

# Arctic foxes observed on St. Paul Island, Pribilof Islands

—=Abridged Version=—

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## Abstract

During May 27-June 2, 2019, a field study was done of the Arctic foxes on St. Paul Island, Pribilof Islands, Alaska. Five trail cameras were deployed on five overnight periods in well-separated locations. The cameras were deployed in four zones: airport/hotel (surplus dump yards and corporation yard), beach and hills near town, utility areas (water processing, USCG buildings), and open grassland. A total of 355 photographs of foxes were obtained on 16 of the 25 locations, an average of 22 photographs per site. Almost all sites showed one or more photos of one particular fox. While it is impossible to identify all individual foxes, it is believed that at least 12 different foxes were photographed, and possibly as many as 16.

Statistical analysis of the photographs indicate that the peak visitation frequency was near midnight, with a near-normal distribution about 2 hours before and after. The visit separations show an exponentially decaying distribution, indicating that the visit intervals were random, i.e., the visits were uncoordinated. In addition, a strong correlation was found between the location of the zones and the density of the fox photos: *the higher the human ensity, the higher the density of fox photos*. Very roughly, we found that for every human/km<sup>2</sup>, we obtained about 10 fox photographs/km<sup>2</sup>. No trail camera deployments were made in the city of St. Paul, hence we have no data on foxes that might be found in the zone of residential buildings and commercial facilities. Our data covers foxes on the outskirts of the city and into the open grassland.

In addition to the trail cameras, handheld cameras with telephoto lenses were used to capture photos of three foxes during daytime hours. It is believed that these three foxes were not imaged by the trail cameras, making the total number of foxes photographed between 15 and 18.

Finally, we make an argument from the trail camera photos that the total number of foxes on St. Paul Island is between 3000±1000

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### Abridged Version

**This is an abridged version of the full document, in which the details about deployments that did not result in fox pictures were removed.**

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## Introduction

### The Pribilof Islands

The Bering Sea lies between the Aleutian Island chain and the Bering Strait. The Sea is divided by the Bering Slope, which runs SE-NW. To the southwest of the slope are abyssal depths (mostly greater than 3,000 m), while to the northeast the depths are relatively shallow (mostly less than 100 m). The latter comprises the Bering Shelf.

The image below shows a map of the Bering Sea, with St. Paul Island, Pribilof Islands, highlighted. [Source: Wikimedia Commons]



## St. Paul Island

St. Paul Island, one of the Pribilof Islands, lies near the edge of the Bering Shelf. It is accessible by air from Anchorage, and provides accommodations, transportation, and reasonable weather during the spring.

The image below is a feature map of St. Paul Island, including roads, coastal geofeatures, inland mountains, and lagoons and lakes. The features are not accurately drawn, but the map does indicate their rough locations. [Source: St. Paul Tours]



## Arctic foxes

The Arctic fox (*Vulpes lagopus*) is a small canid with a circumpolar Arctic distribution. Several subspecies are recognized, including a subspecies known as the Pribilof fox (*V. l. pribilofensis*) endemic to the Pribilof Islands. [Source: Bolton, et al., 2017]

The following excerpt is from G Dallas Hanna (2008, Chapter IX):

Normally the species is a beautiful snowy white in winter and on account of its abundance and wide range it does not command a high price on the market. But on these and a few other islands, a melanistic strain predominates and the slate colored pelts are called "blue" in the fur markets. Because of their relative scarcity they command a much higher price than the white. On St. George Island, through selective breeding, the white strain has been almost entirely eliminated, but on St. Paul it still runs about 25 per cent of the total catch. It would be a comparatively easy matter for the animals to reach the islands in winter over the drift ice since they would have but 200 miles to travel in a straight line. They are given to such wanderings and have been observed several miles away from land on the ice floes. And Otter Island seems to have been so stocked from St. Paul Island, many times in the past.

The blue fox is the chief enemy of the breeding birds. This little animal almost defies the laws of gravitation in its scaling of the perpendicular cliffs for bird eggs. The animals jump from ledge to ledge on dizzy heights with a sheer drop of a hundred or a thousand feet below them, many times with an unbroken egg in the mouth.

