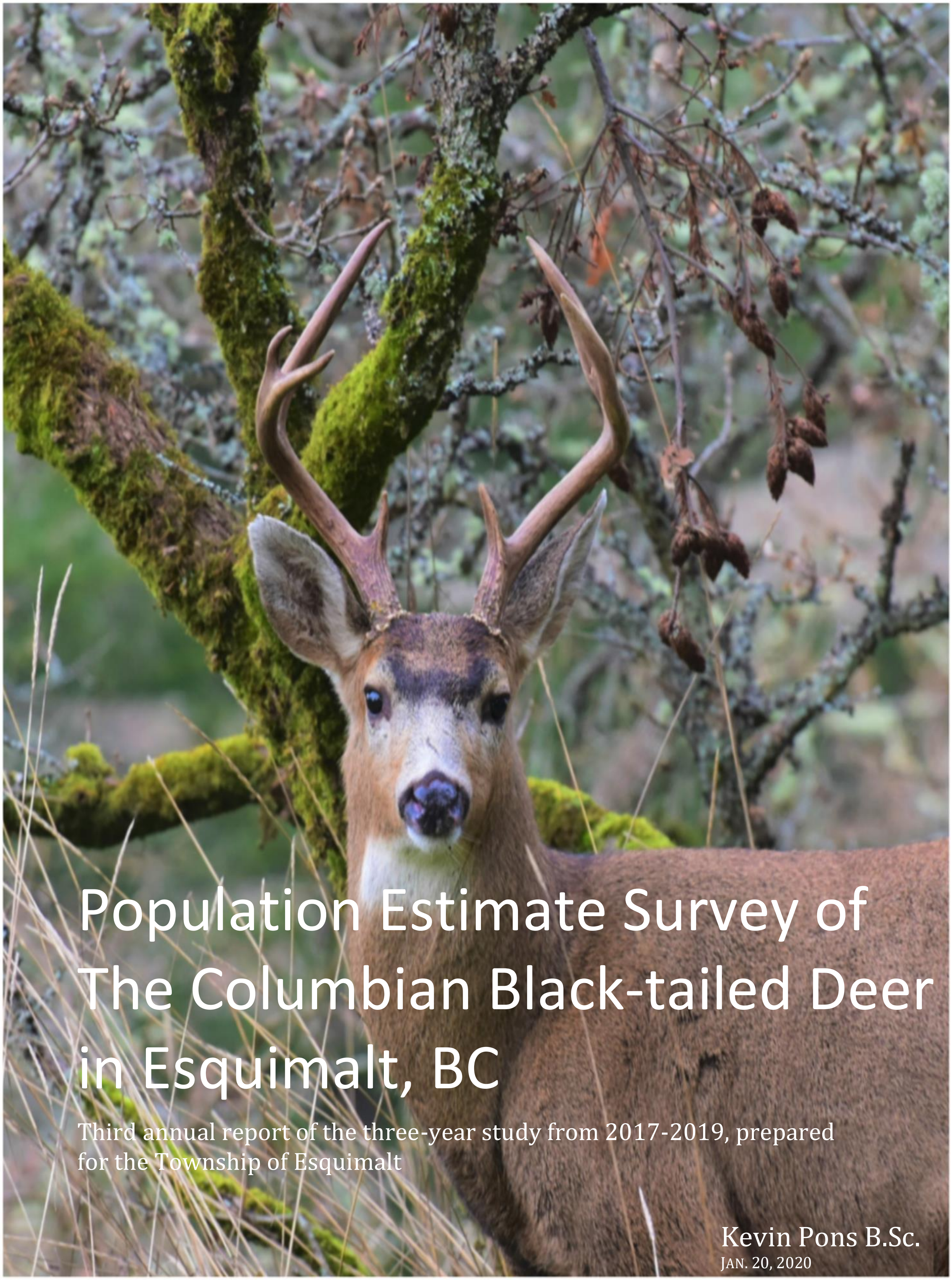

Population Estimate Survey of The Columbian Black-tailed Deer in Esquimalt, BC

Third annual report of the three-year study from 2017-2019, prepared for the Township of Esquimalt

Kevin Pons B.Sc.

JAN. 20, 2020

Executive Summary

The purpose of this report is to provide scientific materials for the Township of Esquimalt in order to help with the implementation of effective deer management strategies.

The sampling method used in all three Fall Esquimalt Deer Surveys is commonly known as the mobile line technique. This method has been adapted for the three habitat types within Esquimalt (The Esquimalt community, the Gorge Vale Golf Course and the Esquimalt parks). The roads were surveyed by driving a car, the golf course was surveyed by driving golf carts and the parks were surveyed while walking on the trails.

Bucks were individually identified based on photos collected during the study and built into a photographic Mark-Recapture catalogue. The Null Model has been applied in all three surveys to generate a robust buck population estimate.

The results of the Null Model (with respect to bucks only) from the Fall 2019 survey (n=10) produced a 95% confidence limit with a lower confidence limit of 27 bucks, an upper confidence limit of 45 bucks, and an estimate of 36 bucks. Following the buck population estimate, the herd composition ratio was applied to the buck estimate to extrapolate the total deer population estimate.
This resulted in a 95% confidence limit with a lower confidence limit of 93 deer, an upper confidence limit of 156 deer, and a population estimate of 125 deer.

These results were similar to the fall 2018 survey (n=10) which resulted in a 95% confidence limit with a lower confidence limit of 26 bucks, an upper confidence limit of 44 bucks, and an estimate of 35 bucks. Following the buck population estimate, the herd composition ratio was applied to the buck estimate to extrapolate the total deer population estimate.
This result obtained showed a 95% confidence limit with a lower confidence limit of 100 deer, an upper confidence limit of 170 deer, and a population estimate of 135 deer.

By applying the same data analysis methods to the fall 2017 survey (n=6), the following statistics were obtained, a 95% confidence limit with a lower confidence limit of 13 bucks, an upper confidence limit of 67 bucks, and a population estimate of 40 bucks. The herd composition ratio was extended to the buck estimate to extrapolate the total deer population estimate. This resulted in 95% confidence limit with a lower confidence limit of 44 deer, an upper confidence limit of 226 deer, and a population estimate of 135 deer.

There was no significant difference in the deer population estimates between 2017, 2018 and 2019 (as evident by overlapping 95% confidence intervals). Increased sampling in 2018 and 2019 (n=10) provided greater certainty around the buck estimate (which extend to the total population estimate) by decreasing the 95% confidence range by two-thirds.

This study provides excellent base data for future deer research as it has successfully generated three population estimates (2017, 2018 and 2019 Fall Esquimalt Deer Survey) as well as identified the population spatial distribution.

2. Acknowledgment

I would like to thank the following people for the valuable help they contributed in this project:

- The UWSS (Urban Wildlife Stewardship Society) for their support during the project
- Jessica Wright and Allie Kozachuk for their great role has field work technician
- Rachel Newman, Megan Moroney and Sergei Popov for volunteering on a regular basis
- The Gorge Vale Golf Course management team for allowing the field work on their property
- Camosun College Environmental Technology Program for lending us the necessary field work equipment
- Megan Sakuma providing me with previous year’s data and project related consultation
- Liam Guy for providing QGIS data and lending photographic equipment
- Sandra Frey for her valuable consultations

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6. Introduction

The growing population of urban Columbian Black-tailed deer (CBTD) has been a controversial issue among residents and visitors within the Greater Victoria Area. Future management decisions with respect to Columbian Black-tailed Deer need to be based on scientific evidence in order to be both ethical and effective. This project aims to provide the Township of Esquimalt with a third population estimate in collaboration with the Department of National Defense (DND) in order to establish future management strategies across jurisdictions. This year's survey is the third survey of an ongoing three-year program (2017-19).

7. Background

7.1 Ecology

The Columbian Black-tailed Deer (Odocoileus hemionus columbianus) rutting season usually takes place in November and early December (Ministry of Environment, Lands and Parks, 2000, page 4). During this time, bucks will compete with each other in order to successfully attract the most suitable mating partner. During the mating season, it is common to see bucks circling their rivals, back arched, head low and tail flickering and sometimes engaging in head-to-head fighting (Ministry of Environment, Lands and Parks, 2000, page 4). Bucks are capable of breeding as yearlings but the dominant bucks do most of the breeding (Ministry of Environment, Lands and Parks, 2000, page 4).

Females will tend to cluster around the largest buck, and the chosen buck will keep other bucks away from the doe until mating happens or if another buck displaces him (Ministry of Environment, Lands and Parks, 2000, page 4). Bucks will drop their antlers from January to March in British Columbia (Ministry of Environment, Lands and Parks, 2000, page 4), which makes September to December the ideal season to perform a Mark-Recapture as Black-tailed Deer enter breeding season (most active period) and bucks have full grown antlers (ideal for identification).

7.2 Previous Studies

2016 Esquimalt Community Survey
The response from this survey recommended that a population estimate should be conducted, in order to make management decisions (Nyberg, 2016, page 27).

2017 Fall DND Survey
The density at CFB Esquimalt was estimated as 40 deer/km^2 (Prentiss, 2017).

2017 Fall Esquimalt Survey
The previous survey to this one, with results of 95% confidence limits with a low of 44 to a high of 226 deer, and an estimate of 135 deer.

2018 Fall Esquimalt Survey
The previous survey to this one, with results of 95% confidence limits with a low of 100 to a high of 170 deer, and an estimate of 135 deer.

8. Project Rationale

Communities in the Victoria Greater Area often vocalize mixed feelings with respect to the local Black-tailed deer population as reflected by the 2016 Esquimalt Community Survey. Concerns identified through the survey relate primarily to damaged gardens and the possibility of vehicle and bicycle collisions (Nyberg, 2016, page 26). The 2016 Community Survey recommended that a population estimate should be conducted in order to help make management decisions, rather than just basing decisions on complaints (Nyberg, 2016, page 27).

This three-year project provides a more robust estimate of CBTD population-size across Esquimalt and its surrounding areas than previously employed method of surveying the deer population.

9. Objective

Determine the population size and distribution of Columbian Black-tailed deer in Esquimalt, BC.

10. Site description

Esquimalt

The Township of Esquimalt encompasses an area of 7.08 km^2, including the 1.59 km^2 of land administered by the DND (Sakuma, 2018). The study site encompasses an area of 5.49 km^2 (Sakuma, 2018). Esquimalt is composed of residential areas, commercial areas, small parks, and the Gorge Vale golf course. The small area of Esquimalt is somewhat fragmented by various features such as the ocean shoreline and the daily vehicle flow between Victoria Greater Area and the Langford/Colwood area, which restrict deer movement in certain directions.

For the purpose of surveying (2017-19), Esquimalt was divided into seven different sub-zones:

Rockheights

Rockheights is primarily a residential area, and has one park called High Rock Park (see Figures 1).

High Rock Park

Figure 1: Highrock Park by Kevin Pons

Esquimalt Village

Esquimalt Village is primarily, a residential area with a greater population density than other zones. Esquimalt Village has two parks, Macaulay Point Park and Saxe Point Park (see figure 2 & 3).

<u>Macaulay Point Park</u>

Figure 2: Sergei Popov and Meagan Moroney volunteering at Macaulay Park by Kevin Pons

Saxe Point Park

Figure 3: Saxe Point Park by Kevin Pons

Parklands

Parklands is for the most part a residential area, with large properties on the border with Gorge Vale golf course.

Gorge

Gorge is primarily a residential area, and is bound by the ocean and a main road. It has one park, Gorge Park (see Figures 4).

Gorge Park

Figure 4: Gorge Park by Kevin Pons

Selkirk

Selkirk is primarily, a residential area and is bound by both the ocean and a main road (Craigflower road).

West Bay

West Bay is primarily a commercial area with a small residential area which include Esquimalt High School.

Golf Course

The Gorge Vale Golf Course is the largest green space in Esquimalt with 140 acres (Sakuma, 2018) (see Figures 5). It is home to a variety of wildlife, including deer, rabbits, squirrels and eagles observed during the surveys.

Figure 5: Gorge Vale Golf Course by Kevin Pons

11. Methods

11.1 Survey Route Design and Sample Protocol

The exact same survey methods were applied in the fall 2017, 2018 and 2019 surveys, to ensure consistency within the data. One difference should be noted, with an increased budget, the sample size was increased from six transect surveys in fall 2017 (n=6) to ten (fall 2018 & 19, n=10), and surveys were always completed in teams of 3, rather than 2. (With the exception of the golf course, which only has room for 2 people in the golf cart). Surveying was conducted during the rutting season. This was because deer are most active during this time of year (Ministry of

Environment, Lands and Parks, 2000, page 4), and bucks still have their antlers which makes them easier to identify. Surveys were conducted from Oct. 21 – Nov. 22, Monday to Friday, twice a day (dawn and dusk) for 5 weeks (50 samples). Sampling was not conducted on weekends to account for changes in traffic patterns. Two of the smaller sub-zones were paired with other sub-zones, so that the entire site could be sampled over 5 days.

1. Rockheights roads and Highrock Park
2. Esquimalt Village roads, Macaulay Point Park, and Saxe Point Park
3. Parklands roads, West Bay
4. Selkirk roads, Gorge roads, and Gorge Park
5. Gorge Vale Golf Course

See figure 6 for visual representation of the survey zones.

* Sub zones 2 and 4 were changed to “Parklands roads, West Bay” and “Selkirk roads, Gorge roads, and Gorge Park” as opposed to “Parkland, Gorge roads, and Gorge Park” and West Bay, Selkirk roads ”in order to ensure proper fan out of the study site with respect to surveying occurring on DND land.

** All sub-zones survey paths are visible in Appendix A, B, C, D E, F and G.

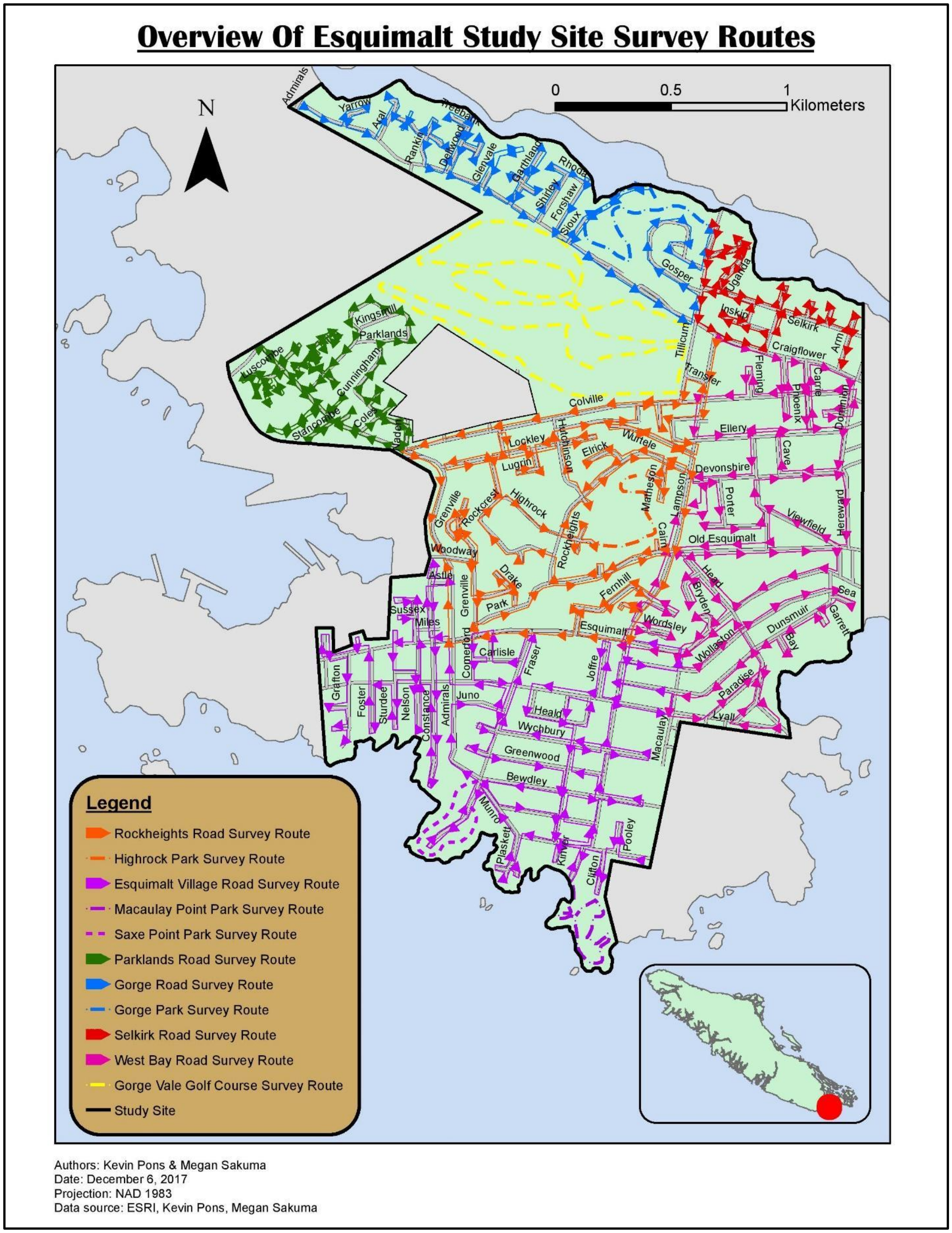


Figure 6: Map of Esquimalt Survey Routes by Kevin Pons and Megan Sakuma

As per the 2017 and 2018 fall Esquimalt surveys, each zone was surveyed for approximately one to two hours at both dawn and dusk on each sampling day. The surveys were repeated in the same order five times over the course of five weeks. This resulted in 25 samples days, sampling twice a day, for a total of 50 sampling events. The direction of the survey route was reversed mid survey to ensure effective photographic capture at peak activity (dawn and dusk).

