54.38134	55.15413	55.87359	56.5466	57.17879	57.77484	58.33865	58.87354
52.46798	53.37534	54.21002	54.98282	55.70228	56.37529	57.00748	57.60353	58.16734	58.70223
52.29754	53.20489	54.03958	54.81238	55.53183	56.20484	56.83703	57.43308	57.9969	58.53178
52.12795	53.0353	53.86999	54.64279	55.36225	56.03525	56.66745	57.26349	57.82731	58.36219
51.95921	52.86657	53.70125	54.47405	55.19351	55.86652	56.49871	57.09476	57.65857	58.19346
51.79132	52.69867	53.53336	54.30616	55.02561	55.69862	56.33081	56.92686	57.49068	58.02556
51.62425	52.53161	53.36629	54.13909	54.85855	55.53156	56.16375	56.7598	57.32361	57.8585
51.45802	52.36537	53.20006	53.97286	54.69231	55.36532	55.99751	56.59356	57.15738	57.69226
51.2926	52.19995	53.03464	53.80744	54.52689	55.1999	55.83209	56.42814	56.99195	57.52684
51.12799	52.03534	52.87003	53.64282	54.36228	55.03529	55.66748	56.26353	56.82734	57.36223
50.96417	51.87153	52.70621	53.47901	54.19847	54.87148	55.50367	56.09972	56.66353	57.19842
50.80116	51.70851	52.5432	53.316	54.03545	54.70846	55.34065	55.9367	56.50052	57.0354
50.63893	51.54628	52.38097	53.15376	53.87322	54.54623	55.17842	55.77447	56.33828	56.87317
50.47747	51.38483	52.21951	52.99231	53.71177	54.38478	55.01697	55.61302	56.17683	56.71172
50.31679	51.22414	52.05883	52.83163	53.55109	54.22409	54.85629	55.45233	56.01615	56.55103
50.15687	51.06422	51.89891	52.67171	53.39117	54.06417	54.69637	55.29241	55.85623	56.39111
49.99771	50.90506	51.73975	52.51254	53.232	53.90501	54.5372	55.13325	55.69706	56.23195
49.83929	50.74665	51.58133	52.35413	53.07359	53.7466	54.37879	54.97484	55.53865	56.07354
49.68162	50.58897	51.42366	52.19646	52.91592	53.58892	54.22112	54.81716	55.38098	55.91586
49.52468	50.43204	51.26672	52.03952	52.75898	53.43199	54.06418	54.66023	55.22404	55.75893
49.36847	50.27583	51.11051	51.88331	52.60277	53.27578	53.90797	54.50402	55.06783	55.60272
49.21299	50.12034	50.95503	51.72782	52.44728	53.12029	53.75248	54.34853	54.91234	55.44723
49.05821	49.96557	50.80025	51.57305	52.29251	52.96552	53.59771	54.19376	54.75757	55.29246
48.90415	49.8115	50.64619	51.41899	52.13844	52.81145	53.44365	54.03969	54.60351	55.13839
48.75079	49.65814	50.49283	51.26562	51.98508	52.65809	53.29028	53.88633	54.45014	54.98503
48.59812	49.50547	50.34016	51.11296	51.83242	52.50542	53.13762	53.73366	54.29748	54.83236
48.44614	49.3535	50.18818	50.96098	51.68044	52.35345	52.98564	53.58169	54.1455	54.68039
48.29485	49.2022	50.03689	50.80969	51.52914	52.20215	52.83434	53.43039	53.9942	54.52909
48.14423	49.05158	49.88627	50.65907	51.37853	52.05153	52.68373	53.27977	53.84359	54.37847

47.99428	48.90164	49.73632	50.50912	51.22858	51.90159	52.53378	53.12983	53.69364	54.22853
47.845	48.75236	49.58704	50.35984	51.0793	51.7523	52.3845	52.98055	53.54436	54.07925
47.69638	48.60373	49.43842	50.21122	50.93067	51.60368	52.23587	52.83192	53.39574	53.93062
47.54841	48.45576	49.29045	50.06325	50.7827	51.45571	52.08791	52.68395	53.24777	53.78265
47.40109	48.30844	49.14313	49.91592	50.63538	51.30839	51.94058	52.53663	53.10044	53.63533
47.25441	48.16176	48.99645	49.76924	50.4887	51.16171	51.7939	52.38995	52.95376	53.48865
47.10836	48.01572	48.8504	49.6232	50.34266	51.01567	51.64786	52.24391	52.80772	53.34261
46.96295	47.8703	48.70499	49.47779	50.19725	50.87025	51.50245	52.0985	52.66231	53.19719
46.81816	47.72552	48.5602	49.333	50.05246	50.72547	51.35766	51.95371	52.51752	53.05241
46.674	47.58135	48.41604	49.18883	49.90829	50.5813	51.21349	51.80954	52.37335	52.90824
46.53044	47.4378	48.27248	49.04528	49.76474	50.43775	51.06994	51.66599	52.2298	52.76469
46.3875	47.29486	48.12954	48.90234	49.6218	50.2948	50.927	51.52305	52.08686	52.62174
46.24516	47.15252	47.9872	48.76	49.47946	50.15247	50.78466	51.38071	51.94452	52.47941
46.10342	47.01078	47.84546	48.61826	49.33772	50.01073	50.64292	51.23897	51.80278	52.33767
45.96228	46.86963	47.70432	48.47712	49.19657	49.86958	50.50177	51.09782	51.66164	52.19652
45.82172	46.72908	47.56376	48.33656	49.05602	49.72903	50.36122	50.95727	51.52108	52.05597
45.68175	46.58911	47.42379	48.19659	48.91605	49.58905	50.22125	50.8173	51.38111	51.916
45.54236	46.44971	47.2844	48.0572	48.77666	49.44966	50.08186	50.6779	51.24172	51.7766
45.40354	46.3109	47.14558	47.91838	48.63784	49.31085	49.94304	50.53909	51.1029	51.63779
45.2653	46.17265	47.00734	47.78013	48.49959	49.1726	49.80479	50.40084	50.96465	51.49954
45.12762	46.03497	46.86966	47.64245	48.36191	49.03492	49.66711	50.26316	50.82697	51.36186
44.99049	45.89785	46.73253	47.50533	48.22479	48.8978	49.52999	50.12604	50.68985	51.22474
44.85393	45.76129	46.59597	47.36877	48.08823	48.76123	49.39343	49.98948	50.55329	51.08818
44.71792	45.62527	46.45996	47.23276	47.95221	48.62522	49.25742	49.85346	50.41728	50.95216
44.58245	45.48981	46.32449	47.09729	47.81675	48.48976	49.12195	49.718	50.28181	50.8167
44.44753	45.35489	46.18957	46.96237	47.68183	48.35483	48.98703	49.58308	50.14689	50.68178
44.31315	45.2205	46.05519	46.82799	47.54744	48.22045	48.85265	49.44869	50.01251	50.54739
44.1793	45.08665	45.92134	46.69414	47.41359	48.0866	48.7188	49.31484	49.87866	50.41354
44.04598	44.95333	45.78802	46.56082	47.28028	47.95328	48.58548	49.18152	49.74534	50.28022
43.91319	44.82054	45.65523	46.42802	47.14748	47.82049	48.45268	49.04873	49.61254	50.14743
43.78092	44.68827	45.52296	46.29575	47.01521	47.68822	48.32041	48.91646	49.48027	50.01516
43.64916	44.55652	45.3912	46.164	46.88346	47.55647	48.18866	48.78471	49.34852	49.88341
43.51792	44.42528	45.25996	46.03276	46.75222	47.42523	48.05742	48.65347	49.21728	49.75217
43.38719	44.29455	45.12923	45.90203	46.62149	47.2945	47.92669	48.52274	49.08655	49.62144
43.25697	44.16432	44.99901	45.77181	46.49126	47.16427	47.79646	48.39251	48.95633	49.49121
43.12724	44.0346	44.86928	45.64208	46.36154	47.03455	47.66674	48.26279	48.8266	49.36149
42.99802	43.90537	44.74006	45.51286	46.23232	46.90532	47.53752	48.13356	48.69738	49.23226
42.86929	43.77664	44.61133	45.38413	46.10359	46.77659	47.40879	48.00483	48.56865	49.10353
42.74105	43.6484	44.48309	45.25589	45.97534	46.64835	47.28055	47.87659	48.44041	48.97529
42.6133	43.52065	44.35534	45.12813	45.84759	46.5206	47.15279	47.74884	48.31265	48.84754
42.48603	43.39338	44.22807	45.00086	45.72032	46.39333	47.02552	47.62157	48.18538	48.72027
42.35923	43.26659	44.10127	44.87407	45.59353	46.26654	46.89873	47.49478	48.05859	48.59348
42.23292	43.14027	43.97496	44.74776	45.46721	46.14022	46.77242	47.36846	47.93228	48.46716
42.10708	43.01443	43.84912	44.62191	45.34137	46.01438	46.64657	47.24262	47.80643	48.34132
41.9817	42.88906	43.72374	44.49654	45.216	45.889	46.5212	47.11725	47.68106	48.21595
41.85679	42.76415	43.59883	44.37163	45.09109	45.7641	46.39629	46.99234	47.55615	48.09104
41.73234	42.6397	43.47438	44.24718	44.96664	45.63965	46.27184	46.86789	47.4317	47.96659
41.60836	42.51571	43.3504	44.12319	44.84265	45.51566	46.14785	46.7439	47.30771	47.8426
41.48482	42.39218	43.22686	43.99966	44.71912	45.39212	46.02432	46.62037	47.18418	47.71907
41.36174	42.26909	43.10378	43.87658	44.59603	45.26904	45.90124	46.49728	47.0611	47.59598
41.2391	42.14646	42.98114	43.75394	44.4734	45.14641	45.7786	46.37465	46.93846	47.47335
41.11692	42.02427	42.85896	43.63175	44.35121	45.02422	45.65641	46.25246	46.81627	47.35116
40.99517	41.90252	42.73721	43.51001	44.22946	44.90247	45.53467	46.13071	46.69453	47.22941
40.87386	41.78122	42.6159	43.3887	44.10816	44.78116	45.41336	46.00941	46.57322	47.10811
40.75299	41.66034	42.49503	43.26783	43.98728	44.66029	45.29249	45.88853	46.45235	46.98723
40.63255	41.5399	42.37459	43.14739	43.86684	44.53985	45.17204	45.76809	46.33191	46.86679
40.51254	41.41989	42.25458	43.02738	43.74683	44.41984	45.05203	45.64808	46.21189	46.74678
40.39295	41.30031	42.13499	42.90779	43.62725	44.30026	44.93245	45.5285	46.09231	46.6272
40.27379	41.18115	42.01583	42.78863	43.50809	44.18109	44.81329	45.40934	45.97315	46.50804
40.15505	41.06241	41.89709	42.66989	43.38935	44.06235	44.69455	45.2906	45.85441	46.38929
40.03673	40.94408	41.77877	42.55157	43.27102	43.94403	44.57622	45.17227	45.73608	46.27097
39.91882	40.82617	41.66086	42.43366	43.15311	43.82612	44.45831	45.05436	45.61818	46.15306
39.80132	40.70868	41.54336	42.31616	43.03562	43.70862	44.34082	44.93687	45.50068	46.03556
39.68423	40.59159	41.42627	42.19907	42.91853	43.59154	44.22373	44.81978	45.38359	45.91848
39.56755	40.4749	41.30959	42.08239	42.80184	43.47485	44.10705	44.70309	45.26691	45.80179
39.45127	40.35862	41.19331	41.96611	42.68556	43.35857	43.99077	44.58681	45.15063	45.68551
39.33539	40.24274	41.07743	41.85023	42.56968	43.24269	43.87489	44.47093	45.03475	45.56963
39.21991	40.12726	40.96195	41.73475	42.4542	43.12721	43.7594	44.35545	44.91926	45.45415
39.10482	40.01217	40.84686	41.61966	42.33912	43.01212	43.64432	44.24036	44.80418	45.33906
38.99012	39.89748	40.73216	41.50496	42.22442	42.89743	43.52962	44.12567	44.68948	45.22437
38.87582	39.78317	40.61786	41.39066	42.11011	42.78312	43.41532	44.01136	44.57518	45.11006
38.7619	39.66925	40.50394	41.27674	41.9962	42.6692	43.3014	43.89744	44.46126	44.99614
38.64837	39.55572	40.39041	41.1632	41.88266	42.55567	43.18786	43.78391	44.34772	44.88261
38.53521	39.44257	40.27725	41.05005	41.76951	42.44252	43.07471	43.67076	44.23457	44.76946
38.42244	39.32979	40.16448	40.93728	41.65673	42.32974	42.96194	43.55798	44.1218	44.65668