The image below shows the blue morph Arctic Fox shedding his winter coat. [Source: Gone Floatabout, 2015]



## The 2019 Field Study

This study was done during the last week of May, 2019, roughly midway between the late-spring and the summer. During this time various beaches that serve as pupping refuges for northern fur seals were still open (they were closed on June 1), so we were able to examine these areas for foxes (none was found in the refuge areas). We had a car that enabled us to drive on most (but not all) roads. Most of the roads were compacted gravel; there were no paved roads. Smaller roads were accessible only with 4-wheel drive vehicles.

The following figure shows the tracks (in cyan) explored during the course of this study. In some cases, one of us (FB) made extended hikes beyond the limit of the car. The four areas ("Zones") in which the trail cameras were deployed are indicated in red. These zones were selected to sample areas of different human density: very low, low, high, and very high.



The zone are shown enlarged in the next image. They are keyed as:

- A**=Airport/hotel;
- B**=Beach;
- G**=Grassland;
- F**=Facilities.





**Zones** in which the trail cameras were deployed

## Trail cameras Descriptions

Five different trail cameras were used, providing some choice in picture dimensions, file size, sensitivity, field of view, night imaging range, interval between pictures. All cameras are powered by AA batteries, and all include the date-time and temperature in a band at the bottom of the picture.

**Table 1 – Cameras used in this study**

Camera	Make	Model	Lens	Picture [px x px]	File size [MP]	Minimum interval [s]
A	Blusmart			4000x3000	12	1
B	Browning	BTC-5XPD				10
C	Browning	BTC-6PXB				60
D	Bushnell	119775	F3.1	4416x3312	14	10
E	Moultrie	MCG-13067		3840x2160	14	10

The trail cameras are shown here (left to right) A,B,C,D,E:



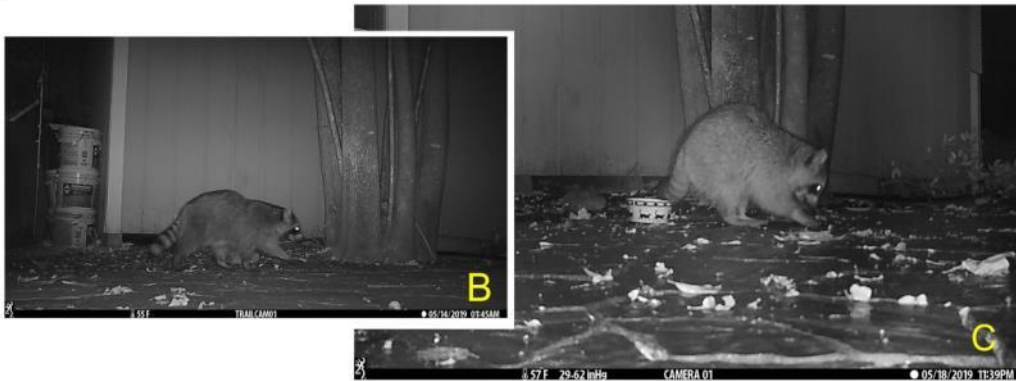
## Locations

Photographs of Arctic Foxes were made at 16 well-separated locations on St. Paul Island, using five motion-triggered trail cameras day and night and two handheld digital cameras during daytime. In most of these locations multiple photographs of a single fox were obtained. A total of **355** photographs were taken with the 5 trail cameras.

**Table 1** lists the deployments of the trail cameras chronologically. The locations of the deployments are shown in the four Google Earth images following the table.



Sample daytime pictures from the trail cameras (to scale)



Sample nighttime pictures from the trail cameras (to scale)