This project was coordinated with DND (Department of National Defense) to conduct our respective surveys on the same days. When possible, we started the survey routes on adjacent properties and fanned out from there. This reduced the probability of deer double count.

In all three surveys, the mobile line technique was used and adapted to the Esquimalt sample site. This method is recognized as being robust and cost efficient for surveying wildlife populations (Krebs, 2014). This method was adapted to survey the golf course where all golf cart paths were driven while surveying (see figure 7).
Roads were driven in each zone as seen on Figure 8. With respect to Parks, major trails were walked on, which covered most of the parks.

Figure 7: Kevin Pons surveying the golf course by Allie

Figure 8: Kevin Pons surveying deer by Rachel Newman

For both safety and quality collection, three people made up the surveying team on a daily basis. With respect to the road survey, the team drove at speed limits on major roads and at a constant 25km/h in the neighborhoods. With respect to the 2019 survey the navigator role was replaced by an observator role as all survey maps were loaded on google maps. This allowed the use of GPS instead of paper maps. Upon deer sighting, the vehicle/golf cart/surveying team pulled over safely (car warning signal on every time) to the side of the road/path/trail. The back-seat passenger would take photos and the front seat passenger would collect GPS coordinates, distance and angle measurements, time/date, and the sex/approximate age of deer seen (see Appendix I). The driver would assist to collect the data if there was an opportunity to safely do so. Most of the time, the driver was able to perform the range estimation.

Protocol for when to **count** or **not count** deer for the 2017-18-19 Esquimalt deer survey (Sakuma, 2018):

- Line of sight rule: If the deer was visible from the transect anywhere WITHIN the boundary of the sub-zone (i.e. Rockheights), it was counted, even if it was on the adjacent transect. If the deer was within line of sight, but was outside of the boundary of the sub-zone, it did NOT count.
- When a deer was sighted, our location on the map was checked to ensure that we weren't double counting deer that may have moved nearby from the last sighting, since the transects sometimes zigzagged.
- Doubling back on a road did not count as part of the survey. However, when doubling back on a road, if it appeared that the deer was highly likely there at the time we were first driving by but just missed sighting it, it was counted.
- The spatial data (GPS location, bearing, distance) was collected from where the first deer was sighted.

11.2 Human Wildlife Conflict Safety Protocols

There are potential risks to taking photos of bucks during the rut. These risks and disturbance to all deer were minimized as much as possible, by following these protocols (WildSafe BC, 2020):

- Giving the deer space.
- Remaining quiet, but did not surprise the deer.
- Avoiding eye contact.
- Never getting in between deer. At all times, a team member watched the photographer to ensure proper safety.
- Watching for deer laying their ears back and lowering their head as these can be signs of agitation.

11.3 Photo Identification

One method to estimate the size of a population is to capture and mark individuals from the population, and then to re-sample to see what fraction of individuals carry marks. This is called the Mark-Recapture technique. In this survey, photos were taken of each deer sighted to "mark" them.

As per the Fall 2017-18 survey by Megan Sakuma, the requirement for proper photographic sampling follow the criteria outlined by Bailey et al.

Ideal criteria:

1. Face and antlers facing forwards.

a. This allows for potential identification of important facial features or distinctions, as well as noting antler size and shape (Bailey et. Al, 2016).

2. Ears flared outwards facing forwards.

a. Not only are the antlers and face important, but ears can also frequently exhibit specific colours or patterns, as well as small nicks or deformities that can be used for identification purposes (Bailey et. Al, 2016).

3. Full body in the image.

a. This is another important one, as it will show any distinguishing features along the length of the body or legs (Bailey et. Al, 2016).

4. Multiple angles.

a. Multiple angles of every deer strongly recommended, as it allows for the largest possibility of catching different markings on different sides of the deer (Bailey et. Al, 2016).

Identification guidelines used in this survey can be seen in Appendix H with sample pictures in Appendix J, K and L.

For the Fall 2019 Fall Esquimalt Survey, a Nikon D7200 with a 70-300mm VR lens and a 24120mm VR lens were used to ensure the best quality data possible. Capturing the finer details were key to identifying individuals in the Mark-Recapture process.

To identify individuals from photos, the following protocols were followed:

- Looked at the general shape of the antlers from the head on front profile shots.
- Compared this angle to the same angle of other individuals. If any appeared to match, we opened the folder to view more photos of different angles of that individual deer.
- Examined antlers carefully – looking for number of points and tines, shape, and coloration.
- Used facial features - scars, coloration, and nicks on ears and face - as a secondary confirmation.
- Used field notes to identify specific behavior that could confirm an identification.

12. Results

12.1 Raw Data

During the 10 samples taken in 7 sub-zones over 50 sampling times, 150 deer were sighted (including multiple sightings of individuals). Table 1 presents the raw data collected in each sample in each sub-zone.

Figures 9 and 10 represent the raw data in bar charts, and compare it to 2017[1] and 2018 fall survey data.

1.In 2017, there were only 6 samples, with 2 observers, rather than 3 observers in 2018 and 2019. Additionally, Gorge & Selkirk and Parkland & West Bay sub-zones were combined in order to better coordinate the surveys with the DND. This ensured proper fan out sampling within Esquimalt to avoid double count between Esquimalt surveyor and DND surveyor.

Table 1: Number of deer sightings for each sample in each sub-zone

Sample	Rockheights	Esquimalt Village	Gorge & Selkirk	Parkland & West Bay	Golf Course	Total
Week 1 Dawn	2	0	2	4	0	8
W1 Dusk	6	3	7	3	0	19
W2 Dawn	7	0	0	0	3	10
W2 Dusk	7	1	6	3	1	18
W3 Dawn	7	9	0	10	6	32
W3 Dusk	0	2	0	4	4	10
W4 Dawn	0	4	0	3	2	9
W4 Dusk	6	2	1	5	3	17
W5 Dawn	3	2	2	5	3	15
W5 Dusk	0	0	0	8	4	12
Total	38	23	18	45	26	150

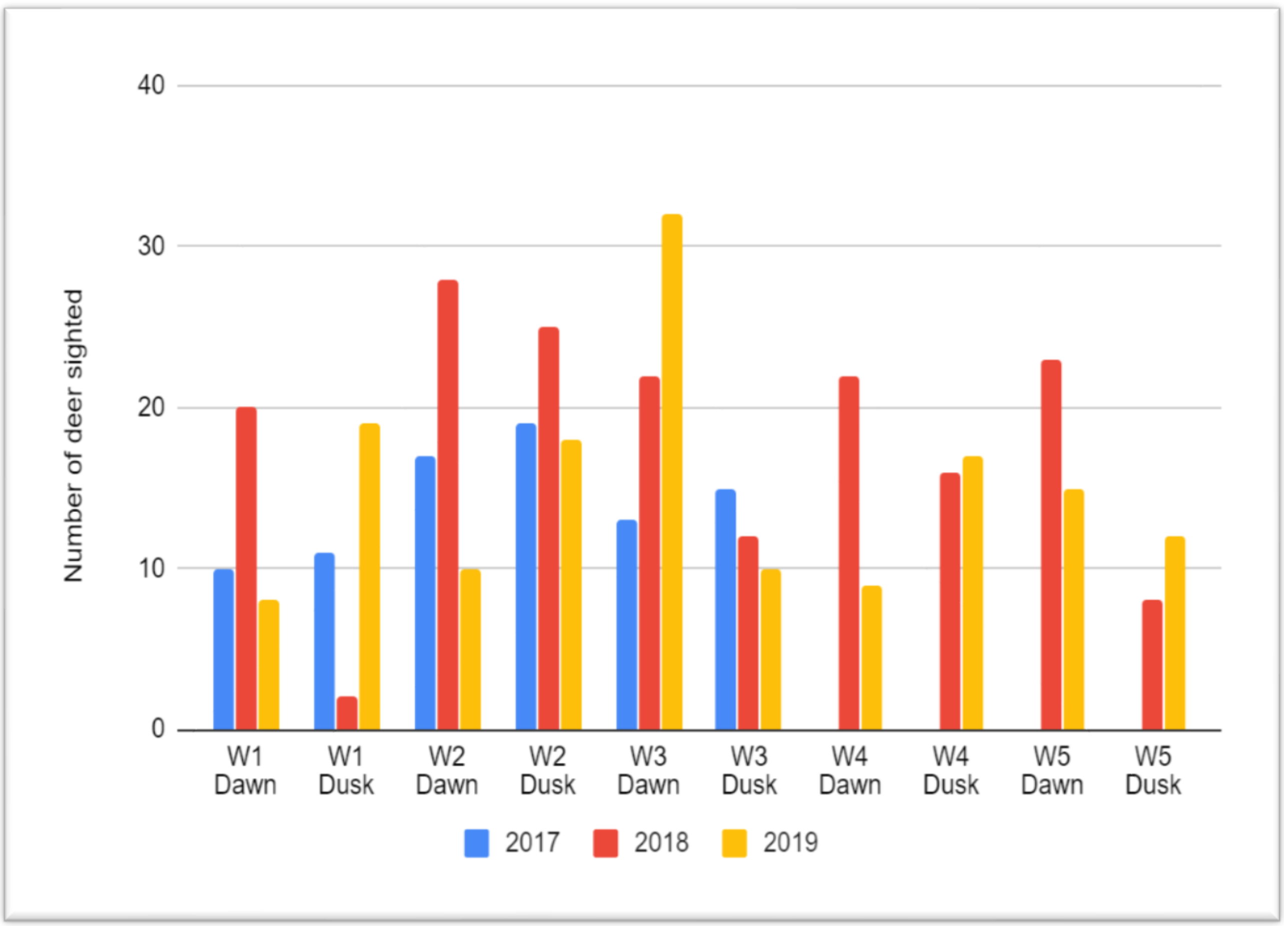


Figure 9: Graph of deer sightings in each sample in 2017, 2018 and 2019 by Kevin Pons

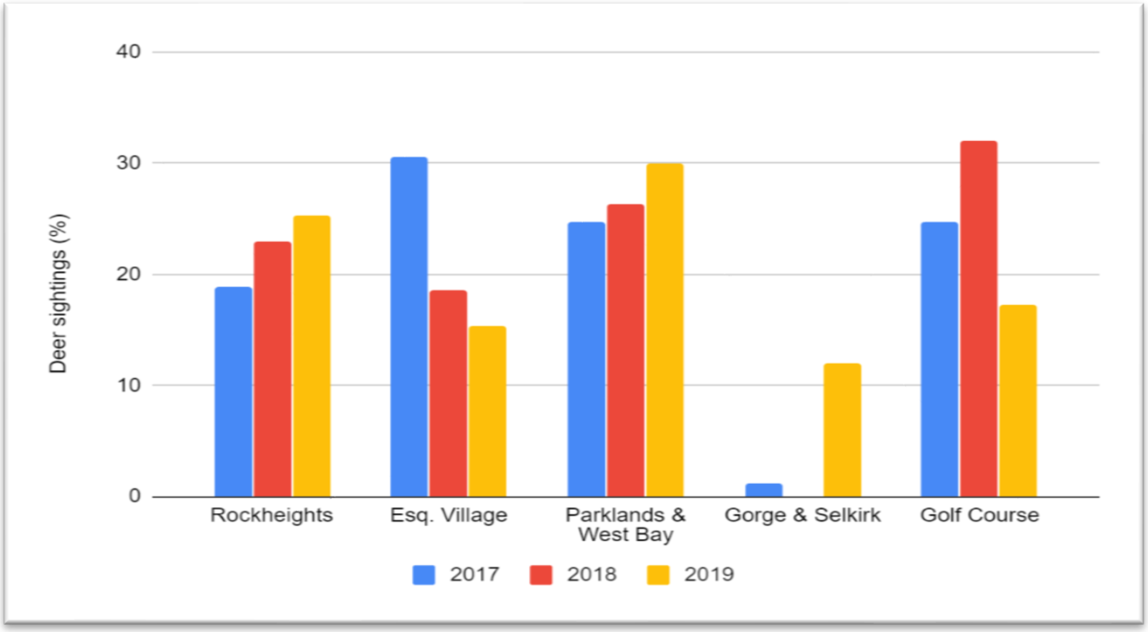


Figure 10: Graph of deer sightings (%) in each sub-zone in 2017, 2018 and 2019 by Kevin Pons

12.2 Spatial Distribution and density

Figure 11. presents the distribution of all 85 deer sightings over the 6 samples from the Esquimalt Fall 2017 survey. Figure 12. shows the spatial distribution of all 178 deer sightings over 10 samples from the Esquimalt Fall 2018 Survey. Figure 13. shows all 150 deer sightings over the 10 samples from the Esquimalt Fall 2019 Survey. Figure 14. shows all 150 deer sightings by sex over the 10 samples from the Esquimalt Fall 2019 Survey. Figure 15. Shows the spring 2018 deer sightings categorized by sex. Figure 16. shows an IDW[2] extrapolation of the Esquimalt deer density performed in the spring 2018 (75 deer sightings over 6 samples).

Figure 17. shows a heatmap[3] extrapolation of the Esquimalt deer density performed in the fall

2018 (178 deer sightings over 10 samples). Figure 18. shows a heatmap extrapolation of the Esquimalt deer density performed in the fall 2019 (150 deer sightings over 10 samples).

With respect to the fall 2017, 2018 and 2019 sightings map, the spatial distribution appears very similar in all three cases. Sightings were mostly concentrated at the Gorge Vale Golf Club, Rockheights, Parkland and Esquimalt Village zone (see figure 11-15). Similarly, very few sightings were recorded in the Gorge, Selkirk and West Bay zone. This similarity can be further observed in the spring 2018 IDW map (figure 16), fall 2018 and fall 2019 heatmap (figure 17 & 18). The Esquimalt deer population appears to be concentrated in the Gorge Vale golf club, Parkland, Esquimalt Village and Rockheights zone (figure 16-18).