formula: Deer_SuccessRate = 188.528 - (33.663*ln(length)) + (10.428*ln(width))

Length/Wi(	5	10	15	20	25	30	35	40	45	50
300	13.30479	20.53293	24.76112	27.76107	30.08801	31.98926	33.59674	34.98921	36.21745	37.31615
301	13.19277	20.4209	24.64909	27.64904	29.97598	31.87723	33.48472	34.87718	36.10542	37.20412
302	13.08111	20.30925	24.53744	27.53739	29.86433	31.76558	33.37306	34.76553	35.99377	37.09247
303	12.96983	20.19797	24.42616	27.42611	29.75305	31.6543	33.26178	34.65425	35.88249	36.98119
304	12.85892	20.08705	24.31524	27.31519	29.64213	31.54338	33.15087	34.54333	35.77157	36.87027
305	12.74836	19.9765	24.20469	27.20464	29.53158	31.43283	33.04031	34.43278	35.66102	36.75972
306	12.63817	19.86631	24.0945	27.09445	29.42139	31.32264	32.93012	34.32259	35.55083	36.64953
307	12.52834	19.75648	23.98467	26.98462	29.31156	31.21281	32.82029	34.21276	35.441	36.5397
308	12.41887	19.64701	23.8752	26.87515	29.20209	31.10334	32.71082	34.10329	35.33153	36.43023
309	12.30975	19.53789	23.76608	26.76603	29.09297	30.99422	32.6017	33.99417	35.22241	36.32111
310	12.20099	19.42912	23.65731	26.65726	28.9842	30.88545	32.49294	33.8854	35.11364	36.21234
311	12.09257	19.32071	23.5489	26.54885	28.87579	30.77704	32.38452	33.77699	35.00523	36.10393
312	11.9845	19.21264	23.44083	26.44078	28.76772	30.66897	32.27645	33.66892	34.89716	35.99586
313	11.87678	19.10492	23.33311	26.33306	28.66	30.56125	32.16873	33.5612	34.78944	35.88814
314	11.7694	18.99754	23.22573	26.22568	28.55262	30.45387	32.06135	33.45382	34.68206	35.78076
315	11.66237	18.8905	23.11869	26.11864	28.44558	30.34683	31.95432	33.34678	34.57502	35.67372
316	11.55567	18.78381	23.012	26.01195	28.33889	30.24014	31.84762	33.24008	34.46833	35.56703
317	11.44931	18.67745	22.90564	25.90559	28.23253	30.13378	31.74126	33.13372	34.36197	35.46067
318	11.34328	18.57142	22.79961	25.79956	28.1265	30.02775	31.63523	33.0277	34.25594	35.35464
319	11.23759	18.46573	22.69392	25.69387	28.02081	29.92206	31.52954	32.92201	34.15025	35.24895
320	11.13223	18.36037	22.58856	25.58851	27.91545	29.8167	31.42418	32.81665	34.04489	35.14359
321	11.0272	18.25533	22.48352	25.48347	27.81041	29.71166	31.31915	32.71161	33.93985	35.03855
322	10.92249	18.15063	22.37882	25.37877	27.70571	29.60696	31.21444	32.60691	33.83515	34.93385
323	10.81811	18.04625	22.27444	25.27439	27.60133	29.50258	31.11006	32.50252	33.73077	34.82947
324	10.71405	17.94219	22.17038	25.17033	27.49727	29.39852	31.006	32.39847	33.62671	34.72541
325	10.61031	17.83845	22.06664	25.06659	27.39353	29.29478	30.90226	32.29473	33.52297	34.62167
326	10.50689	17.73503	21.96322	24.96317	27.29011	29.19136	30.79884	32.19131	33.41955	34.51825
327	10.40379	17.63193	21.86012	24.86007	27.18701	29.08826	30.69574	32.08821	33.31645	34.41515
328	10.301	17.52914	21.75733	24.75728	27.08422	28.98547	30.59295	31.98542	33.21366	34.31236
329	10.19853	17.42667	21.65486	24.6548	26.98175	28.88299	30.49048	31.88294	33.11118	34.20988
330	10.09636	17.3245	21.55269	24.55264	26.87958	28.78083	30.38831	31.78078	33.00902	34.10772
331	9.994508	17.22265	21.45084	24.45079	26.77773	28.67898	30.28646	31.67892	32.90717	34.00587
332	9.89296	17.1211	21.34929	24.34924	26.67618	28.57743	30.18491	31.57738	32.80562	33.90432
333	9.791718	17.01986	21.24805	24.248	26.57494	28.47619	30.08367	31.47613	32.70438	33.80308
334	9.690779	16.91892	21.14711	24.14706	26.474	28.37525	29.98273	31.3752	32.60344	33.70214
335	9.590142	16.81828	21.04647	24.04642	26.37336	28.27461	29.88209	31.27456	32.5028	33.6015
336	9.489806	16.71794	20.94613	23.94608	26.27302	28.17427	29.78176	31.17422	32.40246	33.50116
337	9.389767	16.61791	20.8461	23.84604	26.17299	28.07423	29.68172	31.07418	32.30242	33.40112
338	9.290025	16.51816	20.74635	23.7463	26.07324	27.97449	29.58198	30.97444	32.20268	33.30138
339	9.190577	16.41872	20.64691	23.64685	25.9738	27.87504	29.48253	30.87499	32.10323	33.20193
340	9.091422	16.31956	20.54775	23.5477	25.87464	27.77589	29.38337	30.77584	32.00408	33.10278
341	8.992559	16.2207	20.44889	23.44884	25.77578	27.67703	29.28451	30.67698	31.90522	33.00392
342	8.893985	16.12212	20.35031	23.35026	25.6772	27.57845	29.18594	30.5784	31.80664	32.90534
343	8.795699	16.02384	20.25203	23.25198	25.57892	27.48017	29.08765	30.48011	31.70836	32.80706
344	8.697698	15.92584	20.15403	23.15398	25.48092	27.38217	28.98965	30.38211	31.61036	32.70906
345	8.599983	15.82812	20.05631	23.05626	25.3832	27.28445	28.89193	30.2844	31.51264	32.61134
346	8.50255	15.73069	19.95888	22.95883	25.28577	27.18702	28.7945	30.18697	31.41521	32.51391
347	8.405398	15.63354	19.86173	22.86168	25.18862	27.08987	28.69735	30.08981	31.31806	32.41676
348	8.308526	15.53667	19.76486	22.7648	25.09175	26.99299	28.60048	29.99294	31.22118	32.31988
349	8.211932	15.44007	19.66826	22.66821	24.99515	26.8964	28.50388	29.89635	31.12459	32.22329
350	8.115615	15.34375	19.57194	22.57189	24.89883	26.80008	28.40757	29.80003	31.02827	32.12697
351	8.019572	15.24771	19.4759	22.47585	24.80279	26.70404	28.31152	29.70399	30.93223	32.03093
352	7.923802	15.15194	19.38013	22.38008	24.70702	26.60827	28.21575	29.60822	30.83646	31.93516
353	7.828304	15.05644	19.28463	22.28458	24.61152	26.51277	28.12026	29.51272	30.74096	31.83966
354	7.733077	14.96122	19.18941	22.18935	24.5163	26.41754	28.02503	29.41749	30.64573	31.74443
355	7.638117	14.86626	19.09445	22.0944	24.42134	26.32259	27.93007	29.32253	30.55078	31.64947
356	7.543425	14.77156	18.99975	21.9997	24.32664	26.22789	27.83538	29.22784	30.45608	31.55478
357	7.448999	14.67714	18.90533	21.90528	24.23222	26.13347	27.74095	29.13342	30.36166	31.46036
358	7.354837	14.58298	18.81117	21.81111	24.13806	26.0393	27.64679	29.03925	30.26749	31.36619
359	7.260937	14.48908	18.71727	21.71721	24.04416	25.9454	27.55289	28.94535	30.17359	31.27229