**Table 1– Locations and descriptions of the trail camera deployments**

Day*	Date*	Deployment	Waypoint	Latitude	Longitude	Zone	Site	Camera**	No. fox photos
<b>1</b>	<b>26 May</b>	No trail cameras deployed this day							<b>0</b>
<b>2</b>	<b>27 May</b>	<b>1</b>	<b>052</b>	57.156110	170.231901	<b>A</b>	Behind shipping container	<b>A</b>	<b>0</b>
		<b>2</b>	<b>053</b>	57.156158	170.232440	<b>A</b>	Behind shipping container	<b>B</b>	<b>10</b>
		<b>3</b>	<b>054</b>	57.156259	170.233277	<b>A</b>	In lumber trash pile	<b>C</b>	<b>7</b>
		<b>4</b>	<b>055</b>	57.156660	170.231076	<b>A</b>	Underneath 8x10x30' steel tank	<b>D</b>	<b>8</b>
		<b>5</b>	<b>056</b>	57.158577	170.232059	<b>A</b>	Corner between shipping containers	<b>E</b>	<b>0</b>
<b>3</b>	<b>28 May</b>	<b>6</b>	<b>062</b>	57.156567	170.230471	<b>A</b>	Side road behind tank	<b>A</b>	<b>14</b>
		<b>7</b>	<b>063</b>	57.156279	170.232769	<b>A</b>	Beside dish antenna	<b>B</b>	<b>18</b>
		<b>8</b>	<b>064</b>	57.156427	170.233160	<b>A</b>	On plywood beside equipment trash pile	<b>C</b>	<b>15</b>
		<b>9</b>	<b>065</b>	57.158569	170.232091	<b>A</b>	Corner between shipping containers	<b>E</b>	<b>14</b>
		<b>10</b>	<b>066</b>	57.158686	170.230269	<b>A</b>	Equipment yard- empty cable spool	<b>D</b>	<b>8</b>
<b>4</b>	<b>29 May</b>	<b>11</b>	<b>069</b>	57.134039	170.262811	<b>B</b>	Driftwood pile on beach	<b>A</b>	<b>123</b>
		<b>12</b>	<b>070</b>	57.134670	170.262800	<b>B</b>	Driftwood pile on beach	<b>E</b>	<b>19</b>
		<b>13</b>	<b>072</b>	57.135070	170.262689	<b>B</b>	Path from road to beach	<b>B</b>	<b>42</b>
		<b>14</b>	<b>073</b>	57.137582	170.264775	<b>B</b>	Parking area next to road	<b>D</b>	<b>13</b>
		<b>15</b>	<b>074</b>	57.140957	170.265817	<b>B</b>	Hillside near road	<b>C</b>	<b>2</b>
<b>5</b>	<b>30 May</b>	<b>16</b>	<b>075</b>	57.176224	170.245055	<b>G</b>	Edge overlooking quarry excavation	<b>A</b>	<b>0</b>
		<b>17</b>	<b>076</b>	57.175082	170.245468	<b>G</b>	Floor of quarry excavation	<b>B</b>	<b>30</b>
		<b>18</b>	<b>077</b>	57.177784	170.239461	<b>G</b>	50m off side of road	<b>C</b>	<b>1</b>
		<b>19</b>	<b>078</b>	57.170538	170.226034	<b>G</b>	Rockpile at edge of road	<b>E</b>	<b>0</b>
		<b>20</b>	<b>079</b>	57.162351	170.230949	<b>G</b>	213m off road	<b>D</b>	<b>0</b>
<b>6</b>	<b>31 May</b>	No trail cameras deployed this day							<b>0</b>
<b>7</b>	<b>1 June</b>	<b>21</b>	<b>090</b>	57.147469	170.262478	<b>F</b>	Water treatment plant buildings	<b>A</b>	<b>0</b>
		<b>22</b>	<b>091</b>	57.145409	170.258881	<b>F</b>	56m off side of main road	<b>B</b>	<b>0</b>
		<b>23</b>	<b>092</b>	57.153638	170.251499	<b>F</b>	Rear corner of utility building	<b>C</b>	<b>1</b>
		<b>24</b>	<b>093</b>	57.151415	170.248997	<b>F</b>	Back side of US Coast Guard building	<b>E</b>	<b>30</b>
		<b>25</b>	<b>094</b>	57.156900	170.230585	<b>A</b>	Parking lot at Airport/Hotel	<b>D</b>	<b>0</b>
<b>8</b>	<b>2 June</b>	No trail cameras deployed this day							<b>0</b>
<b>TOTAL</b>								<b>355</b>	

Notes: \*The trail cameras were deployed in the PM of the Day listed, and recovered on the next Day. For instance, Camera A was deployed at GPS waypoint 052 in Zone A (behind shipping container) on Day 2/Date 27 May, remained active overnight, and was recovered in the AM of Day 3/28 May.

\*\*Cameras are listed in the order of deployment.