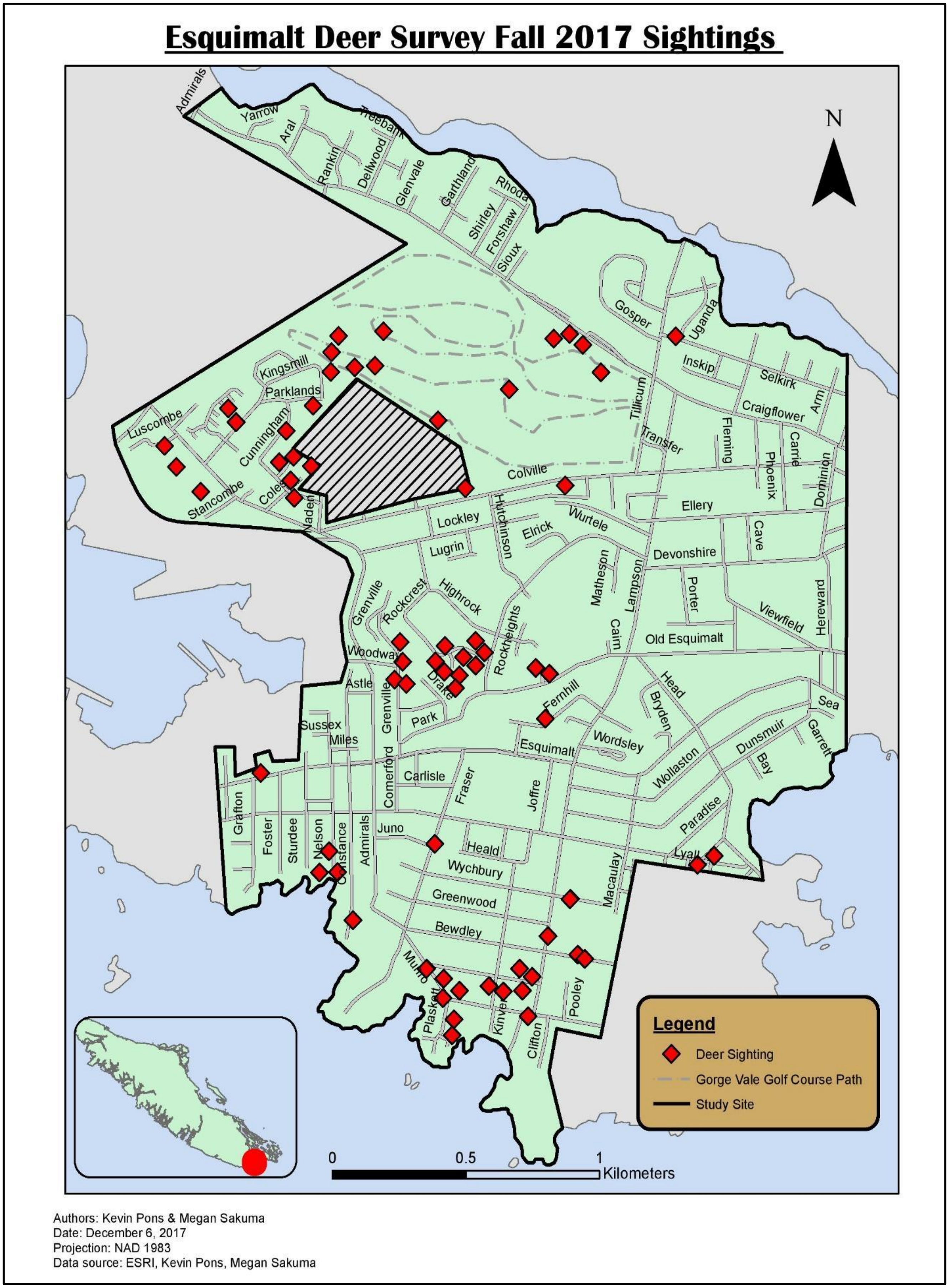


Figure 11: Map of Esquimalt deer survey Fall 2017 sightings

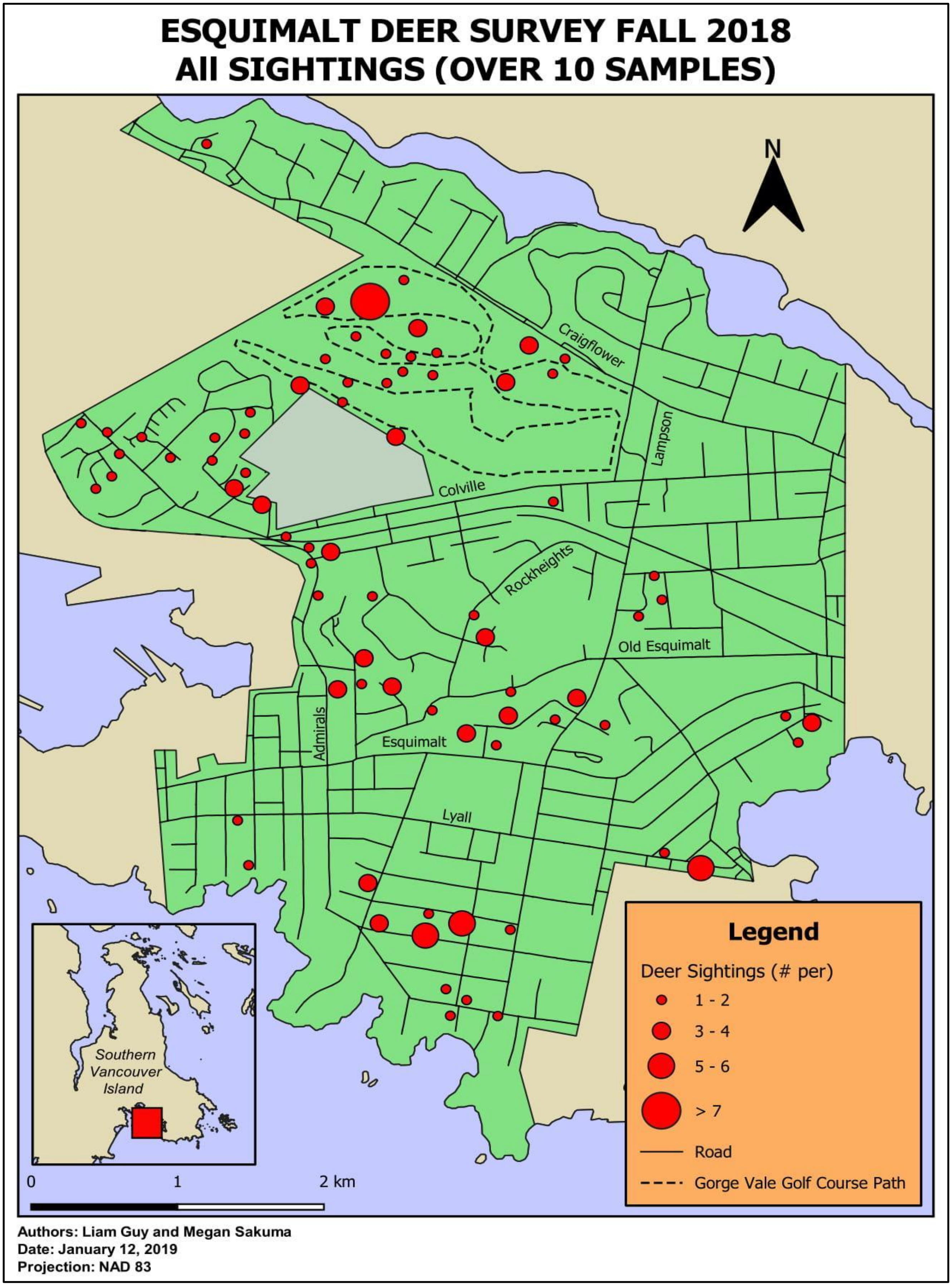


Figure 12: Map of Esquimalt deer survey Fall 2018 sightings

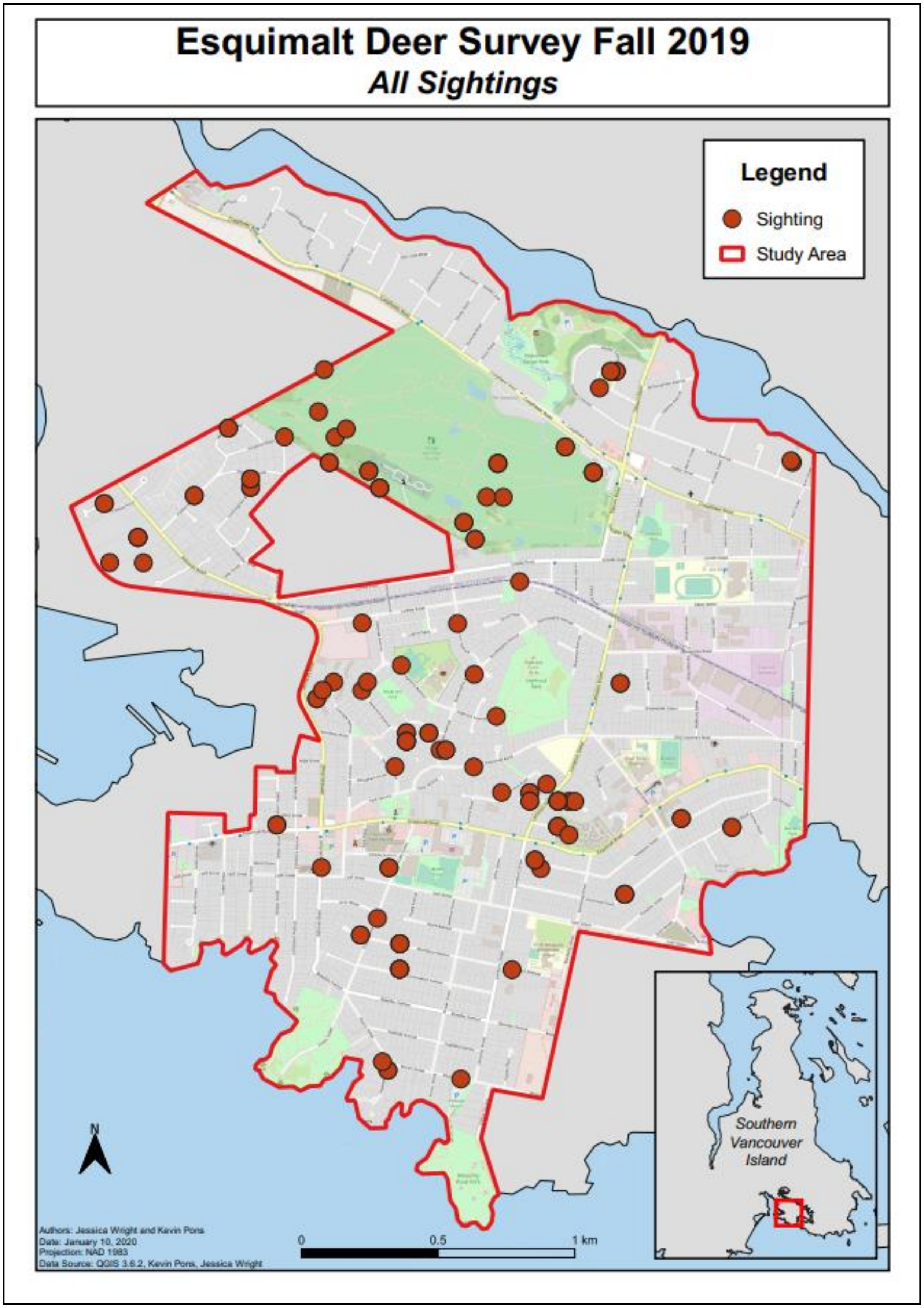


Figure 13: Map of Esquimalt deer survey Fall 2019 sightings

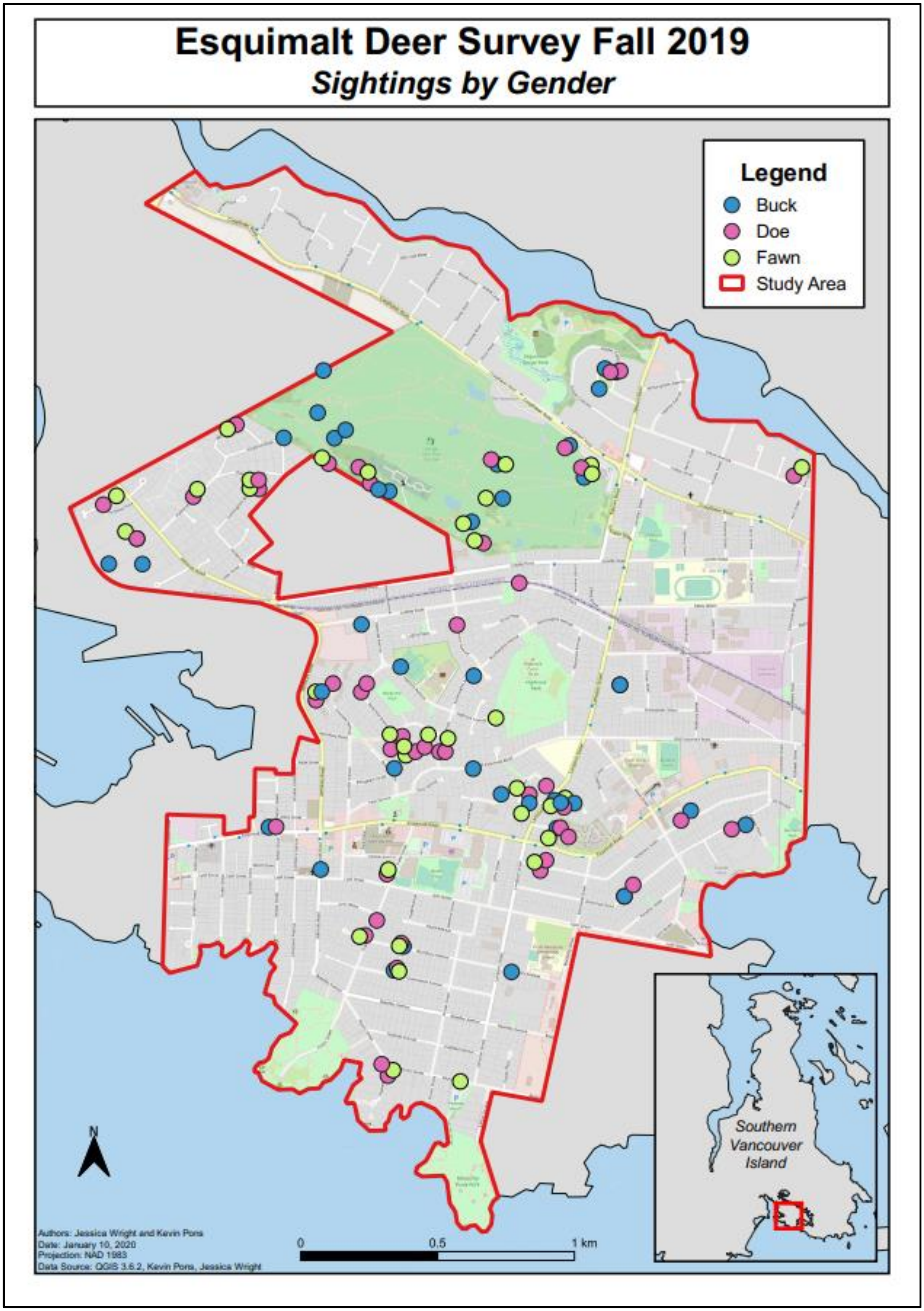


Figure 14: Map of Esquimalt deer survey Fall 2019 (sex and Age-Group map)