360	7.167299	14.39544	18.62363	21.62358	23.95052	25.85177	27.45925	28.85171	30.07996	31.17866
361	7.07392	14.30206	18.53025	21.5302	23.85714	25.75839	27.36587	28.75834	29.98658	31.08528
362	6.980799	14.20894	18.43713	21.43708	23.76402	25.66527	27.27275	28.66522	29.89346	30.99216
363	6.887936	14.11607	18.34426	21.34421	23.67115	25.5724	27.17989	28.57235	29.80059	30.89929
364	6.795328	14.02347	18.25166	21.25161	23.57855	25.4798	27.08728	28.47974	29.70799	30.80669
365	6.702974	13.93111	18.1593	21.15925	23.48619	25.38744	26.99492	28.38739	29.61563	30.71433
366	6.610873	13.83901	18.0672	21.06715	23.39409	25.29534	26.90282	28.29529	29.52353	30.62223
367	6.519023	13.74716	17.97535	20.9753	23.30224	25.20349	26.81097	28.20344	29.43168	30.53038
368	6.427423	13.65556	17.88375	20.8837	23.21064	25.11189	26.71937	28.11184	29.34008	30.43878
369	6.336071	13.56421	17.7924	20.79235	23.11929	25.02054	26.62802	28.02049	29.24873	30.34743
370	6.244967	13.47311	17.7013	20.70124	23.02819	24.92943	26.53692	27.92938	29.15762	30.25632
371	6.154109	13.38225	17.61044	20.61039	22.93733	24.83858	26.44606	27.83852	29.06677	30.16547
372	6.063495	13.29163	17.51982	20.51977	22.84671	24.74796	26.35545	27.74791	28.97615	30.07485
373	5.973124	13.20126	17.42945	20.4294	22.75634	24.65759	26.26508	27.65754	28.88578	29.98448
374	5.882996	13.11113	17.33932	20.33927	22.66621	24.56746	26.17495	27.56741	28.79565	29.89435
375	5.793108	13.02125	17.24944	20.24939	22.57633	24.47758	26.08506	27.47752	28.70577	29.80447
376	5.703459	12.9316	17.15979	20.15974	22.48668	24.38793	25.99541	27.38788	28.61612	29.71482
377	5.614049	12.84219	17.07038	20.07033	22.39727	24.29852	25.906	27.29847	28.52671	29.62541
378	5.524875	12.75301	16.9812	19.98115	22.30809	24.20934	25.81683	27.20929	28.43753	29.53623
379	5.435937	12.66408	16.89227	19.89221	22.21916	24.12041	25.72789	27.12035	28.3486	29.44729
380	5.347234	12.57537	16.80356	19.80351	22.13045	24.0317	25.63918	27.03165	28.25989	29.35859
381	5.258763	12.4869	16.71509	19.71504	22.04198	23.94323	25.55071	26.94318	28.17142	29.27012
382	5.170525	12.39866	16.62685	19.6268	21.95374	23.85499	25.46248	26.85494	28.08318	29.18188
383	5.082517	12.31066	16.53885	19.53879	21.86574	23.76698	25.37447	26.76693	27.99517	29.09387
384	4.994738	12.22288	16.45107	19.45102	21.77796	23.67921	25.28669	26.67915	27.9074	29.0061
385	4.907188	12.13533	16.36352	19.36347	21.69041	23.59166	25.19914	26.5916	27.81985	28.91855
386	4.819865	12.048	16.27619	19.27614	21.60308	23.50433	25.11182	26.50428	27.73252	28.83122
387	4.732768	11.96091	16.1891	19.18905	21.51599	23.41724	25.02472	26.41718	27.64543	28.74413
388	4.645896	11.87403	16.10222	19.10217	21.42911	23.33036	24.93785	26.33031	27.55855	28.65725
389	4.559247	11.78739	16.01558	19.01552	21.34247	23.24371	24.8512	26.24366	27.4719	28.5706
390	4.472821	11.70096	15.92915	18.9291	21.25604	23.15729	24.76477	26.15724	27.38548	28.48418
391	4.386616	11.61475	15.84294	18.84289	21.16983	23.07108	24.67857	26.07103	27.29927	28.39797
392	4.300631	11.52877	15.75696	18.75691	21.08385	22.9851	24.59258	25.98505	27.21329	28.31199
393	4.214866	11.443	15.67119	18.67114	20.99808	22.89933	24.50682	25.89928	27.12752	28.22622
394	4.129318	11.35746	15.58565	18.5856	20.91254	22.81379	24.42127	25.81373	27.04198	28.14068
395	4.043987	11.27213	15.50032	18.50026	20.82721	22.72845	24.33594	25.7284	26.95664	28.05534
396	3.958872	11.18701	15.4152	18.41515	20.74209	22.64334	24.25082	25.64329	26.87153	27.97023
397	3.873972	11.10211	15.3303	18.33025	20.65719	22.55844	24.16592	25.55839	26.78663	27.88533
398	3.789285	11.01742	15.24561	18.24556	20.5725	22.47375	24.08124	25.4737	26.70194	27.80064
399	3.70481	10.93295	15.16114	18.16109	20.48803	22.38928	23.99676	25.38923	26.61747	27.71617
400	3.620548	10.84869	15.07688	18.07683	20.40377	22.30502	23.9125	25.30496	26.53321	27.6319