Locations of the trail cameras in **Zone A** (Airport/Hotel)



Locations of the trail cameras in **Zone B** (Beach)



Locations of the trail cameras in **Zone F** (Facilities)





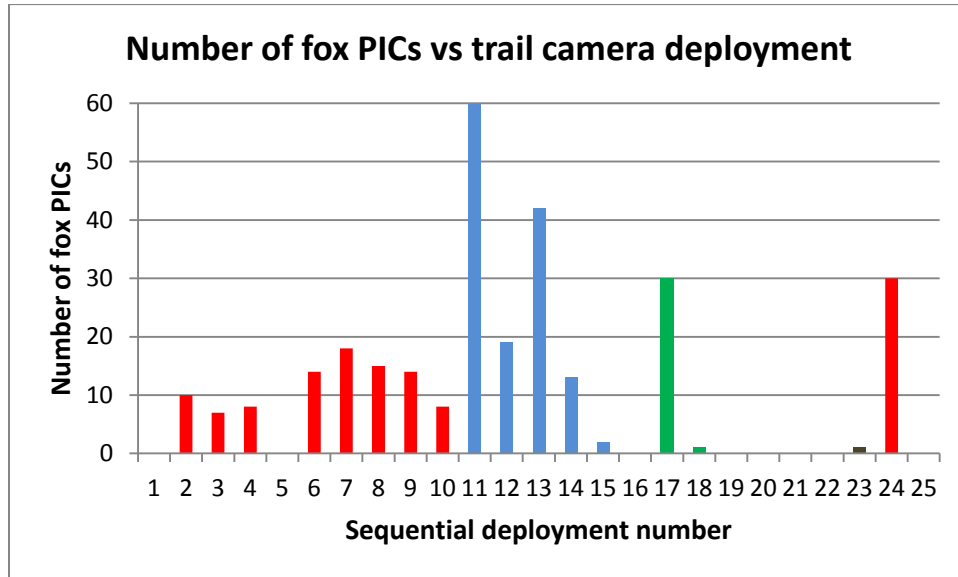
Locations of the trail cameras in **Zone G** (Grassland)

## Numbers of trail camera photos

Pictures of foxes were obtained on 16 of the 25 deployments of the trail cameras (5 cameras x 5 days). Of the 9 deployments that produced no fox pictures, 6 were due to the absence of fox visits, while 3 apparently were due to failure to arm the camera.

The following plot shows the number of fox pictures obtained in the successive deployments (cf., Table 1). In the plot, the colors indicate the (zones):

- Red** (1-10,25) = **Airport/hotel**
- Blue** (11-15) = **Beach**
- Green** (16-20) = **Grassland**
- Black** (21-24) = **Facilities**



The peak for deployment 11 is actually 123 pictures (not 60 as the plot limit shows). The average number of pictures, including all 25 deployments, is 14.2; including only the 16 deployments that produced fox pictures it is 22.1. For zones A and B (very high and high human density), neglecting the two highest and the lowest number, the average is about 12 fox pictures per overnight deployment.

The following sections (**Day 1-Day 8**) show pictures of the deployments in chronological order. For each day, the pictures are arranged in the following order:

### Day #

**Deployment # Day # Camera # Zone # Site description**

Deployment (Comments)

Fox pictures (“Selected from N pictures”)

Recovery (Comments).

## Day 2

### Deployment 3 Day 2 Camera C Zone A In lumber trash pile

Deployment (PICs from Camera Y)



Fox picture (Selected from 4 pictures Camera C)



**Deployment 4 Day 2 Camera D Zone A Underneath 8x10x30' steel tank**

Deployment (PIC from Camera D)



Fox pictures (Selected from 5 pictures Camera D)



## Day 3

### Deployment 6 Day 3 Camera A Zone A Side road behind tank

Deployment (PICs from Camera Y)



Fox pictures (Selected from 13 pictures Camera A)





**Deployment 7 Day 3 Camera B Zone A Side road behind tank**

Deployment (PIC from Camera Y)



Fox pictures (Selected from 14 pictures Camera B)







**Deployment 8 Day 3 Camera C Zone A On plywood beside equipment trash pile**

Deployment (PICs from Camera Y)



Fox pictures (Selected from 10 pictures Camera C)





**Deployment 9 Day 3 Camera E Zone A Corner between shipping containers**

Deployment (PIC from Camera E)



Fox picture (Selected from 14 pictures Camera E,)



Almost all pictures were very indistinct. Picture above was enhanced.