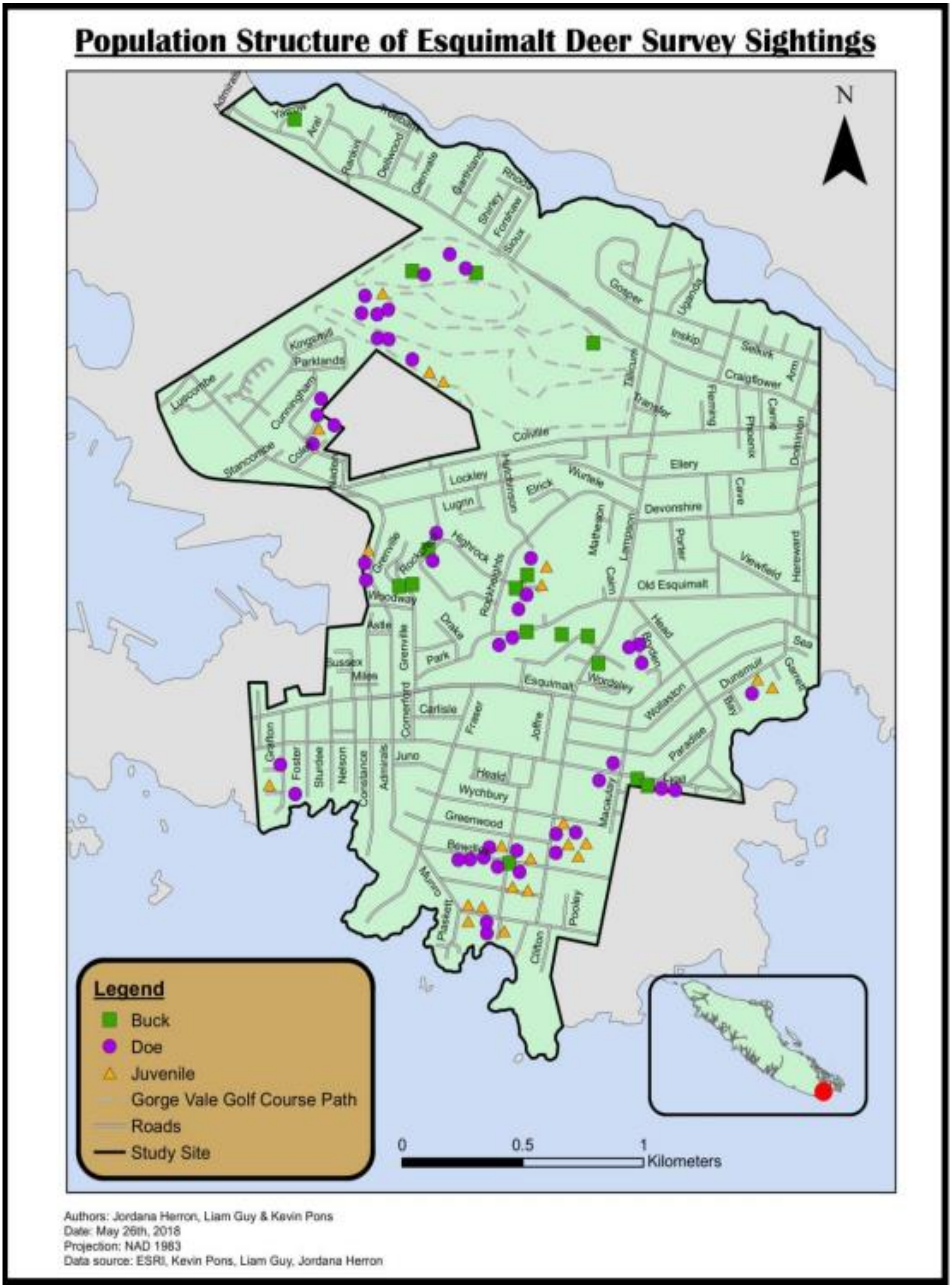


Figure 15: Map of Esquimalt deer survey spring 2018 (sex map)

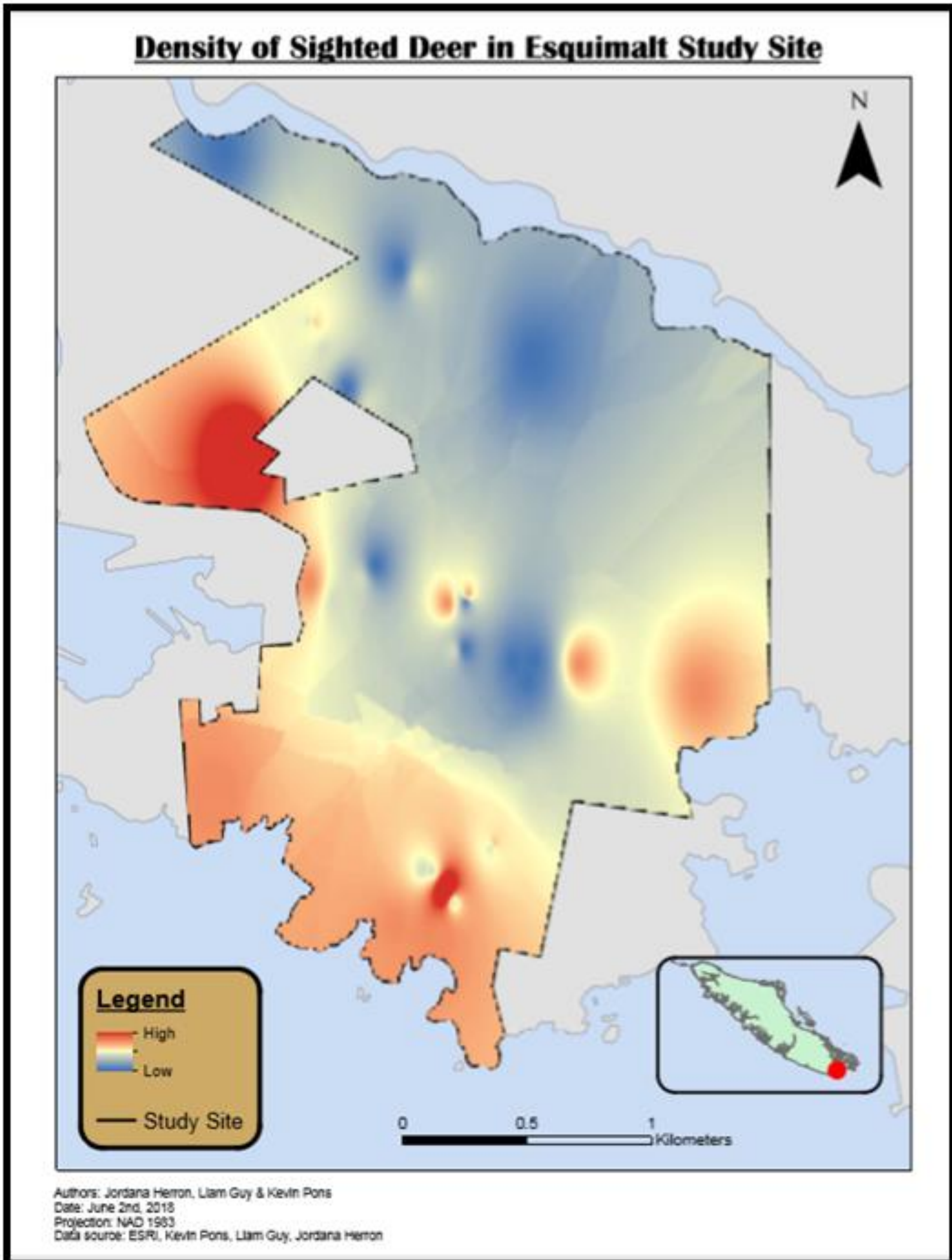


Figure 16: Map of Esquimalt deer survey Spring 2018 (IDW)

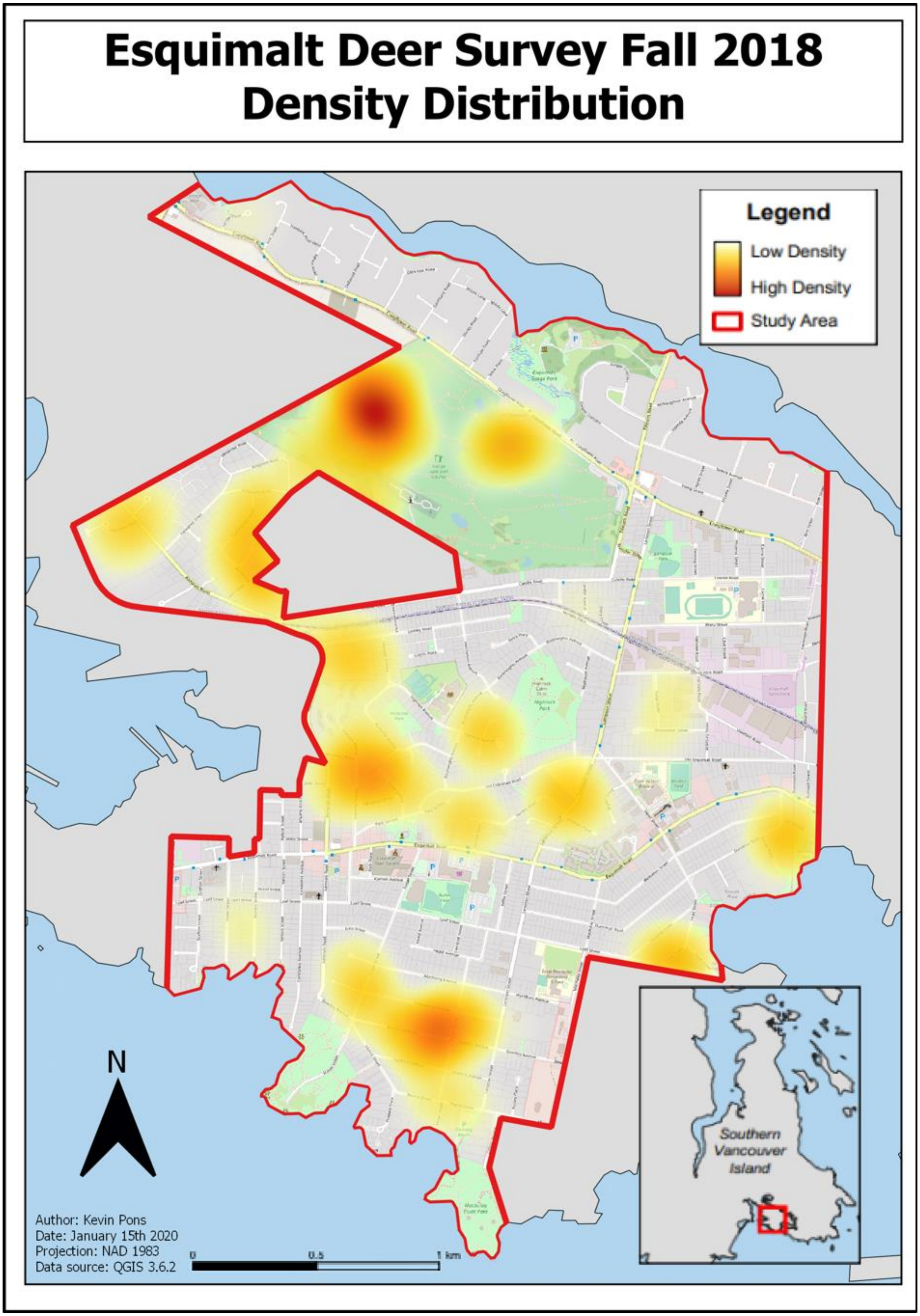


Figure 17: Map of Esquimalt deer survey Fall 2018 (heatmap)

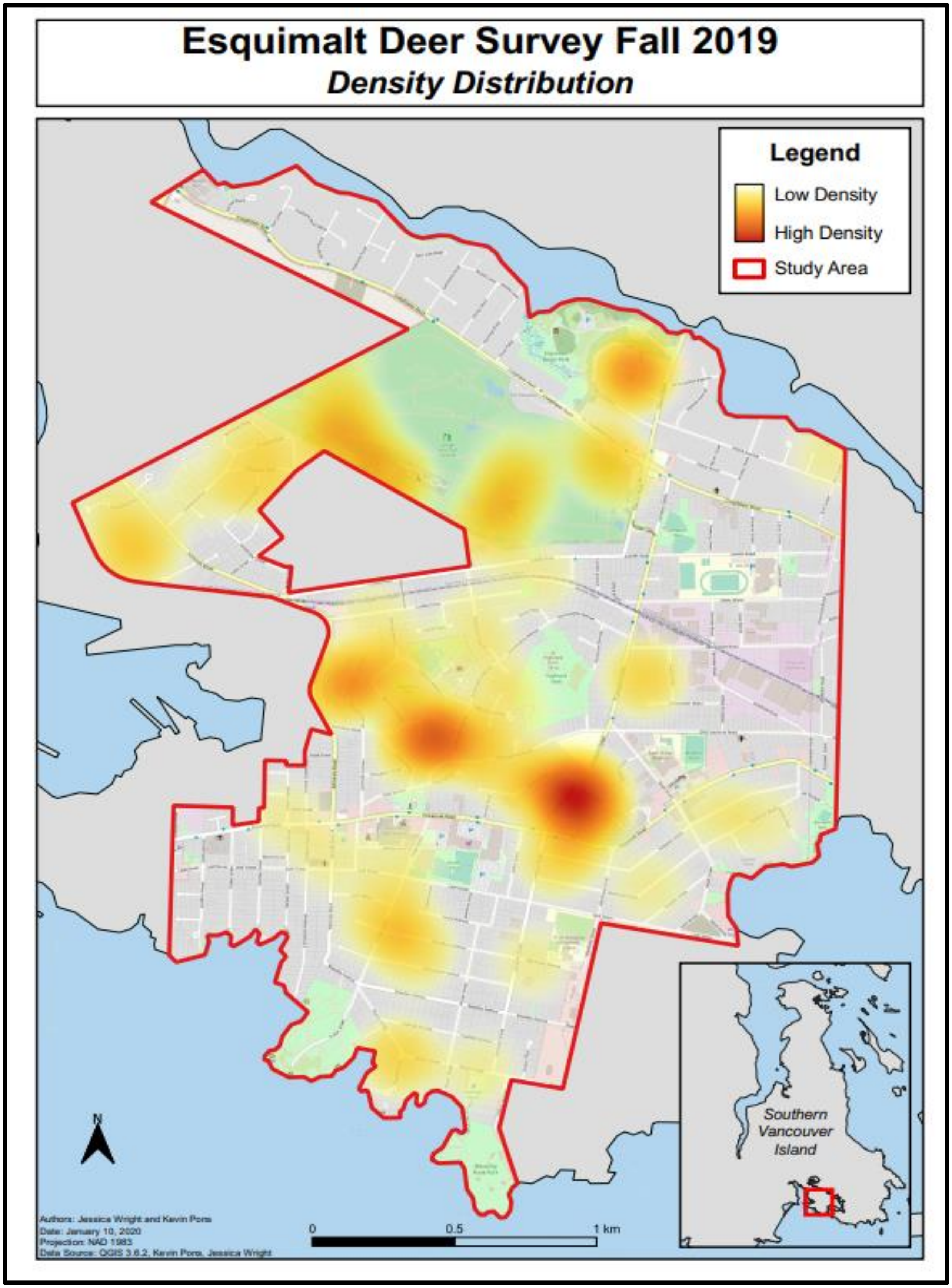


Figure 18: Map of Esquimalt deer survey Fall 2019 (heatmap)

1.An IDW (Inverse Distance Weighted) Interpolation tool was used in ArcGIS to generate a visual representation of the density of deer in Esquimalt (Spring 2018 Survey). ESRI defines the IDW tool as follows: "An interpolation technique that estimates cell values in a raster from a set of sample points that have been weighted so that the farther a sampled point is from the cell being evaluated, the less weight it has in the calculation of the cell's value" (ESRI, n.d.).
The sample points here are the deer sightings collected in the field and these points then become the reference points for all other cells being evaluated in the study area. The Esquimalt study site was used as an extent to define the reach of the raster layer.

2.The Heatmap interpolation tool was used in QGIS to generate a visual representation of the density of deer in Esquimalt (Fall 2018-19). QGIS define the Heatmap tool as follows: “the Heatmap plugin uses Kernel Density Estimation to create a density raster of an input point vector layer. The density is calculated based on the number of points in a location, with larger numbers of clustered points resulting in larger values. Heatmaps allow easy identification of “hotspots” and clustering of points.” (QGIS User Guide, n.d.). The sample points here are the deer sightings collected in the field and these points then become the reference points for all other cells being evaluated in the study area. The Esquimalt study site was used as an extent to define the reach of the raster layer.

12.3 Herd Composition

In order to estimate a local (Esquimalt study site) herd composition ratio, deer sighted were categorized as either buck, doe or fawn. With respect to the 2019 fall survey, a fawn was defined as a deer born around fall or spring 2018. Otherwise, the observed deer was categorized as either mature doe or buck.

Table 2. Outline the herd composition for the 2019 fall survey. Herd composition is determined by comparing the buck:doe and doe:fawn ratios. Each ratio was calculated by dividing the number of sightings in each category by the total number of sightings.

Table 2: Herd Composition in Esquimalt Fall 2018

	Buck	Doe	Fawn	Total
Total number observed	49	58	43	150
Percentage	32.66%	38.67%	28.67%	100%

Doe:buck = 1.18

Meaning that for every 1 buck, there are 1.18 does.

Fawn:doe = 0.74

Meaning that for every 1 doe, there are 0.74 fawns.

Figures 19 and 20 show herd composition percentages and ratios for all Fall 2017 and 2018 and 2019 surveys in Esquimalt and DND land. It can be observed that the herd compositions are very similar. This indicates that the herd composition is stable across the study site and throughout 2017, 2018 and 2019.