55	60	65	70	75	80	85	90	95	100
38.31004	39.2174	40.05208	40.82488	41.54434	42.21734	42.84954	43.44559	44.0094	44.54429
38.19802	39.10537	39.94006	40.71286	41.43231	42.10532	42.73751	43.33356	43.89738	44.43226
38.08637	38.99372	39.82841	40.6012	41.32066	41.99367	42.62586	43.22191	43.78572	44.32061
37.97508	38.88244	39.71712	40.48992	41.20938	41.88239	42.51458	43.11063	43.67444	44.20933
37.86417	38.77152	39.60621	40.379	41.09846	41.77147	42.40366	42.99971	43.56352	44.09841
37.75362	38.66097	39.49566	40.26845	40.98791	41.66092	42.29311	42.88916	43.45297	43.98786
37.64343	38.55078	39.38547	40.15826	40.87772	41.55073	42.18292	42.77897	43.34278	43.87767
37.53359	38.44095	39.27563	40.04843	40.76789	41.4409	42.07309	42.66914	43.23295	43.76784
37.42412	38.33148	39.16616	39.93896	40.65842	41.33142	41.96362	42.55967	43.12348	43.65837
37.315	38.22236	39.05704	39.82984	40.5493	41.22231	41.8545	42.45055	43.01436	43.54925
37.20624	38.11359	38.94828	39.72108	40.44053	41.11354	41.74573	42.34178	42.90559	43.44048
37.09782	38.00518	38.83986	39.61266	40.33212	41.00512	41.63732	42.23337	42.79718	43.33207
36.98975	37.89711	38.73179	39.50459	40.22405	40.89706	41.52925	42.1253	42.68911	43.224
36.88203	37.78939	38.62407	39.39687	40.11633	40.78934	41.42153	42.01758	42.58139	43.11628
36.77465	37.68201	38.51669	39.28949	40.00895	40.68196	41.31415	41.9102	42.47401	43.0089
36.66762	37.57497	38.40966	39.18246	39.90191	40.57492	41.20711	41.80316	42.36698	42.90186
36.56092	37.46827	38.30296	39.07576	39.79522	40.46822	41.10042	41.69647	42.26028	42.79516
36.45456	37.36191	38.1966	38.9694	39.68886	40.36186	40.99406	41.5901	42.15392	42.6888
36.34853	37.25589	38.09057	38.86337	39.58283	40.25584	40.88803	41.48408	42.04789	42.58278
36.24284	37.1502	37.98488	38.75768	39.47714	40.15015	40.78234	41.37839	41.9422	42.47709
36.13748	37.04484	37.87952	38.65232	39.37178	40.04478	40.67698	41.27303	41.83684	42.37173
36.03245	36.9398	37.77449	38.54729	39.26674	39.93975	40.57194	41.16799	41.73181	42.26669
35.92774	36.8351	37.66978	38.44258	39.16204	39.83505	40.46724	41.06329	41.6271	42.16199
35.82336	36.73071	37.5654	38.3382	39.05766	39.73066	40.36286	40.95891	41.52272	42.0576
35.7193	36.62666	37.46134	38.23414	38.9536	39.6266	40.2588	40.85485	41.41866	41.95355
35.61556	36.52292	37.3576	38.1304	38.84986	39.52287	40.15506	40.75111	41.31492	41.84981
35.51214	36.4195	37.25418	38.02698	38.74644	39.41945	40.05164	40.64769	41.2115	41.74639
35.40904	36.3164	37.15108	37.92388	38.64334	39.31634	39.94854	40.54459	41.1084	41.64329
35.30625	36.21361	37.04829	37.82109	38.54055	39.21356	39.84575	40.4418	41.00561	41.5405
35.20378	36.11113	36.94582	37.71862	38.43807	39.11108	39.74328	40.33932	40.90314	41.43802
35.10161	36.00897	36.84365	37.61645	38.33591	39.00892	39.64111	40.23716	40.80097	41.33586
34.99976	35.90711	36.7418	37.5146	38.23406	38.90706	39.53926	40.1353	40.69912	41.234
34.89821	35.80557	36.64025	37.41305	38.13251	38.80552	39.43771	40.03376	40.59757	41.13246
34.79697	35.70432	36.53901	37.31181	38.03127	38.70427	39.33647	39.93251	40.49633	41.03121
34.69603	35.60339	36.43807	37.21087	37.93033	38.60333	39.23553	39.83158	40.39539	40.93028
34.59539	35.50275	36.33743	37.11023	37.82969	38.5027	39.13489	39.73094	40.29475	40.82964
34.49506	35.40241	36.2371	37.0099	37.72935	38.40236	39.03455	39.6306	40.19442	40.7293
34.39502	35.30237	36.13706	36.90986	37.62931	38.30232	38.93452	39.53056	40.09438	40.62926
34.29528	35.20263	36.03732	36.81011	37.52957	38.20258	38.83477	39.43082	39.99463	40.52952
34.19583	35.10318	35.93787	36.71067	37.43012	38.10313	38.73533	39.33137	39.89519	40.43007
34.09667	35.00403	35.83871	36.61151	37.33097	38.00398	38.63617	39.23222	39.79603	40.33092
33.99781	34.90517	35.73985	36.51265	37.23211	37.90511	38.53731	39.13336	39.69717	40.23205
33.89924	34.80659	35.64128	36.41407	37.13353	37.80654	38.43873	39.03478	39.59859	40.13348
33.80095	34.70831	35.54299	36.31579	37.03525	37.70825	38.34045	38.9365	39.50031	40.03519
33.70295	34.6103	35.44499	36.21779	36.93725	37.61025	38.24245	38.8385	39.40231	39.93719
33.60523	34.51259	35.34727	36.12007	36.83953	37.51254	38.14473	38.74078	39.30459	39.83948
33.5078	34.41516	35.24984	36.02264	36.7421	37.41511	38.0473	38.64335	39.20716	39.74205
33.41065	34.31801	35.15269	35.92549	36.64495	37.31795	37.95015	38.5462	39.11001	39.64489
33.31378	34.22113	35.05582	35.82862	36.54807	37.22108	37.85328	38.44932	39.01314	39.54802
33.21718	34.12454	34.95922	35.73202	36.45148	37.12449	37.75668	38.35273	38.91654	39.45143
33.12087	34.02822	34.86291	35.6357	36.35516	37.02817	37.66036	38.25641	38.82022	39.35511
33.02482	33.93218	34.76686	35.53966	36.25912	36.93213	37.56432	38.16037	38.72418	39.25907
32.92905	33.83641	34.67109	35.44389	36.16335	36.83636	37.46855	38.0646	38.62841	39.1633
32.83356	33.74091	34.5756	35.34839	36.06785	36.74086	37.37305	37.9691	38.53291	39.0678
32.73833	33.64568	34.48037	35.25317	35.97262	36.64563	37.27783	37.87387	38.43769	38.97257
32.64337	33.55072	34.38541	35.15821	35.87766	36.55067	37.18287	37.77891	38.34273	38.87761
32.54868	33.45603	34.29072	35.06352	35.78297	36.45598	37.08817	37.68422	38.24804	38.78292
32.45425	33.36161	34.19629	34.96909	35.68855	36.36155	36.99375	37.5898	38.15361	38.6885
32.36009	33.26744	34.10213	34.87493	35.59438	36.26739	36.89959	37.49563	38.05945	38.59433
32.26619	33.17354	34.00823	34.78103	35.50048	36.17349	36.80569	37.40173	37.96555	38.50043

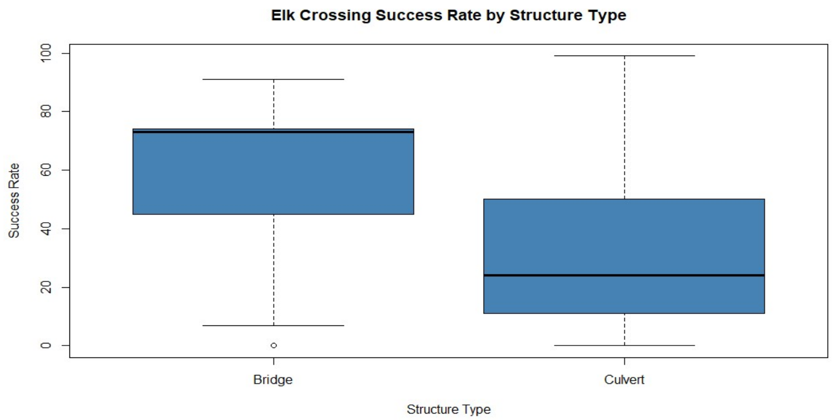
32.17255	33.07991	33.91459	34.68739	35.40685	36.07985	36.71205	37.3081	37.87191	38.40679
32.07917	32.98653	33.82121	34.59401	35.31347	35.98648	36.61867	37.21472	37.77853	38.31342
31.98605	32.89341	33.72809	34.50089	35.22035	35.89335	36.52555	37.1216	37.68541	38.2203
31.89319	32.80054	33.63523	34.40803	35.12748	35.80049	36.43268	37.02873	37.59255	38.12743
31.80058	32.70793	33.54262	34.31542	35.03488	35.70788	36.34008	36.93612	37.49994	38.03482
31.70823	32.61558	33.45027	34.22306	34.94252	35.61553	36.24772	36.84377	37.40758	37.94247
31.61612	32.52348	33.35816	34.13096	34.85042	35.52343	36.15562	36.75167	37.31548	37.85037
31.52427	32.43163	33.26631	34.03911	34.75857	35.43158	36.06377	36.65982	37.22363	37.75852
31.43267	32.34003	33.17471	33.94751	34.66697	35.33998	35.97217	36.56822	37.13203	37.66692
31.34132	32.24868	33.08336	33.85616	34.57562	35.24863	35.88082	36.47687	37.04068	37.57557
31.25022	32.15757	32.99226	33.76506	34.48451	35.15752	35.78972	36.38576	36.94958	37.48446
31.15936	32.06672	32.9014	33.6742	34.39366	35.06666	35.69886	36.29491	36.85872	37.3936
31.06875	31.9761	32.81079	33.58358	34.30304	34.97605	35.60824	36.20429	36.7681	37.30299
30.97838	31.88573	32.72042	33.49321	34.21267	34.88568	35.51787	36.11392	36.67773	37.21262
30.88825	31.7956	32.63029	33.40309	34.12254	34.79555	35.42774	36.02379	36.58761	37.12249
30.79836	31.70571	32.5404	33.3132	34.03266	34.70566	35.33786	35.9339	36.49772	37.0326
30.70871	31.61607	32.45075	33.22355	33.94301	34.61601	35.24821	35.84426	36.40807	36.94296
30.6193	31.52666	32.36134	33.13414	33.8536	34.5266	35.1588	35.75485	36.31866	36.85354
30.53013	31.43748	32.27217	33.04497	33.76442	34.43743	35.06962	35.66567	36.22948	36.76437
30.44119	31.34854	32.18323	32.95603	33.67548	34.34849	34.98069	35.57673	36.14055	36.67543
30.35249	31.25984	32.09453	32.86732	33.58678	34.25979	34.89198	35.48803	36.05184	36.58673
30.26402	31.17137	32.00606	32.77885	33.49831	34.17132	34.80351	35.39956	35.96337	36.49826
30.17578	31.08313	31.91782	32.69061	33.41007	34.08308	34.71527	35.31132	35.87513	36.41002
30.08777	30.99512	31.82981	32.60261	33.32206	33.99507	34.62727	35.22331	35.78713	36.32201
29.99999	30.90734	31.74203	32.51483	33.23429	33.90729	34.53949	35.13553	35.69935	36.23423
29.91244	30.81979	31.65448	32.42728	33.14674	33.81974	34.45194	35.04798	35.6118	36.14668
29.82512	30.73247	31.56716	32.33996	33.05941	33.73242	34.36461	34.96066	35.52447	36.05936
29.73802	30.64537	31.48006	32.25286	32.97232	33.64532	34.27752	34.87356	35.43738	35.97226
29.65115	30.5585	31.39319	32.16599	32.88544	33.55845	34.19064	34.78669	35.35051	35.88539
29.5645	30.47185	31.30654	32.07934	32.79879	33.4718	34.104	34.70004	35.26386	35.79874
29.47807	30.38543	31.22011	31.99291	32.71237	33.38538	34.01757	34.61362	35.17743	35.71232
29.39187	30.29922	31.13391	31.90671	32.62616	33.29917	33.93136	34.52741	35.09123	35.62611
29.30588	30.21324	31.04792	31.82072	32.54018	33.21319	33.84538	34.44143	35.00524	35.54013
29.22012	30.12747	30.96216	31.73496	32.45441	33.12742	33.75961	34.35566	34.91948	35.45436
29.13457	30.04192	30.87661	31.64941	32.36887	33.04187	33.67407	34.27011	34.83393	35.36881
29.04924	29.95659	30.79128	31.56408	32.28353	32.95654	33.58874	34.18478	34.7486	35.28348
28.96412	29.87148	30.70616	31.47896	32.19842	32.87143	33.50362	34.09967	34.66348	35.19837
28.87922	29.78658	30.62126	31.39406	32.11352	32.78653	33.41872	34.01477	34.57858	35.11347
28.79454	29.70189	30.53658	31.30937	32.02883	32.70184	33.33403	33.93008	34.49389	35.02878
28.71006	29.61742	30.4521	31.2249	31.94436	32.61737	33.24956	33.84561	34.40942	34.94431
28.6258	29.53315	30.36784	31.14064	31.86009	32.5331	33.1653	33.76134	34.32516	34.86004