**Deployment 10 Day 3 Camera D Zone A Equipment yard- empty cable spool**

Deployment (PIC from Camera Y)



Fox pictures (Selected from 8 pictures Camera D)



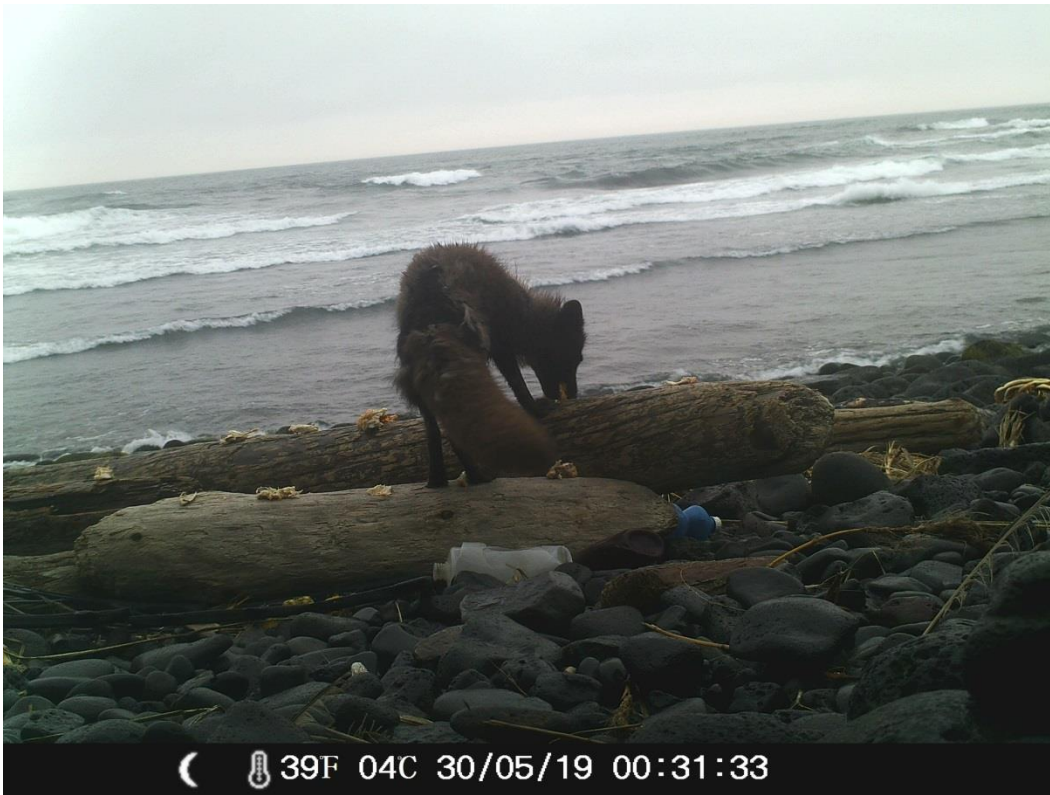
## Day 4

### Deployment 11 Day 4 Camera A Zone B Driftwood pile on beach

Deployment (PICs from Camera Y)



Fox pictures (Selected from 89 pictures Camera A)











**Deployment 12 Day 4 Camera E Zone B Driftwood pile on beach**

Deployment (PICs from Camera Y)



Fox pictures (Selected from 16 pictures Camera E)





**Deployment 13 Day 4 Camera B Zone B Path from road to beach**

Deployment (PICs from Camera Y)



Fox pictures (Selected from 40 pictures Camera B)







**Deployment 14 Day 4 Camera D Parking area next to road**

Deployment (PICs from Camera Y)



Fox pictures (Selected from 8 pictures Camera D)



**Deployment 15 Day 4 Camera C Zone B Hillside near road**

Deployment (PICs from Camera Y)



Fox pictures (Selected from 2 pictures Camera C)



## Day 5

### Deployment 17 Day 5 Camera B Zone G Floor of quarry excavation

Deployment (PICs from Camera Y)



Fox pictures (Selected from 27 pictures Camera B)







41F TRAILCAM01 05/31/2019 09:17AM



41F TRAILCAM01 05/31/2019 09:28AM



**Deployment 18 Day 5 Camera C Zone G 50m off side of road**

Deployment (PICs from Camera Y)



Fox picture (1 picture Camera C)



## Day 7

### Deployment 23 Day 7 Camera C Zone F Rear corner of utility building

Deployment (PICs from Camera Y)



Fox pictures (1 picture Camera C)



Apparently the fox passed the camera on the shelf

**Deployment 24 Day 7 Camera E Zone F Back side of US Coast Guard building**

Deployment (PICs from Camera Y)



Fox pictures (Selected from 30 pictures Camera E)





## Handheld cameras



### Descriptions

Two handheld digital cameras were used to document the deployment of the trail cameras, listed in **Table 3**.