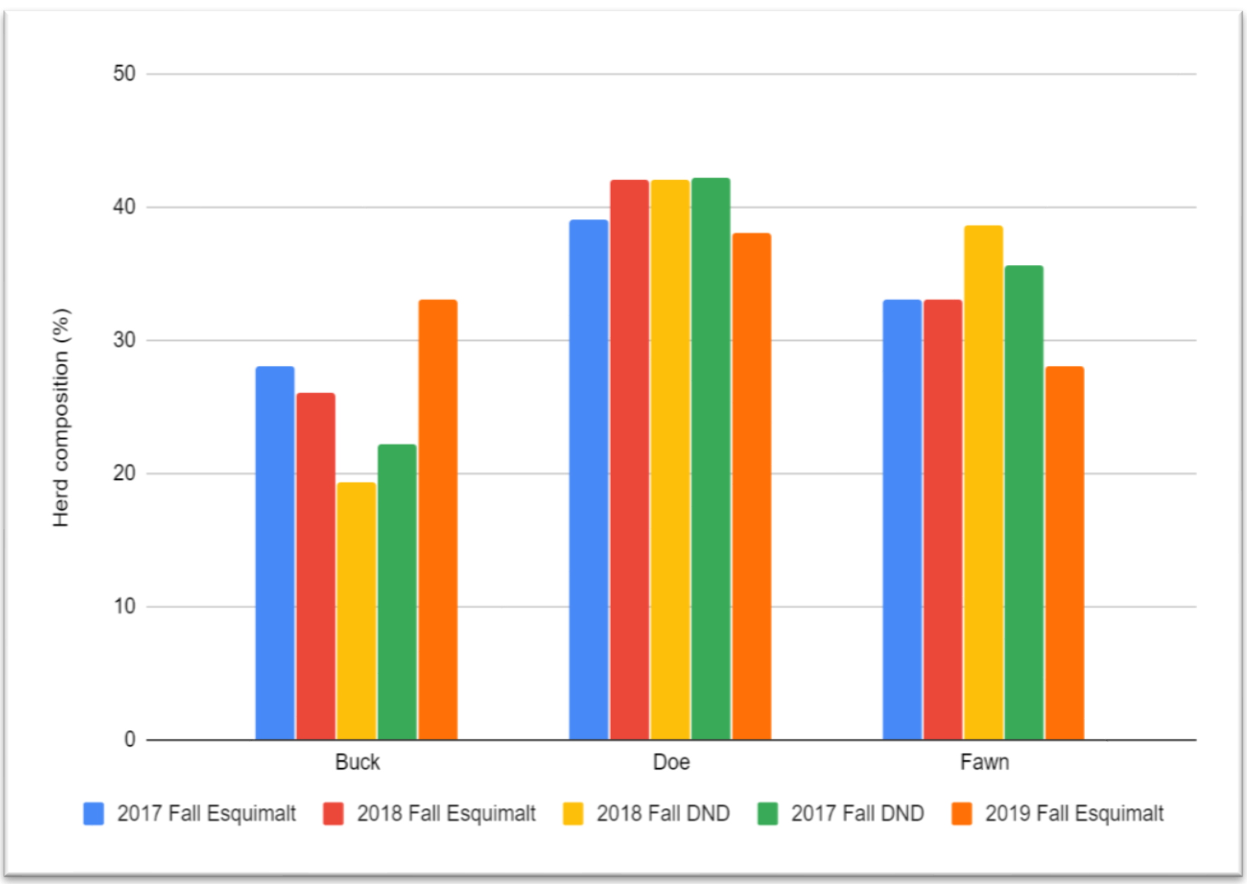


Figure 19: Graph of herd composition % between 5 studies

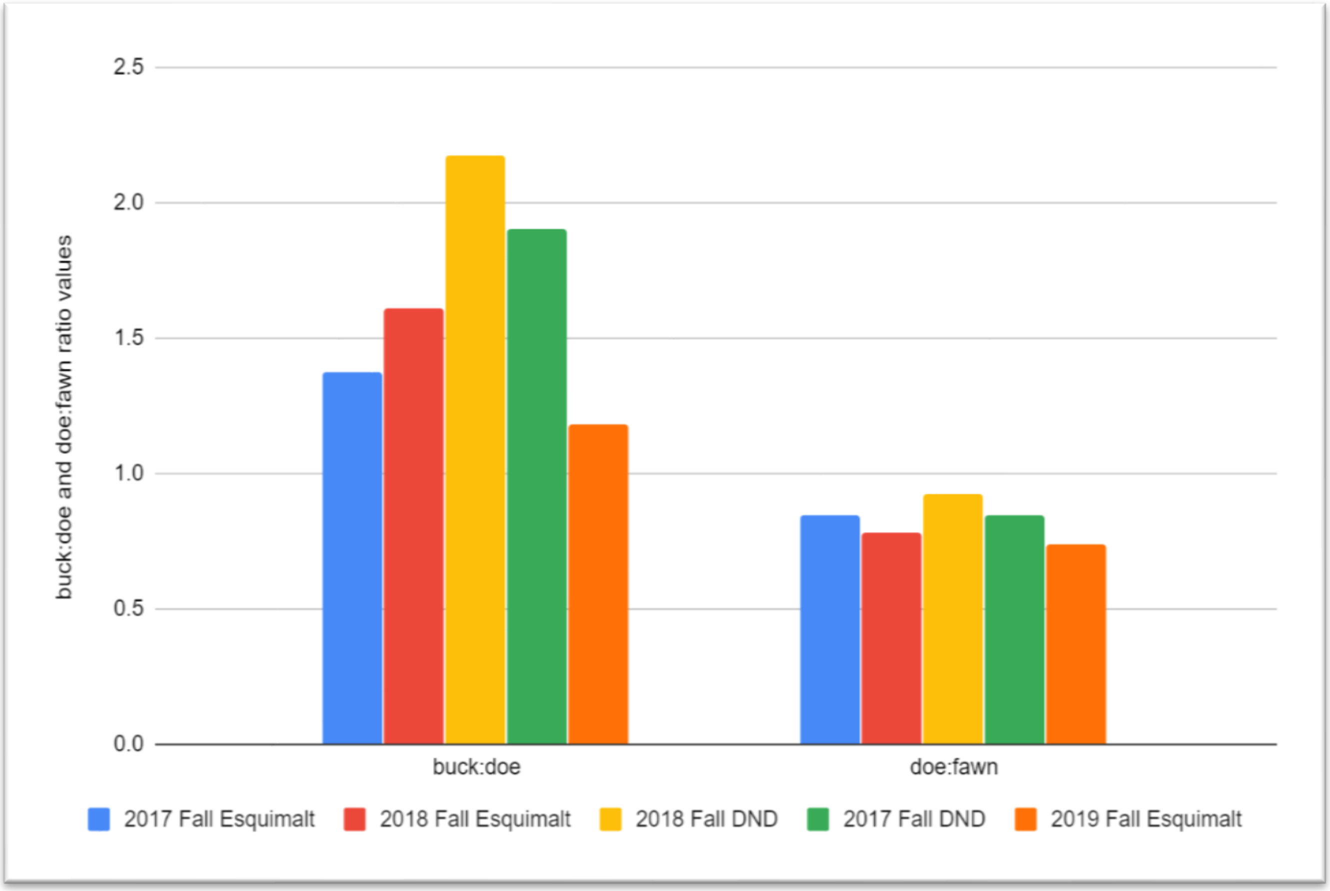


Figure 20: Graph of herd composition ratios between 5 studies

12.4 Null Model

As described in Ecological Methodology by Charles Krebs, the null model uses a provisional range of estimates of population size and a method of maximum likelihood to find the population estimate (N) of interest.

In order for this model to be statistically sound, it should respect the following assumptions:

<u>Assumptions:</u>

1. The population is closed[4], so that N is constant.
2. All animals have the same chance of getting caught in the first sample.
3. Marking individuals does not affect their catchability.

4. Animals do not lose marks between the two sample periods.
5. All marks are reported upon discovery in the second sample.

(Krebs, 2014, p.38)

4.With respect to the assumptions, assuming closed population means that we presume no immigration/emigration occur during the sampling event. In this model, deer are “marked” by taking a picture, this guarantees that marked individuals will not lose their mark, nor the mark will affect their catchability.

The following equation is used in the Null Model to find the buck population estimate in Esquimalt by running a series of trials and errors by using a range of provisional population estimates.

$L(\hat{N}_0, \hat{p}|X) = ln\, ln\, \left(\frac{N!}{(N-M)!}\right) + (n)\, ln\, ln\, (n) + (tN-n)\, ln\, ln\, (tN-n) - (tN) ln\, (tN)$ (Krebs, 2014, p.54)

$\hat{N}_0 = estimated\ population\ size\ from\ the\ null\ model\ of\ CAPTURE$
$N = provisional\ estimate\ of\ population\ size$
$\hat{p} = probability\ of\ capture$
$M = total\ number\ of\ different\ individuals\ captured\ in\ the\ entire\ sampling\ period$
$n = total\ number\ of\ captures\ during\ the\ entire\ sampling\ period$
$t = total\ number\ of\ sample\ days\ (e.g. days)$
$ln = natural\ log\ (log_e)$
$L = log\ likelihood\ of\ the\ estimated\ value\ \hat{N}_0\ and\ p, given\ the\ observed\ data$ (Krebs, 2014, p.54)

The relevant information inputted were t = 25 days, M = 28 different individuals captured in the entire sampling period and n = 49 overall captured individuals during the entire sampling period.

Sample calculation for N = 36:

$$L(\hat{N}_0, \hat{p}|X) =$$

$$ln\, ln\, \left(\frac{36!}{(36-28)!}\right) + (49)\, ln\, ln\, (49) + (10(36) - 49)\, ln\, ln\, (10(36) - 49) - (10(36)) ln\, (10(36))$$
$$= -58.10$$

The following figure represents the results of the Null Model calculations on Excel generated from provisional population estimate ranging between

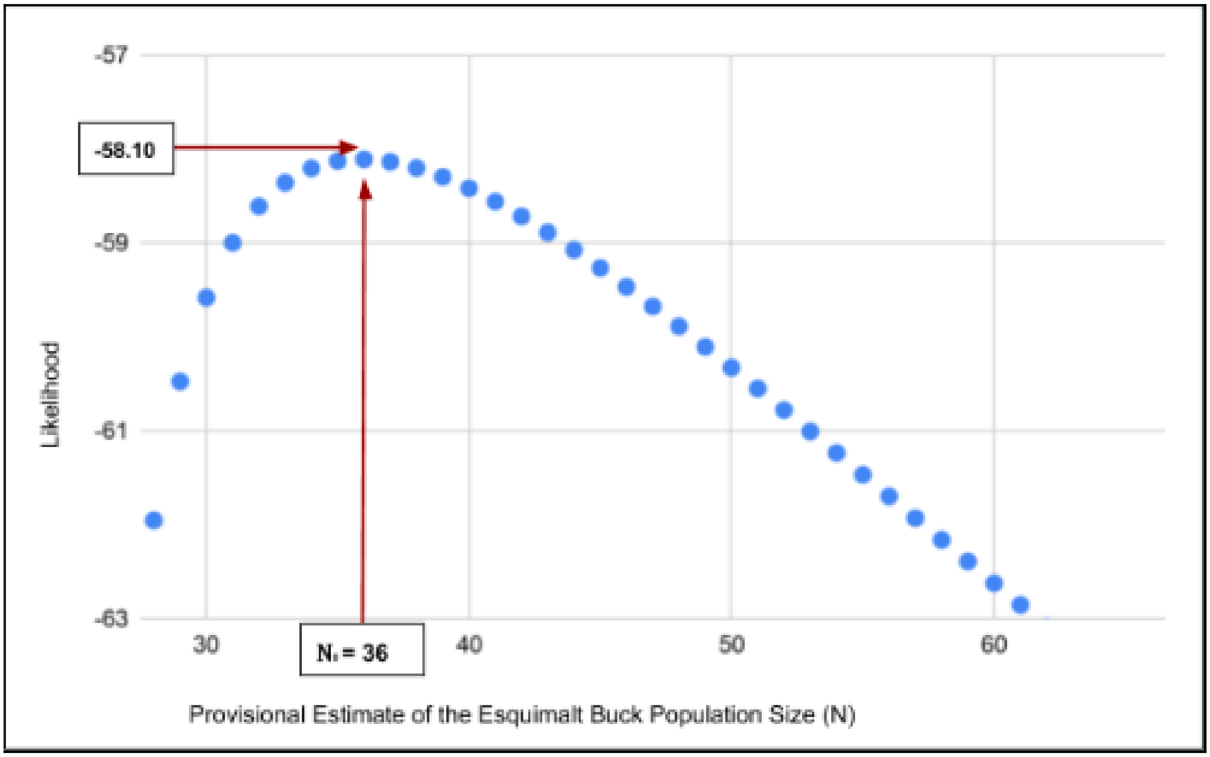


Figure 21: Graph of the Null Model used to generate the 2019 Esquimalt Buck Population Estimate by Kevin Pons

The graph indicates that the maximum likelihood of the 2019 buck population size is 36.

Following this estimate, is the probability of capture. It can be calculated with the following equation:

$$\hat{p} = \frac{n}{t\hat{N}_0}$$ (Krebs, 2014, p.55)

Given the parameters of the Survey (n = 49 bucks, t = 10 sampling event per week and a buck population estimate of 36 bucks),

$$\hat{p} = \frac{n}{t\hat{N}_0} = \frac{49}{10\ (36)} = 0.13$$

The next step will be to estimate the variance given that we know the probability of capture, which can be determined from the following equation:

$$\widehat{Var}(\hat{N}_0) = \frac{\hat{N}_0}{(1-\hat{p})^{-t} - \left(\frac{t}{1-\hat{p}}\right) + t - 1}$$ (Krebs, 2014, p.55)

Given n = 49 bucks, t = 10 sampling event per week, p_0 = 0.13 and N_0 = 36 bucks, the variance is:

$$\widehat{Var}(\hat{N}_0) = \frac{36}{(1-0.13)^{-10} - \left(\frac{10}{1-0.13}\right) + 10 - 1} = 20.64$$

The resulting 95% confidence interval can be calculated from the equation (where z_α = standard normal deviate):

$$95\%\ confidence\ intervals = \hat{N}_0 \pm z_a\sqrt{\widehat{Var}(\hat{N}_0)} \qquad \text{(Krebs, 2014, p.55)}$$

The resulting 95% confidence interval from the previous variance equation is:

$$\hat{N}_0 \pm 1.96\sqrt{20.64}$$

$$36 \pm 9\ bucks$$

In this case, the Null Model indicates that the Esquimalt study site is home to 36 ± 9bucks.

The results from the 2019 Null Model estimate is compared to the 2017 and 2018 fall results, and represented in Table 3 and Figure22.

Table 3: Null model population estimate for bucks

Bucks only	2017 Fall	2018 Fall	2019 Fall
Lower 95% confidence limit	13	26	27
Population estimate	40	35	36
Upper 95% confidence limit	67	44	45

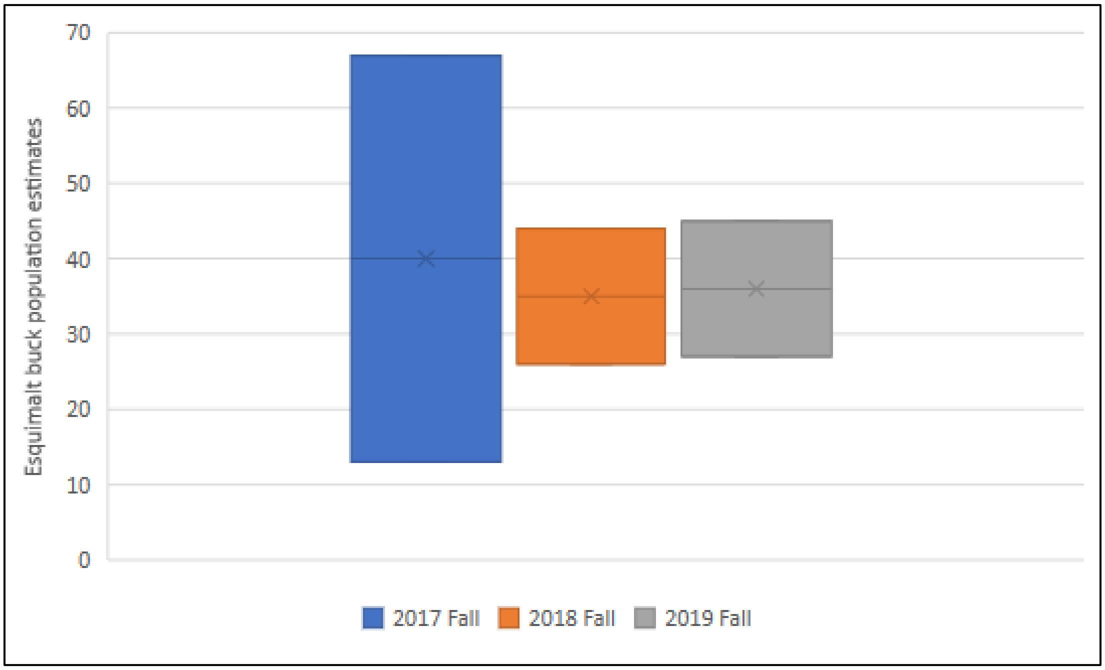


Figure 22: Graph of population estimate for bucks in Esquimalt for Fall 2017, 2018 and 2019 by Kevin Pons

While looking at the 95% confidence interval displayed in figure 22, we can see that the 95% confidence interval of the 2017 fall survey is roughly three times larger than the 2018 and 2019 fall survey. This was mainly driven by the fact that the 2017 Fall survey (pilot study) had a much smaller sample size. Only three weeks was allocated for the Esquimalt deer survey which resulted in 30 samples, whereas both the fall 2018 and 2019 survey allocated 5 weeks for a total of 50 samples. Increasing the number of samples from 30 to 50 samples has decreased the 95% confidence interval by approximately 67 **%** for both the fall 2018 and 2019 survey.