Analyze Elk Reaction to Various Scenarios

Summary (33 Observations)

1) Elk to Structure Type: Conclusion is there IS a significant difference between structure types

StructureType	mean	sd	# of rec
1 Bridge	56.9	32.7	18
2 Culvert	32.5	32.7	15



ONE WAY ANOVA

Model Summary	Df	Sum Sq	Mean Sq	F Value	Pr(>F)	
StructureType	1	4853	4853	5.133	0.0306	less than .05, reject Hyp that all groups are equal
Residuals	31	29312	946			

Tukey HSD between structure types

Type	diff	lwr	upr	p adj
Culvert-Bridge	-24.356	-46.28	-2.43	0.0306

significant difference if p adj < .05

Elk to Culvert Size: Length appears to be a driver

Data Summary (15 culverts)

	SuccessRate	Length	Width	Height
Minimum	0.00	66.00	7.00	6.00
1st Quar	11.00	66.00	10.00	8.00
Median	24.00	188.00	24.00	12.00
Mean	32.53	192.90	24.53	11.40
3rd Quar	50.00	236.50	42.00	14.00
Maximum	99.00	558.00	42.00	15.00
Correlation (1:1)		-0.51	0.66	0.49
Significance on Individual Basis		0.00911	0.0162	0.0644

SKEWNESS & KURTOSIS (LOG, SQUARE ROOT, CUBED)

	SuccessRate	Length	Width	Height
Skew, no adj	0.929	1.346	0.205	-0.483
Kurtosis, no adj	2.473	5.014	1.447	1.7
Skew, log	na	-0.087	-0.215	-0.06
Kurtosis, log	na	1.944	1.529	2.09
Skew, sqrt	0.099	0.524	0.006	-0.588
Kurtosis, sqrt	2.204	2.971	1.453	1.858
Skew, cube	-0.606	0.289	-0.065	-0.625
Kurtosis, cube	2.844	2.52	1.468	1.468

RESULTS: Do not apply transformation to SuccessRate;

JARQUE-BERA NORMALITY TEST (per transformation above)

	SuccessRate	Length	Width	Height
JB	2.33	0.716	1.47	1.762
p-value	0.3117	0.699	0.479	0.4140
	normal	*normal*	*normal*	*normal*

LINEAR REGRESSION (LM) VARIABLE INITIAL ANALYSIS:

	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	118.34	162.56	0.728	0.481
Length	-22.49	20.41	-1.102	0.292
Width	9.2	21.46	0.429	0.676

Residential standard error	26.25	12 df
Multiple R-squared	0.4275	
Adjusted R-squared	0.3321	
F-statistic	4.481	2 and 12 df

p-value

	Length	Width	Height	
Var Inflation Factor (Multicollinearity)	4.04	4.04		***<5, low collinearity***
Importation of Variables	1.1	0.429		

ANOVA LM model

				Residuals	
Df	1	1	1		26
Sum Sq					
Mean Sq					
F value					
Pr(>F)					

BEST FIT MODEL (glmulti analysis): SuccessRate ~ 1 + Length

Evidence
Worst IC
2 models to reach 95% of evidence weight
1 models within 2 IC units

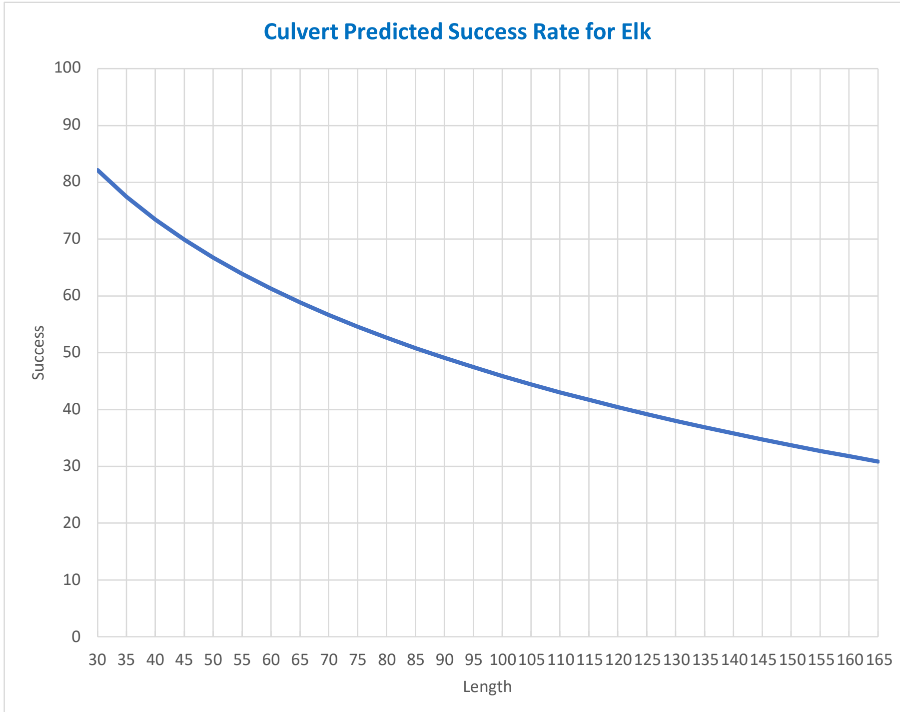
model	aicc	weights
Elk_SuccessRate ~ 1 + Length	**145.66**	0.557
Elk_SuccessRate ~ 1 + Width	**146.88**	0.303

PSEUDO R SQUARED

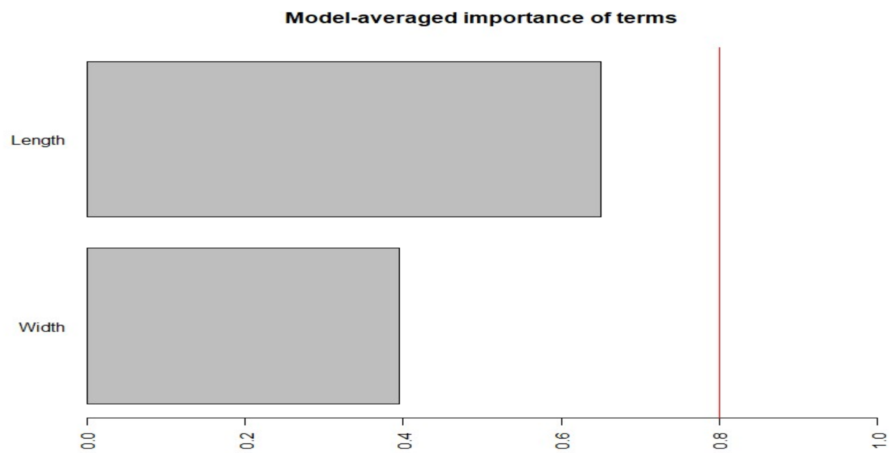
McFadden	0.1
Cox and Snell (ML)	0.649
Nagelkerke (Craig & Uhler)	0.649

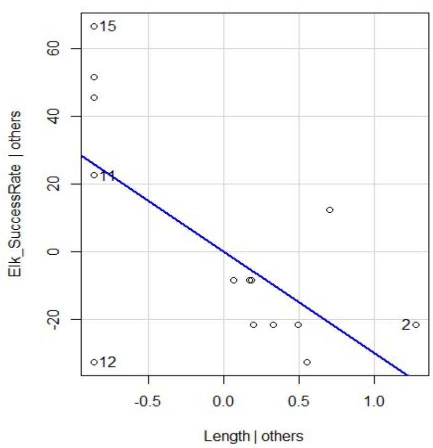
formula: Elk Success Rate = 184.411 - (30.075 * ln(length))

Length	Success
30	82.12
35	77.48
40	73.47
45	69.93
50	66.76
55	63.89
60	61.27
65	58.87
70	56.64
75	54.56
80	52.62
85	50.8
90	49.08
95	47.45
100	45.91
105	44.44
110	43.04
115	41.71
120	40.43
125	39.2
130	38.02
135	36.88
140	35.79
145	34.74
150	33.72
155	32.73
160	31.78
165	30.85



LINEAR REGRESSION (LM) VARIABLE ANALYSIS: Best Fit with Length					
	Estimate	Std Error	t value	Pr(>|t|)	
(Intercept)	**184.411**	50.057	3.684	0.00275	sig to 0.001
Length	**-30.075**	9.827	-3.061	0.00911	sig to 0.001
Residential standard er	25.42	13 df			
Multiple R-squared	0.4188				
Adjusted R-squared	0.3741				
F-statistic	9.367	1 and 13 df			
p-value	0.009113	Too few input makes this as a basis of further study			


Model-averaged importance of terms
Length
Width
0.0
0.2
0.4
0.6
0.8
1.0


Elk_SuccessRate | others
Length | others
15
11
12
2
60
40
20
0
-20
-0.5
0.0
0.5
1.0

No conclusions should be made regarding bridge underpass size. The data is too homogenous with 10 of the 18 observations having a success rate between 72 and 75, but lengths from 30' to 180' and heights from 9' to 24'.