The final step in order to provide a population estimate is to apply the herd composition ratio to the buck estimate to extrapolate total deer population size.
Herd ratios are used because it is much more time consuming and challenging to perform a Mark-Recapture with the does and fawns. Both are harder to identify as they do not have distinctive features unlike the bucks. This limits the capacity of the crew on site to build a photographic catalogue with high quality pictures for the identification process.

The herd composition of the Fall 2019 survey was determined by comparing the ratios buck to doe and buck to fawn ratios. In order to ensure that the experimental herd ratios were representative of the deer population in Esquimalt, it was averaged with the previous 2018 spring survey and the 2017, 2018 and 2019 fall surveys. It is assumed that herd composition and demographics have stayed constant over the years. The averaged doe:buck ratio is 1.74 and the averaged doe:fawn ratio is 0.72. The doe and fawn population were extrapolated to a total population estimate of **125 deer**.

Table 4:Extrapolating buck estimates to total deer estimates

	ratio	**Estimate**
Bucks	-	36
Does	1.74	63
Fawns	0.72	26
Total	-	125

The ratios for the 95% confidence interval of both does and fawns were extrapolated from the buck 95% confidence interval and the herd composition ratios.

Table 5: 2017, 2018 and 2019 deer population extrapolated from the null model the local herd composition ratios

Esquimalt deer population	2017 Fall	2018 Fall	2019 Fall
Lower 95% confidence limit	44	100	93
Population estimate	135	135	125
Upper 95% confidence limit	226	170	156

13 Discussion

13.1 Herd Composition

As previously stated by Megan Sakuma in the Esquimalt Fall 2018 Survey, studies of un-hunted deer population generated a buck:doe ratio of 45:100 (Hines, 1975), 61:100 (Anderson et al, 1974), 74:100 (Longhurst et al, 1952), and 83:100 (Swank 1958) (as cited by Connolly, 1981, pp. 261). In the same manner as the Esquimalt Fall 2018 Survey, the Esquimalt Fall 2019 Survey has buck:doe and doe:fawn ratios comparable to those identified by Connolly. One simple reason for the underrepresentation of bucks in the population is likely due to a high mortality rate following injuries sustained during the rutting season. Furthermore, it was also identified in the previous 2018 report, that fawn survival rate is estimated to range between 45-69% (Hatter & Janz, 1994). This coincides with the 2019 doe:fawn ratio of 0.72 as it was estimated that healthy does contribute approximately one and a half fawn per year (Bunnell, 1990, page 36). F

13.2 Extrapolating Buck to Total Deer Estimate

As cited in the previous 2018 report by Megan Sakuma, it is important to extrapolate buck to total deer estimate during the rutting season as it is the time of the year when adult males are most likely to be freely intermixed with other population components thus providing an unbiased adult sex ratio (Bender, 2006, p. 1227) (as cited by Sakuma, 2018).

The total deer population estimate was derived by extrapolating the buck estimate to the observed herd composition ratio (which is an averaged herd composition ratio of the Fall Esquimalt Survey 2017/2018/2019 and Spring 2018 survey). This report assumes that the averaged herd composition observed is a true representation of the Esquimalt deer population.

As previously cited by Sakuma M., the rutting season provides an ideal opportunity to observe a non-biased herd composition. If the survey were to be performed outside this mating window, it would likely result in a herd composition biased towards bucks. This could greatly skew the data resulting in an inaccurate population estimate.

13.3 Department of National Defense Deer Survey

The DND started conducting yearly surveys since 2016 on Canadian Forces Base (CFB) Esquimalt which is located adjacent to the Township of Esquimalt. Survey methods differed slightly in both the Esquimalt study site and CFB Esquimalt site, as there are differences in habitat, traffic and site use. Some areas of CFB Esquimalt are not open to the public, don't allow pets and have enforced lower speed limits. There is also significantly less traffic on base properties as opposed to the main driving road in the Esquimalt study site, which is one of two ways people from Langford, Colwood and the rest of the upper Vancouver Island can reach Victoria.

The Esquimalt surveys were coordinated with DND surveys in the fall 2017, 2018 and 2019 to be performed simultaneously. When possible, both the Esquimalt and the DND survey teams would survey areas adjacent to each other and fan out in opposite directions to reduce the probability of potential double counts to its minimum.

The survey methodology differed slightly between the two teams. In 2019, DND maintained the same methodology with respect to their Fall 2017 and 2018 surveys (P. Swan, personal communication, January 23, 2020). DND staff surveyed each site, every week, for three weeks at the same time that the Esquimalt Survey was happening. CFB Esquimalt sites surveyed were: Dockyard, Signal Hill, Naden, North Naden and Work Point properties for a total area surveyed of 1.59 km^2.

During the Fall 2019 Survey, DND estimated the deer population density to be 41.51 deer/km^2 for all surveyed properties (P. Swan, personal communication, January 14, 2020). This result is consistent with the previous 2017 Deer Survey (40 deer/km^2) and the 2018 Deer Survey (44 deer/km^2) (Sakuma, 2018, pp.25) and appears to indicate a stable population (P. Swan, personal communication, January 23, 2020).

13.5 Sources of error

- IDW**:** "This method assumes that the variable being mapped decreases in influence with distance from its sampled location" (ESRI, 2016). The cells surrounding a sample point will have decreasing weight with increasing distance from the sample data. In other words, areas further away from the sample data will have more unpredictable densities.
- On main roads, slowest constant speed was highly variable as traffic affected the speed consistency during the survey. Driving at higher speed can decrease the probability of sighting a deer which would cause an underrepresentation of buck, doe and fawn in the observed population.
- Daylight savings occurs midway through the survey and tends to align the dusk survey with the peak traffic at around 4pm. This can greatly slow the survey down and cause difficult light conditions for photography, which can impact the data quality as well the probability of sighting a deer.
- Probability of double count greater when dealing with doe and fawns during the survey as they are more difficult to recognize This can lead to an overrepresentation of doe and fawn in the observed population.
- The Gorge Vale Golf Course could not be sampled in reverse as it would have caused too much disruption for the golfers, and we therefore did not have permission to do so. This affected the probability of sighting deer which has the potential to skew the data.
- Uncertainties regarding the herd composition given a 45-69% juvenile survival and recruitment rate, as well as overall immigration/emigration between

Esquimalt and the surrounding areas. Double-counting does/fawns would skew herd ratio in favor of does/fawns, which in turns would inflate the overall deer population estimate.

14. Conclusion

The result of the Null Model (buck population estimate only) from the Fall 2019 survey (n = 10) produced 95% confidence limits with a lower confidence limit of 27 to an upper confidence limit of 45 bucks, with an estimate of 36 bucks. Furthermore, the herd composition ratio was extended to the buck estimate to extrapolate the total deer population estimate. This resulted in 95% confidence limits with a lower confidence limit of 93 to an upper confidence limit of 156 total deer, with an estimate of 125 deer.

The result of the Null Model (buck population estimate only) from the Fall 2018 survey (n = 10) produced 95% confidence limits with a lower confidence limit of 26 to an upper confidence limit of 44 bucks, with an estimate of 35 bucks. Furthermore, the herd composition ratio was extended to the buck estimate to extrapolate the total deer population estimate. This resulted in 95% confidence limits with a lower confidence limit of 100 to an upper confidence limit of 170 total deer, with an estimate of 135 deer.

With respect to the Esquimalt Fall 2017 survey, the result of the Null Model (buck population estimate only, n = 6) produced 95% confidence limits with a lower confidence limit of 13 to an upper confidence limit of 67 bucks, with an estimate of 40 bucks. Furthermore, the herd composition ratio was extended to the buck estimate to extrapolate the total deer population estimate. This resulted in 95% confidence limits with a lower confidence limit of 44 to an upper confidence limit of 226 total deer, with an estimate of 135 deer.

As mentioned in the previous 2017 and 2018 Fall Esquimalt reports, total deer population estimates were based on the observed herd composition ratios and assume equal probabilities for sighting bucks, does, and fawns.

There is no statistical difference in the deer population estimates between the 2017, 2018 and 2019 Esquimalt Deer Surveys (as evident by overlapping 95% confidence intervals). While cautiously considering the low confidence in the Esquimalt Fall 2017 survey (as indicated by the large confidence intervals), the Null Model generated three population estimates of 135 deer for the fall 2017 and 2018 surveys and 125 deer for the fall 2019 survey. After increasing the number of samples from 30 total samples in 2017 to 50 total samples in 2018 and 2019, we obtained closely similar confidence ranges that overlapped each other.

Through consistent application of the Null Model to conducted deer surveys, we observed highly similar total deer population estimates over the last three years. However, overlapping confidence intervals between survey estimates preclude us from definitely concluding that this population has not fluctuated over the duration of this study. While it is equally possible that the total deer population has been increasing or decreasing over the last three years, the similar observed deer population size estimates offer some confidence that this population remains relatively stable. Continued monitoring will provide insights into any dramatic population-level changes, while application of a more comprehensive survey approach (e.g. camera trapping) may yield more precise population estimates for monitoring smaller, short-term fluctuations in deer abundance across Esquimalt.

15. Recommendations

- Continued deer monitoring in Esquimalt to confirm if the long-term population trend is stable. This would likely be achieved through a more rigorous study methodology using camera trapping while the current approach should detect any obvious changes to overall deer abundance in Esquimalt over time, a more comprehensive survey approach would be needed to monitor for smaller short-term population size responses.

- Further surveys should consider cutting the park survey from the method as almost no deer were sighted in those areas (due to high traffic, dog presence etc…).

- Compare the Esquimalt herd composition with other projects (such as the Oak Bay project) to ensure buck:doe and doe:fawn ratios are accurate.

- Use camera traps for a more precise estimate of the deer population, movement patterns and density.

- Focus on public education and signage in areas with higher deer densities as identified over the 2017/2018/2019 surveys.

16. Reference

Bailey, J; Brown, S; Sakuma, M. (2016). An Assessment of the Population and Ecology of the Columbian Black-tailed Deer (Odocoileus heimonus columbianus) in Oak Bay, Vancouver Island.

Bender, L. (2006). Uses of Herd Composition and Age Ratios in Ungulate Management. Wildlife Society Bulletin 34(4): 1225-1230.

Bunnell, F. L. (1990). Chapter 2 – Black-tailed deer ecology. In: Special Report Series 5: Deer and elk habitats in coastal forests of southern British Columbia. (page 35). Nyberg, J. B., and Janz, D. W., BC Ministry of Forests Special Report Series 5 and BC Ministry of Environment Technical Monograph #2.

Connolly, G. (1981). Chapters 6, 7, & 8. In: Wallmo, O.C. (Eds.), Mule and Black-tailed Deer of North America (pp. 225-346). Lincoln, N.E: University of Nebraska Press.

Krebs, C. J. (2014). Estimating Abundance in Animal and Plant Populations. In C. J. Krebs, Ecological Methodology (3rd Edition ed., pp. 54-55). Vancouver: Pearson. Retrieved from: http://www.zoology.ubc.ca/~krebs/books.html

Ministry of Environment, Lands and Parks. (2000). *Mule and Black-tailed Deer.* Retrieved from: http://www.env.gov.bc.ca/wld/documents/muledeer.pdf

ESRI. (2016). How IDW works. Retrieved January 12, 2020, from ArcGIS for Desktop: http://desktop.arcgis.com/en/arcmap/10.3/tools/3d-analyst-toolbox/how-idw-works.htm

ESRI. (n.d.). GIS Dictionary. Retrieved January 12, 2020, from ESRI: https://support.esri.com/en/other-resources/gis-dictionary/term/bf355b00-7abc-4e49-8668-7999519ead42

Hatter, I; Janz, D. (1994). Apparent demographic changes in black-tailed deer associated with wolf control on northern Vancouver Island. Can. J. Zool. 72: 878-884.

Nyberg, B. (2016). *Urban Deer in Esquimalt: Resident Experiences and Opinions.* *https://www.esquimalt.ca/sites/default/files/docs/public-safety/CSS/urban_deer_in_esquimalt_final_13dec2016.pdf*

Prentiss, J. (2017). *CFB Esquimalt Black-tailed Deer Count- Dockyard, Signal Hill & Naden, North Naden and Work Point Properties.*

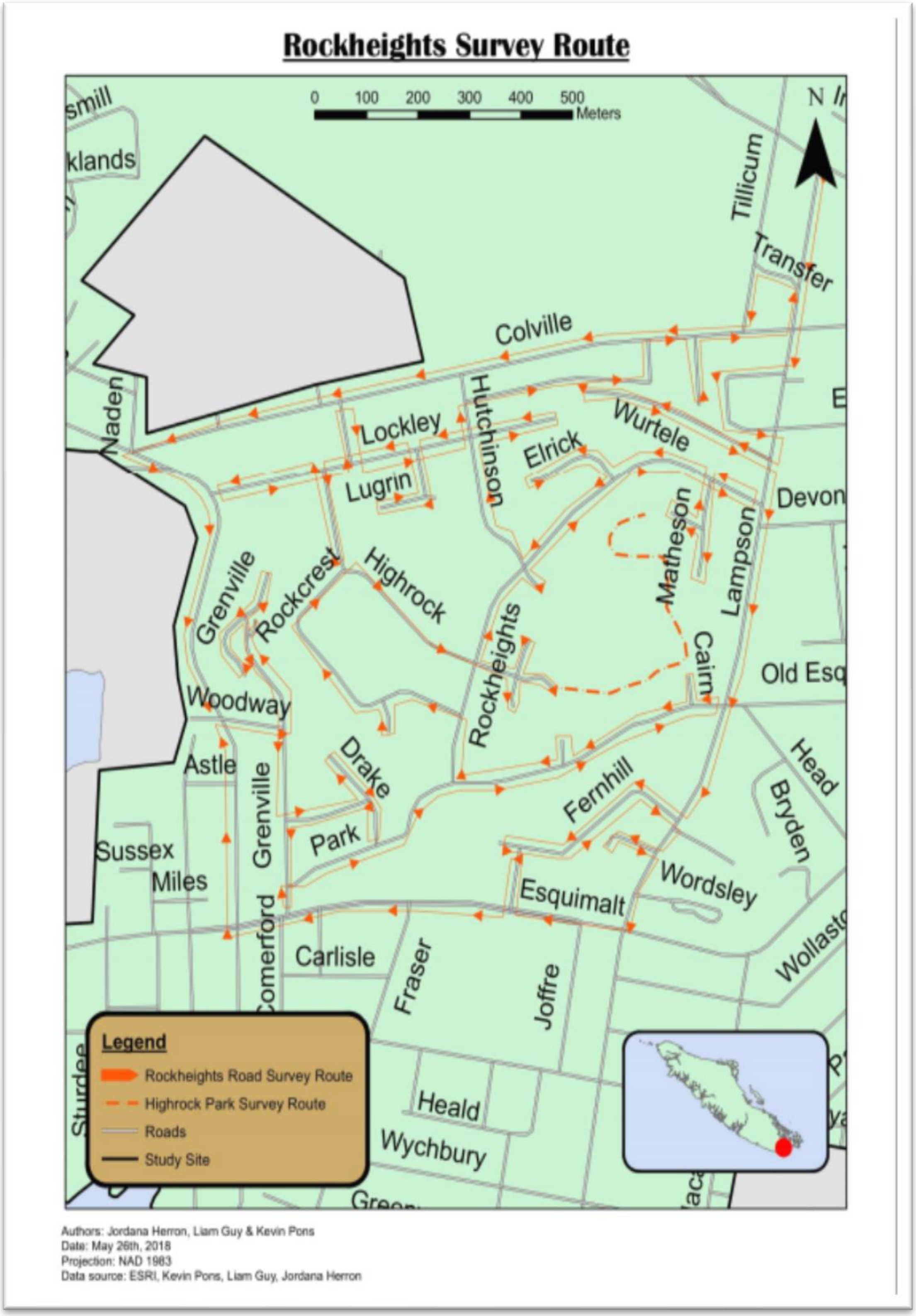
QGIS User Guide. Heatmap Plugin. (n.d.). Retrieved from https://docs.qgis.org/2.18/en/docs/user_manual/plugins/plugins_heatmap.html

Sakuma, M. (2018). Population Estimate Survey of the Columbian Black-tailed Deer in Esquimalt, BC (pp. 10–30). Victoria, British Columbia.

WildSafe BC. (2020). Deer. Retrieved from: https://wildsafebc.com/deer/

17. Appendix

Appendix A

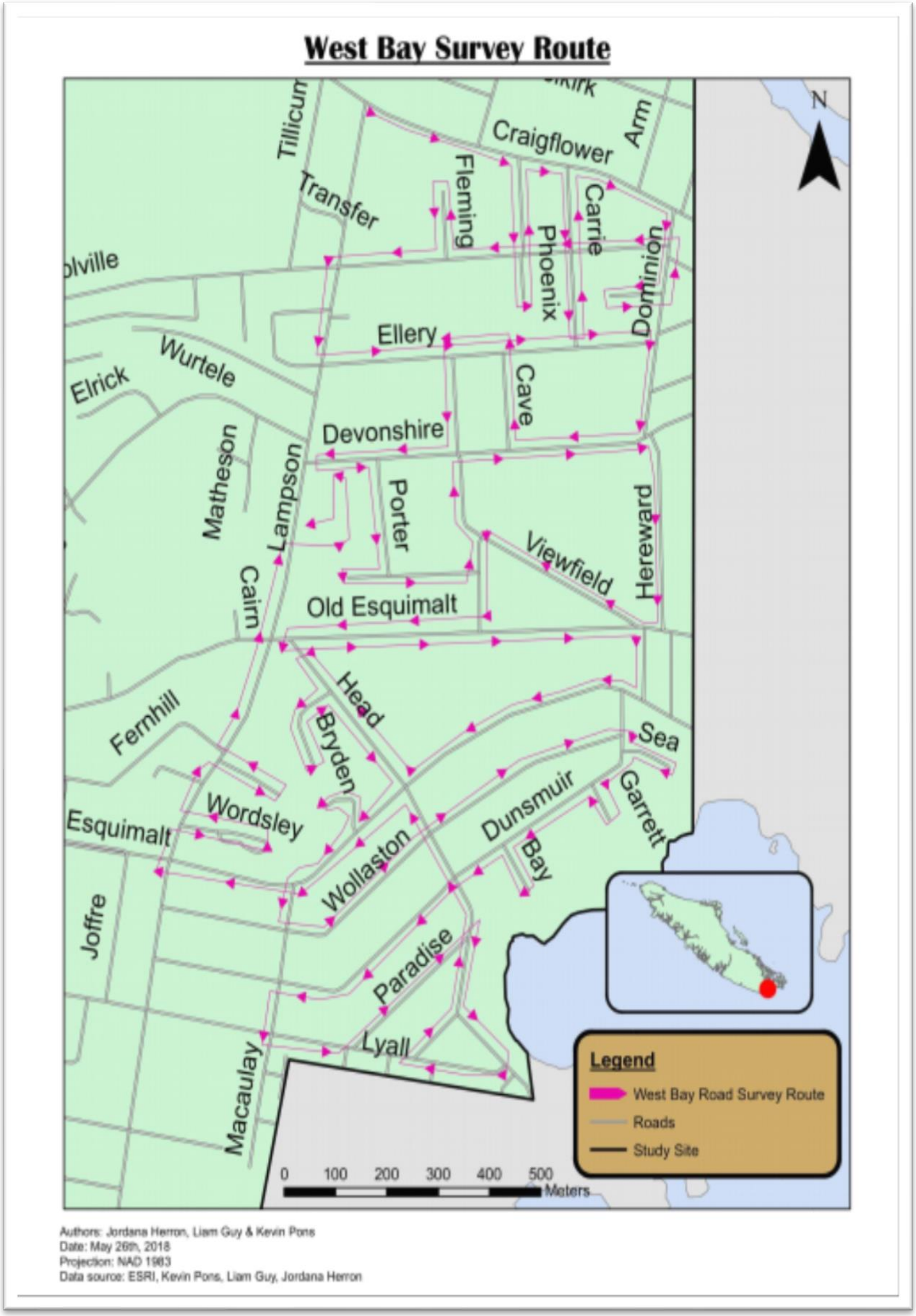


Appendix B

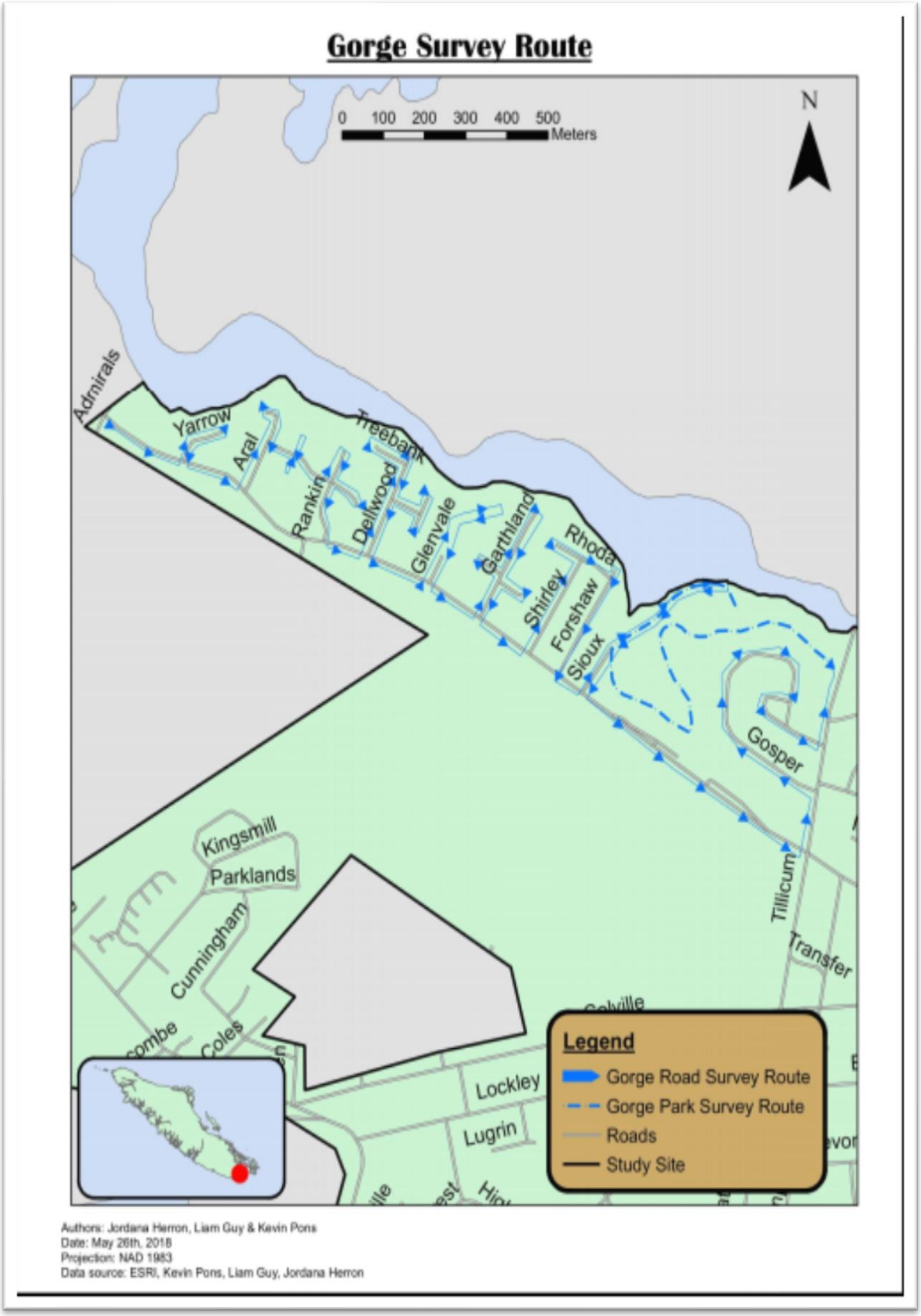
Esquimalt Village Survey Route

Authors: Jordana Herron, Liam Guy & Kevin Pons
Date: May 26th, 2018
Projection: NAD 1983
Data source: ESRI, Kevin Pons, Liam Guy, Jordana Herron

Appendix C

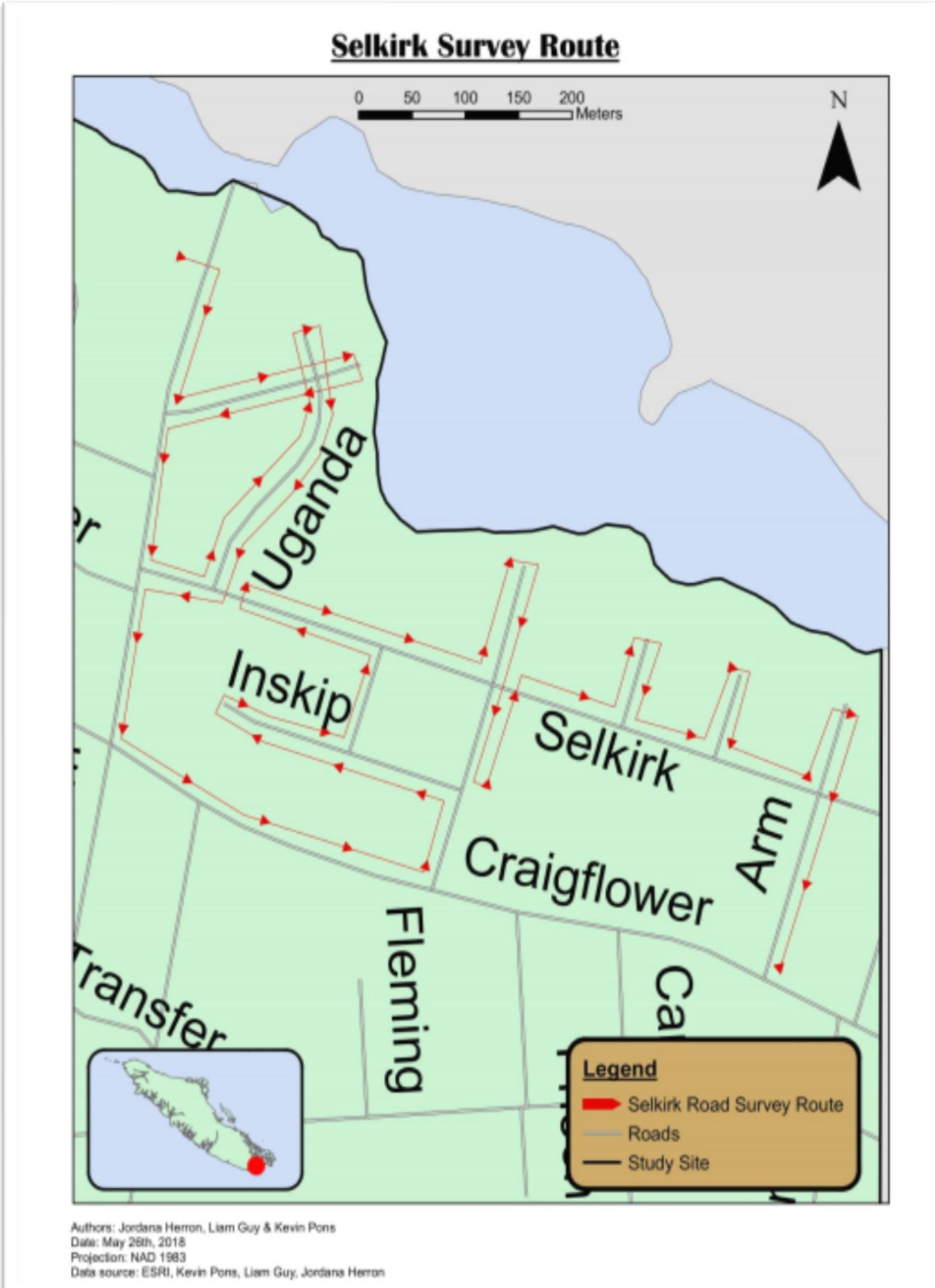

West Bay Survey Route
Craigflower
Arm
Tillicum
Transfer
Fleming
Phoenix
Carrie
Dominion
Ellery
Wurtele
Elrick
Cave
Devonshire
Matheson
Lampson
Porter
Viewfield
Hereward
Cairn
Old Esquimalt
Head
Fernhill
Bryden
Sea
Wordsley
Esquimalt
Dunsmuir
Garrett
Bay
Wollaston
Joffre
Paradise
Lyall
Macaulay
N
Legend
West Bay Road Survey Route
Roads
Study Site
0
100
200
300
400
500
Meters
Authors: Jordana Herron, Liam Guy & Kevin Pons
Date: May 26th, 2018
Projection: NAD 1983
Data source: ESRI, Kevin Pons, Liam Guy, Jordana Herron