Elk to Bridge Size: Best Fit Model is Elk_SuccessRate = Inconclusive

Data Summary (18 bridges)

	SuccessRate	Length	Width	Height
Minimum	0.00	84.00	30.00	7.00
1st Quar	49.50	131.00	32.00	9.25
Median	73.00	177.50	37.50	10.00
Mean	56.89	173.30	110.40	16.33
3rd Quar	74.00	201.20	120.00	22.00
Maximum	91.00	365.00	900.00	38.00
Correlation (1:1)		-0.37	0.26	0.33
Significance on Individual Basis		0.077	0.667	0.126

SKEWNESS & KURTOSIS (LOG, SQUARE ROOT, CUBED)

	SuccessRate	Length	Width	Height
Skew, no adj	-1.082	1.063	3.56	0.985
Kurtosis, no adj	2.507	4.357	14.447	2.605
Skew, log	na	0.009	1.579	0.58
Kurtosis, log	na	2.624	5.079	1.791
Skew, sqrt	-1.381	0.51	2.767	0.772
Kurtosis, sqrt	3.361	3.229	10.501	2.121
Skew, cube	-1.721	0.335	2.37	0.706
Kurtosis, cube	4.879	2.97	8.603	1.993

RESULTS: Do not apply transformation to SuccessRate;

JARQUE-BERA NORMALITY TEST (per transformation above)

	SuccessRate	Length	Width	Height
JB	3.698	0.106	10.72	2.106
p-value	0.1574	0.948	0.0047	0.3488
	normal	*normal*	*not normal*	*normal*

LINEAR REGRESSION (LM) VARIABLE INITIAL ANALYSIS: (Length & Height)

	Estimate	Std Error	t value	Pr(>|t|)	
(Intercept)	225.05	68.93	3.265	0.00522	sig to 0.001
Length	-50.45	14.63	-3.448	0.00358	sig to 0.001
Height	33.46	10.3	3.249	0.00539	sig to 0.001

Residential standa	21.8	14 df
Multiple R-square	0.5202	
Adjusted R-square	0.4562	
F-statistic	8.132	2 and 15 df
p-value	0.004054	

	Length	Width	Height	
Var Inflation Factor (Multicollinearity)	1.17	na	1.17	***<5, low collinearity***
Importation of Variables	**3.45**	na	**3.25**	

ANOVA LM model

				Residuals
Df	1	1	1	14
Sum Sq				
Mean Sq				
F value				
Pr(>F)				

BEST FIT MODEL (glmulti analysis): SuccessRate ~ 1 + Length + Height

Evidence	0.906
Worst IC	176.98

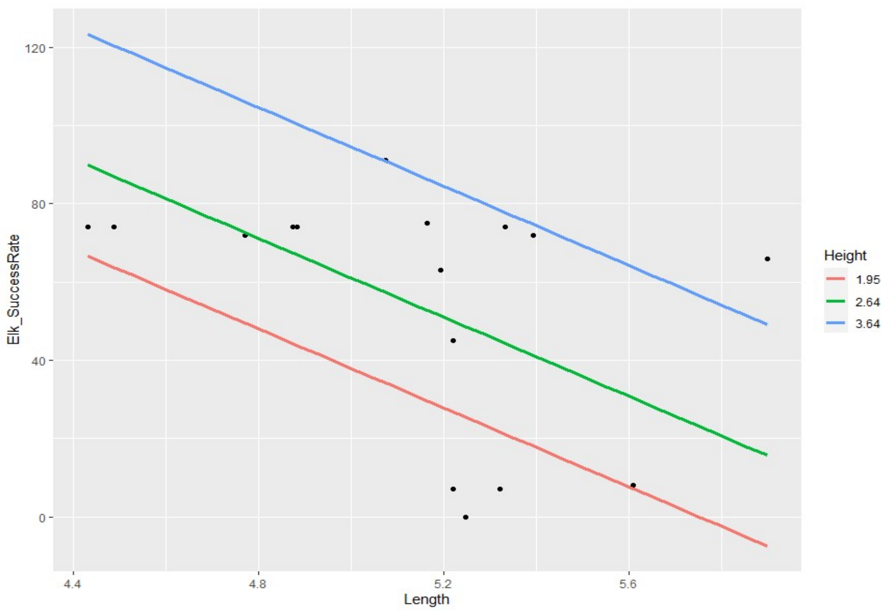
2 models to reach 95% of evidence weight

1 models within 2 IC units

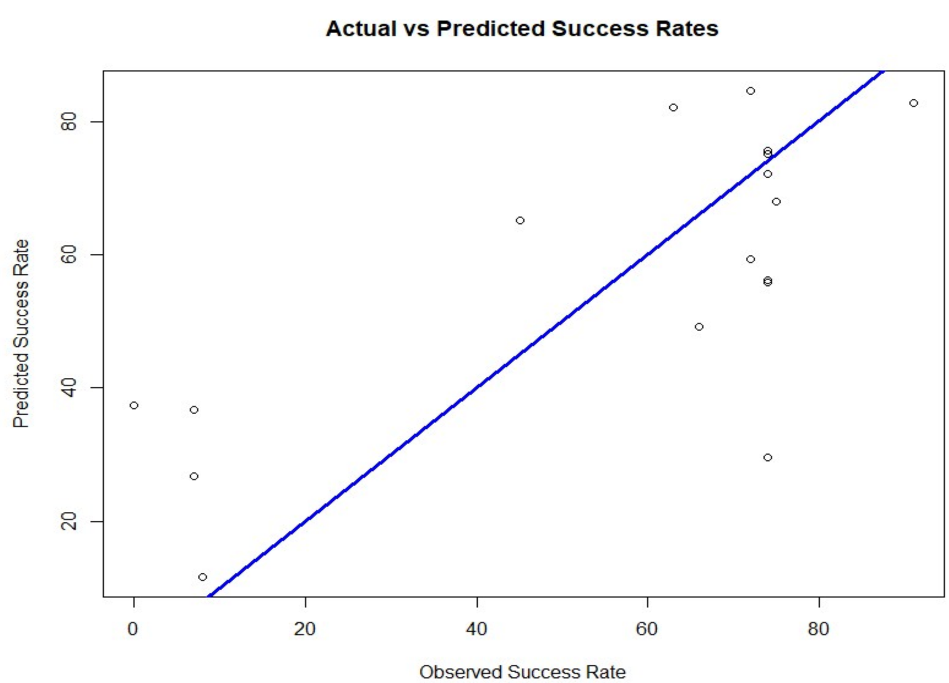
model	aicc	weights
Elk_SuccessRate ~ 1 + Length + Height	**169.83**	0.906