Appendix D



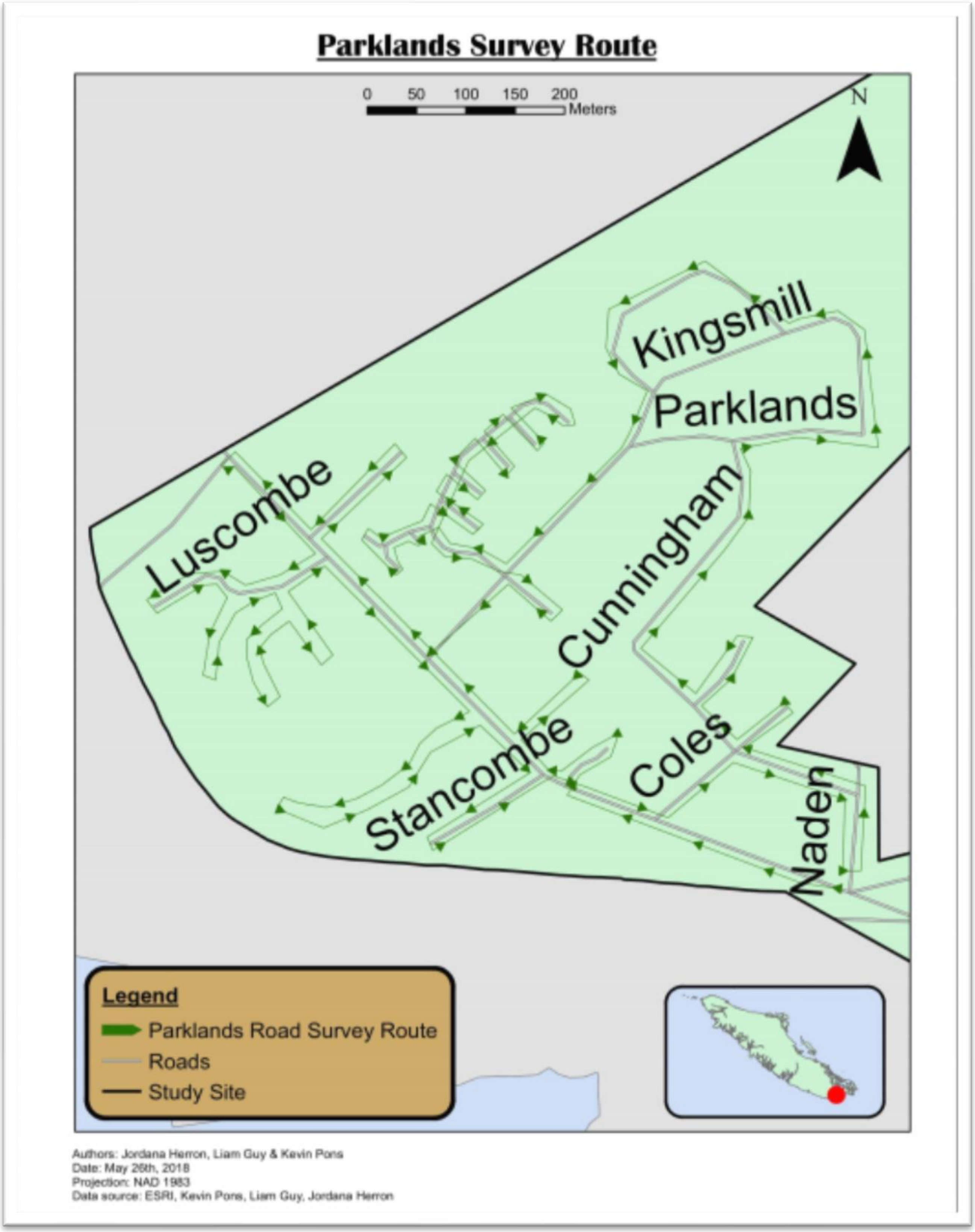
Gorge Survey Route
0 100 200 300 400 500
Meters
N
Admirals
Yarrow
Aral
Treebank
Rankin
Dellwood
Glenvale
Garthland
Rhoda
Shirley
Forshaw
Sioux
Gosper
Tillicum
Transfer
Kingsmill
Parklands
Cunningham
Coles
Lockley
Lugrin
Legend
Gorge Road Survey Route
Gorge Park Survey Route
Roads
Study Site
Authors: Jordana Herron, Liam Guy & Kevin Pons
Date: May 26th, 2018
Projection: NAD 1983
Data source: ESRI, Kevin Pons, Liam Guy, Jordana Herron

Appendix E



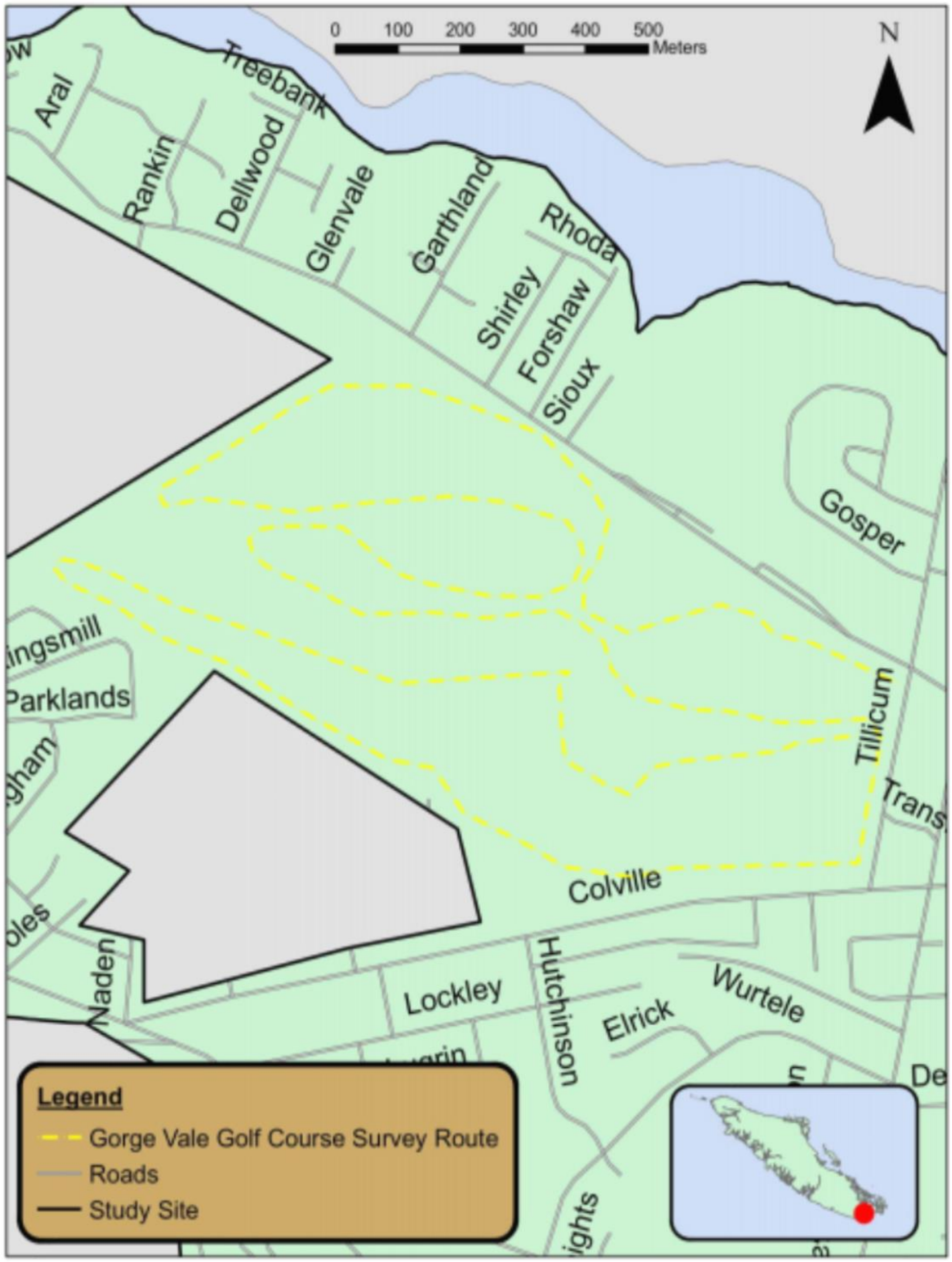
Selkirk Survey Route
0 50 100 150 200
Meters
N
Uganda
Inskip
Selkirk
Craigflower
Arm
Fleming
Transfer
Legend
Selkirk Road Survey Route
Roads
Study Site
Authors: Jordana Herron, Liam Guy & Kevin Pons
Date: May 26th, 2018
Projection: NAD 1983
Data source: ESRI, Kevin Pons, Liam Guy, Jordana Herron

Appendix F


Parklands Survey Route
0 50 100 150 200
Meters
N
Kingsmill
Parklands
Luscombe
Cunningham
Stancombe
Coles
Naden
Legend
Parklands Road Survey Route
Roads
Study Site
Authors: Jordana Herron, Liam Guy & Kevin Pons
Date: May 26th, 2018
Projection: NAD 1983
Data source: ESRI, Kevin Pons, Liam Guy, Jordana Herron

Appendix G

Gorge Vale Golf Course Survey Route



Authors: Jordana Herron, Liam Guy & Kevin Pons
Date: May 26th, 2018
Projection: NAD 1983
Data source: ESRI, Kevin Pons, Liam Guy, Jordana Herron

Appendix H

Field Guide for Aging and Sexing Black Tailed Deer*

Age Class	General Description		
Fawn	• Still has spotted coat • Small, square body • Short neck, nose and forehead • Travels with mum, but also seen hiding alone	**MALE & FEMALE** 	
Yearling	• No spots • Small, square body • Short neck, nose and forehead	**MALE** • Head appears flatter • Presence of antler pedicles 	**FEMALE** • Head appears rounder • No developing antlers 
Mature	• Large rectangular body • Long neck, nose and forehead • Often has swaying back or sagging belly	**MALE** • Presence of antlers or pedicles • Head appears flatter 	**FEMALE** • No antlers or pedicles • Head appears rounder 

*Some Deer individuals pictured above are not specifically Black Tailed Deer species, but do exhibit the same identifying characteristics

Appendix I

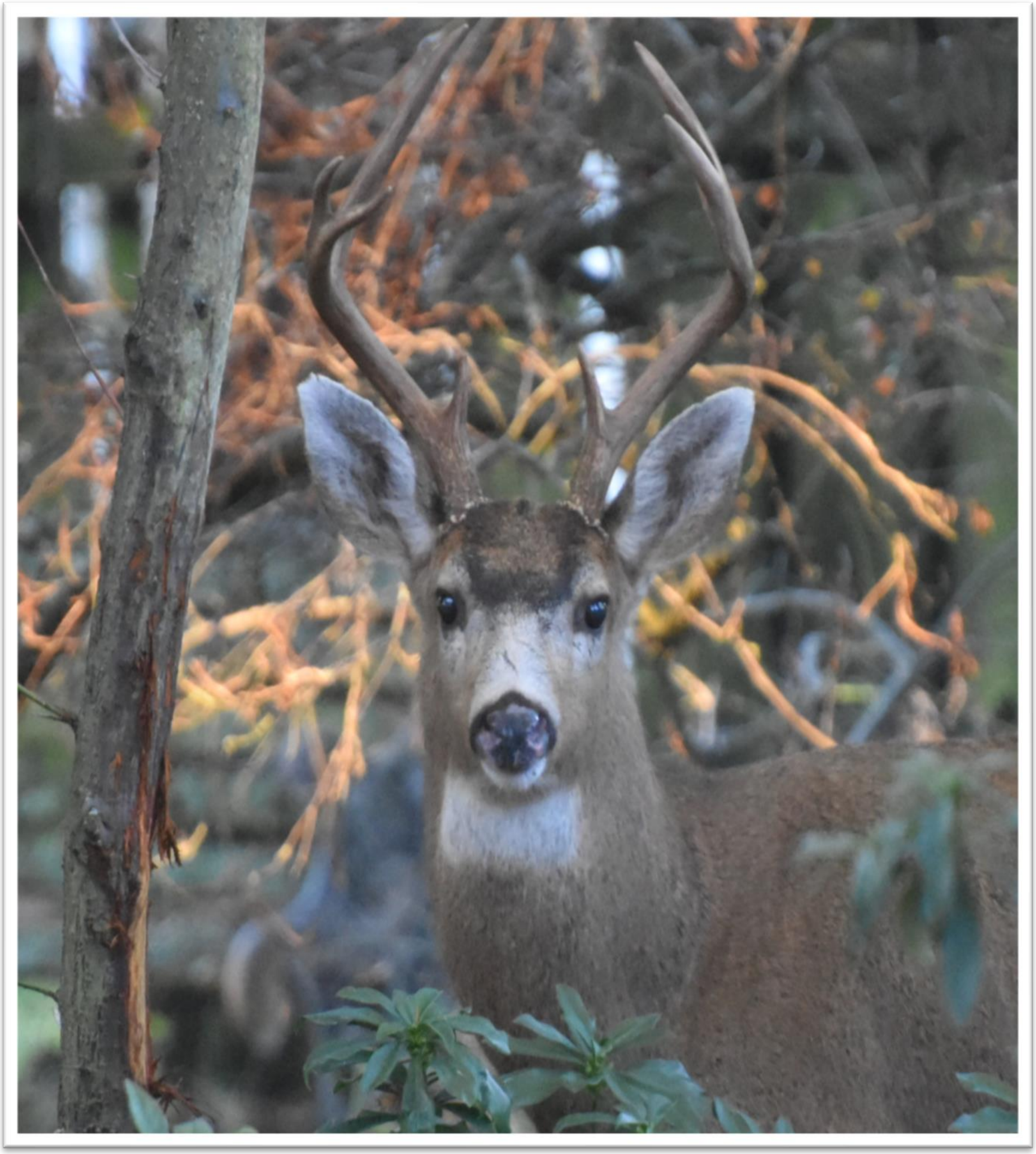
2019 Deer Population Estimate Survey in Esquimalt, BC

Zone	Date	Surveyors	Weather (Environment Canada)	Total Start/End Time	Road Start/End Time	Park Start/End Time	Forward/ Reverse	Total Length Driven (km)

Road/Park Zone	Time Observed	Buck/Doe/Fawn	Coordinates	Distance (m)	Deer Bearing	Road/Path Bearing	Photo #s	Behaviour/Notes

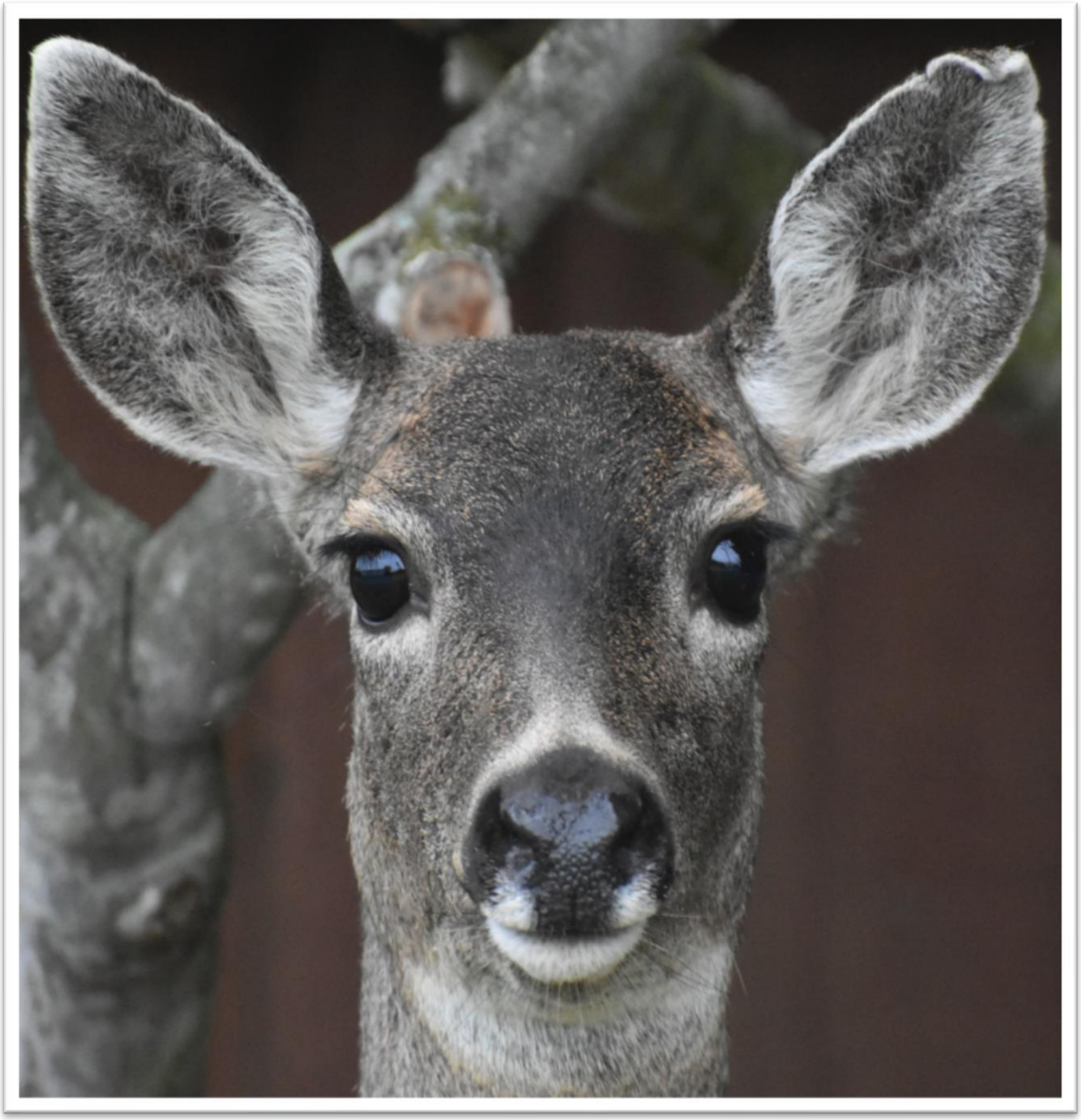
Notes

Appendix J



Sample Buck photograph by Rachel Newman

Appendix K



Sample Doe photograph by Allie Kozachuk

Appendix L

Sample Fawn photograph by Kevin pons