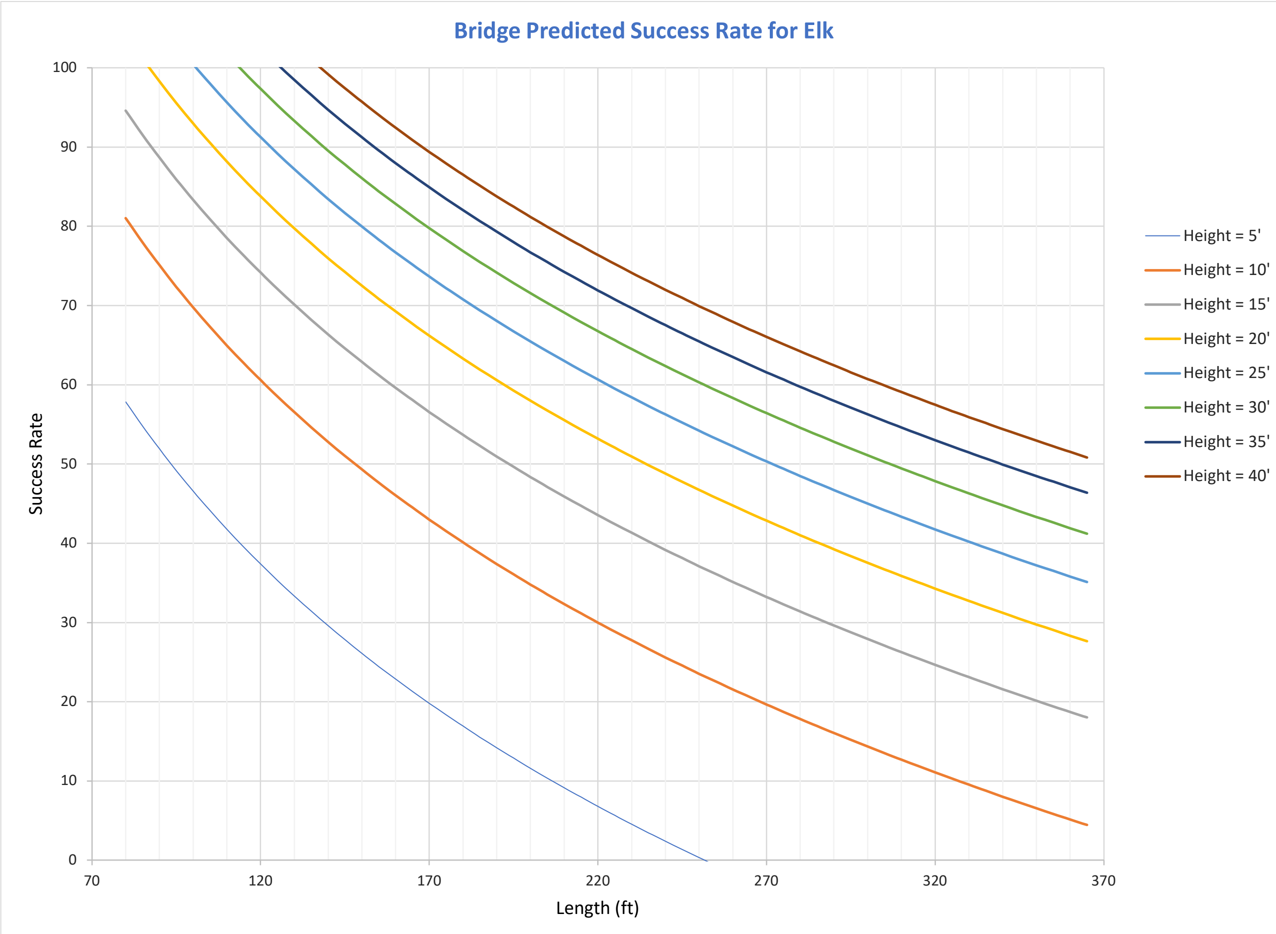
PSEUDO R SQUARED

McFadden	0.209
Cox and Snell (ML)	0.9
Nagelkerke (Craig & Uhler)	0.9



LINEAR REGRESSION (LM) VARIABLE ANALYSIS: Best Fit with Length and Height					
	Estimate	Std Error	t value	Pr(>|t|)	
(Intercept)	**225.05**	68.93	3.265	0.00522	sig to 0.001
Length	**-50.45**	14.63	-3.448	0.00358	sig to 0.001
Height	**33.46**	10.3	3.249	0.00539	sig to 0.001
Residential standard error	21.8	15 df			
Multiple R-squared	0.5202				
Adjusted R-squared	0.4562				
F-statistic	8.132	2 and 15 df			
p-value	0.004054	Marginal size dataset			



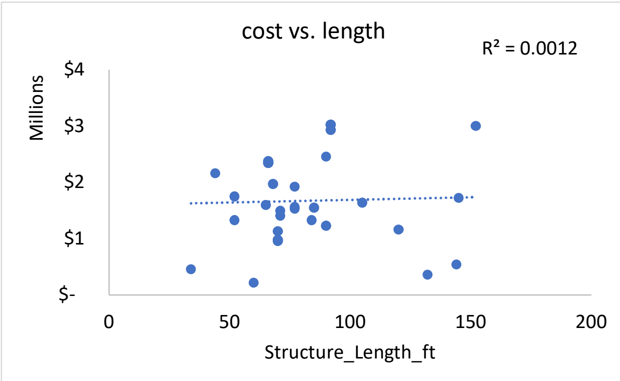

Bridge Predicted Success Rate for Elk
100
90
80
70
60
50
40
30
20
10
0
Success Rate
70
120
170
220
270
320
370
Length (ft)
Height = 5'
Height = 10'
Height = 15'
Height = 20'
Height = 25'
Height = 30'
Height = 35'
Height = 40'

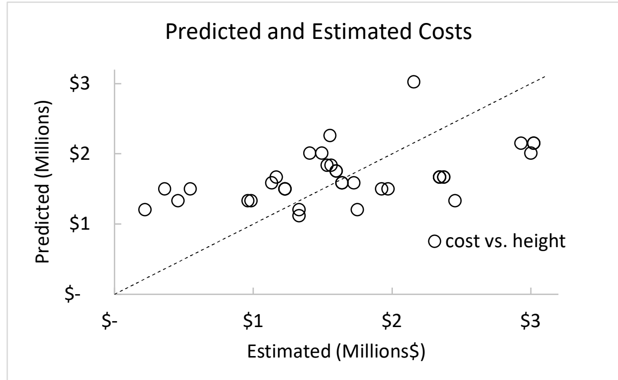
Bridge formula: Elk_SuccessRate = 225.05 - (50.45*ln(length)) + (33.46*ln(height))

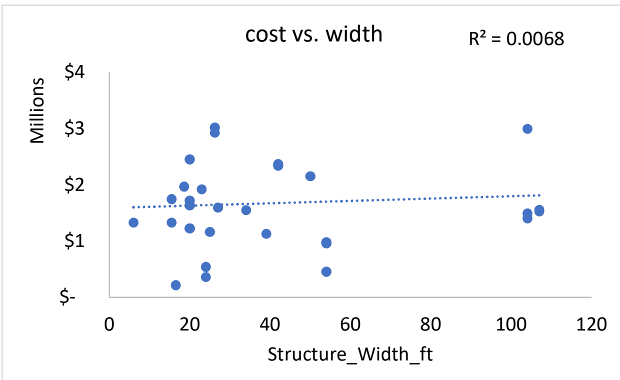
Length/ Height	5	10	15	20	25	30	35	40
80	57.82855	81.02125	94.58812	104.214	111.6803	117.7808	122.9387	127.4067
85	54.77004	77.96274	91.5296	101.1554	108.6218	114.7223	119.8802	124.3482
90	51.88639	75.0791	88.64596	98.2718	105.7382	111.8387	116.9965	121.4645
95	49.1587	72.35141	85.91827	95.54411	103.0105	109.111	114.2689	118.7368
100	46.57096	69.76366	83.33052	92.95637	100.4227	106.5232	111.6811	116.1491
105	44.10949	67.3022	80.86906	90.4949	97.96129	104.0618	109.2196	113.6876
110	41.76256	64.95526	78.52213	88.14797	95.61435	101.7148	106.8727	111.3407
115	39.51997	62.71267	76.27953	85.90538	93.37176	99.47224	104.6301	109.0981
120	37.37283	60.56554	74.1324	83.75824	91.22463	97.32511	102.483	106.9509
125	35.31336	58.50607	72.07293	81.69877	89.16516	95.26564	100.4235	104.8915
130	33.33468	56.52738	70.09425	79.72009	87.18647	93.28695	98.44483	102.9128
135	31.43068	54.62338	68.19025	77.81609	85.28247	91.38295	96.54083	101.0088
140	29.59593	52.78864	66.3555	75.98134	83.44772	89.5482	94.70609	99.17405
145	27.82558	51.01828	64.58514	74.21098	81.67737	87.77785	92.93573	97.40369
150	26.11524	49.30795	62.87481	72.50065	79.96703	86.06751	91.2254	95.69336
155	24.461	47.6537	61.22056	70.8464	78.31279	84.41327	89.57115	94.03911
160	22.85927	46.05198	59.61884	69.24468	76.71107	82.81155	87.96943	92.43739
165	21.30684	44.49955	58.06641	67.69225	75.15864	81.25912	86.417	90.88496
170	19.80076	42.99347	56.56033	66.18617	73.65255	79.75303	84.91091	89.37888
175	18.33834	41.53104	55.09791	64.72375	72.19013	78.29061	83.44849	87.91645
180	16.91712	40.10982	53.67669	63.30253	70.76891	76.86939	82.02727	86.49523
185	15.53484	38.72755	52.29441	61.92025	69.38663	75.48711	80.64499	85.11296
190	14.18943	37.38213	50.949	60.57484	68.04122	74.1417	79.29958	83.76754
195	12.87896	36.07167	49.63853	59.26437	66.73076	72.83124	77.98912	82.45708
200	11.60168	34.79439	48.36125	57.98709	65.45347	71.55395	76.71183	81.1798
205	10.35594	33.54864	47.11551	56.74135	64.20773	70.30821	75.46609	79.93405
210	9.140218	32.33292	45.89978	55.52563	62.99201	69.09249	74.25037	78.71833
215	7.953104	31.14581	44.71267	54.33851	61.8049	67.90538	73.06326	77.53122
220	6.793283	29.98599	43.55285	53.17869	60.64508	66.74555	71.90344	76.3714
225	5.659527	28.85223	42.41909	52.04494	59.51132	65.6118	70.76968	75.23764
230	4.550691	27.7434	41.31026	50.9361	58.40248	64.50296	69.66085	74.12881
235	3.465703	26.65841	40.22527	49.85111	57.3175	63.41798	68.57586	73.04382
240	2.403559	25.59626	39.16313	48.78897	56.25535	62.35583	67.51371	71.98167
245	1.363316	24.55602	38.12288	47.74873	55.21511	61.31559	66.47347	70.94143
250	0.344089	23.53679	37.10366	46.7295	54.19588	60.29636	65.45424	69.9222
255	-0.65495	22.53775	36.10461	45.73046	53.19684	59.29732	64.4552	68.92316
260	-1.6346	21.55811	35.12497	44.75081	52.2172	58.31768	63.47556	67.94352
265	-2.59558	20.59713	34.16399	43.78983	51.25622	57.35669	62.51458	66.98254
270	-3.5386	19.65411	33.22097	42.84681	50.3132	56.41368	61.57156	66.03952
275	-4.46431	18.7284	32.29526	41.9211	49.38748	55.48796	60.64584	65.1138
280	-5.37334	17.81936	31.38622	41.01207	48.47845	54.57893	59.73681	64.20477
285	-6.26629	16.92642	30.49328	40.11912	47.58551	53.68599	58.84387	63.31183
290	-7.1437	16.049	29.61587	39.24171	46.70809	52.80857	57.96645	62.43441
295	-8.00611	15.18659	28.75345	38.3793	45.84568	51.94616	57.10404	61.572
300	-8.85403	14.33867	27.90553	37.53138	44.99776	51.09824	56.25612	60.72408
305	-9.68794	13.50477	27.07163	36.69747	44.16386	50.26434	55.42222	59.89018
310	-10.5083	12.68442	26.25129	35.87713	43.34351	49.44399	54.60187	59.06983
315	-11.3155	11.87721	25.44407	35.06991	42.5363	48.63677	53.79466	58.26262
320	-12.11	11.0827	24.64957	34.27541	41.74179	47.84227	53.00015	57.46811
325	-12.8922	10.30052	23.86738	33.49322	40.9596	47.06008	52.21797	56.68593
330	-13.6624	9.530273	23.09714	32.72298	40.18936	46.28984	51.44772	55.91568
335	-14.4211	8.771612	22.33847	31.96432	39.4307	45.53118	50.68906	55.15702
340	-15.1685	8.024191	21.59105	31.2169	38.68328	44.78376	49.94164	54.4096
345	-15.905	7.287681	20.85454	30.48039	37.94677	44.04725	49.20513	53.67309
350	-16.6309	6.56177	20.12863	29.75447	37.22086	43.32134	48.47922	52.94718
355	-17.3465	5.846155	19.41302	29.03886	36.50524	42.60572	47.7636	52.23156
360	-18.0522	5.140549	18.70741	28.33325	35.79964	41.90012	47.058	51.52596
365	-18.748	4.444676	18.01154	27.63738	35.10376	41.20424	46.36212	50.83009

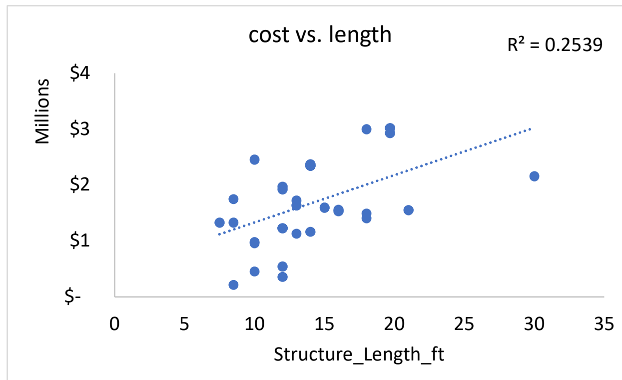
Appendix E
Model 5 Diminishing Return Statistical Analysis

			Data for regression analysis				linear model form
			Structure_Length_ft	Structure_Width_ft	Structure_Height_ft	Estimated_Costs_2021$	y = 84,614*x+485,639
Record_ID	Estimated_Costs	Year_Completed_Estimate	X1	X2	X3	Y	Predicted Costs
110	$ 1,000,000	2010	90	20	12	$ 1,228,000	$ 1,501,008
111	$ 1,000,000	2010	90	20	12	$ 1,228,000	$ 1,501,008
113	$ 1,000,000	2010	90	20	12	$ 1,228,000	$ 1,501,008
114	$ 2,200,000	2016	90	20	10	$ 2,454,000	$ 1,331,780
115	$ 1,500,000	2013	145	20	13	$ 1,724,000	$ 1,585,622
117	$ 1,500,000	2017	105	20	13	$ 1,638,000	$ 1,585,622
118	$ 1,500,000	2017	105	20	13	$ 1,638,000	$ 1,585,622
130	$ 1,500,000	2020	85	34	21	$ 1,551,000	$ 2,262,535
135	$ 308,748	2012	132	24	12	$ 360,000	$ 1,501,008
136	$ 96,316	1988	60	17	9	$ 218,000	$ 1,204,858
204	$ 2,100,000	2015	66	42	14	$ 2,372,000	$ 1,670,236
206	$ 2,100,000	2016	66	42	14	$ 2,343,000	$ 1,670,236
207	$ 2,100,000	2016	66	42	14	$ 2,343,000	$ 1,670,236
208	$ 2,100,000	2016	66	42	14	$ 2,343,000	$ 1,670,236
210	$ 2,100,000	2015	66	42	14	$ 2,372,000	$ 1,670,236
245	$ 1,300,000	2010	65	27	15	$ 1,596,000	$ 1,754,850
246	$ 1,300,000	2010	65	27	15	$ 1,596,000	$ 1,754,850
257	$ 2,460,755	2010	92	26	20	$ 3,021,000	$ 2,151,267
259	$ 2,460,755	2010	92	26	20	$ 3,021,000	$ 2,151,267
260	$ 2,460,755	2011	92	26	20	$ 2,929,000	$ 2,151,267
263	$ 970,000	2012	70	39	13	$ 1,131,000	$ 1,585,622
264	$ 1,850,000	2012	44	50	30	$ 2,157,000	$ 3,024,062
265	$ 1,140,000	2012	84	6	8	$ 1,329,000	$ 1,120,244
266	$ 1,140,000	2012	52	16	9	$ 1,329,000	$ 1,204,858
267	$ 1,500,000	2012	52	16	9	$ 1,749,000	$ 1,204,858
268	$ 1,690,000	2012	68	19	12	$ 1,971,000	$ 1,501,008
269	$ 1,650,000	2012	77	23	12	$ 1,924,000	$ 1,501,008
271	$ 950,000	2020	70	54	10	$ 983,000	$ 1,331,780
272	$ 928,000	2020	70	54	10	$ 960,000	$ 1,331,780
273	$ 441,000	2020	34	54	10	$ 456,000	$ 1,331,780
274	$ 1,443,000	2020	71	104	18	$ 1,493,000	$ 2,008,692
275	$ 1,359,000	2020	71	104	18	$ 1,406,000	$ 2,008,692
276	$ 2,899,000	2020	152	104	18	$ 2,999,000	$ 2,008,692
277	$ 1,480,000	2020	77	107	16	$ 1,531,000	$ 1,839,464
278	$ 1,507,000	2020	77	107	16	$ 1,559,000	$ 1,839,464
279	$ 876,000	2006	120	25	14	$ 1,164,000	$ 1,670,236
280	$ 436,000	2009	144	24	12	$ 544,000	$ 1,501,008


cost vs. length
R² = 0.0012
Millions
$4
$3
$2
$1
$-
0
50
100
150
200
Structure_Length_ft


Predicted and Estimated Costs
Predicted (Millions)
$3
$2
$1
$-
$-
$1
$2
$3
Estimated (Millions$)
cost vs. height


cost vs. width
R² = 0.0068
Millions
$4
$3
$2
$1
$-
0
20
40
60
80
100
120
Structure_Width_ft


cost vs. length
R² = 0.2539
Millions
$4
$3
$2
$1
$-
0
5
10
15
20
25
30
35
Structure_Length_ft

Multivariate Regression
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.5182
R Square	0.2686
Adjusted R Square	0.2021
Standard Error	656239
Observations	37

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	5.21773E+12	1.73924E+12	4.0387	0.0150
Residual	33	1.42114E+13	4.30649E+11		
Total	36	1.94291E+13			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	465093	490915	0.9474	0.3503	-533681	1463866
X1	412	4001	0.1029	0.9186	-7729	8553
X2	-3272	4110	-0.7961	0.4317	-11635	5090
X3	92865	27108	3.4258	0.0017	37714	148017

Bivariate Regression
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.5039
R Square	0.2539
Adjusted R Square	0.2325
Standard Error	643578
Observations	37

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.932E+12	4.932E+12	1.191E+01	1.476E-03
Residual	35	1.450E+13	4.142E+11		
Total	36	1.943E+13			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	485639	359878.681	1.349	0.186	-244954.009	1216231.118
X3	84614	24519.650	3.451	0.001	34836.568	134391.6389

CPI-U Inflation Factor Lookup Table

Year	Avg	Factor
1988	118.275	2.264
1989	123.942	2.160
1990	130.658	2.049
1991	136.167	1.966
1992	140.308	1.908
1993	144.475	1.853
1994	148.225	1.806
1995	152.383	1.757
1996	156.858	1.707
1997	160.525	1.668
1998	163.008	1.642
1999	166.583	1.607
2000	172.192	1.555
2001	177.042	1.512
2002	179.867	1.488
2003	184.000	1.455
2004	188.908	1.417
2005	195.267	1.371
2006	201.558	1.328
2007	207.344	1.291
2008	215.254	1.244
2009	214.565	1.248
2010	218.076	1.228
2011	224.923	1.190
2012	229.586	1.166
2013	232.952	1.149
2014	236.715	1.131
2015	237.002	1.130
2016	240.005	1.116
2017	245.136	1.092
2018	251.102	1.066
2019	255.653	1.047
2020	258.844	1.034
2021	267.728	1.000

CPI for All Urban Consumers (CPI-U)
Original Data Value

Series Id:	CUSR0000SA0
Seasonally Adjusted	
Series Title:	All items in U.S. city average, all urban consumers, seasonally adjusted
Area:	U.S. city average
Item:	All items
Base Period:	1982-84=100
Years:	1988 to 2021

Source:
https://data.bls.gov/pdq/SurveyOutputServlet