Camera	Make	Model	Lens	PIC dim [px x px]	File size [MP]	Photo- grapher.
X						Belton
Y	Canon	SX50 HS	Zoom 24 mm F3.4-1200 mm/F6.5; autoshutter and speed			Schmieder

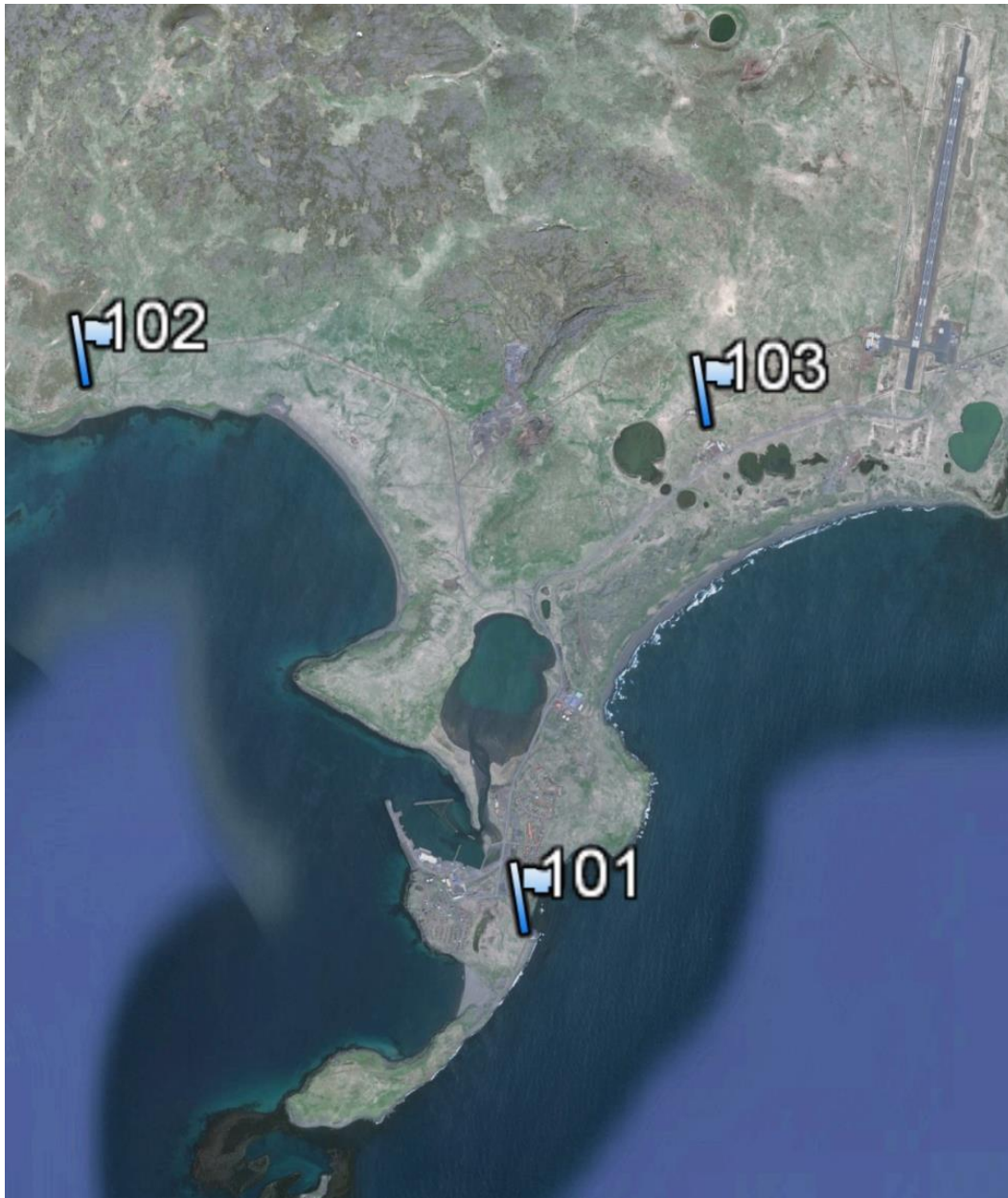
### Locations

**Table 4** lists the particulars about the handheld camera photos of foxes.

**Table 4– Locations and descriptions of the handheld camera photographs**

Day	Date	Waypoint	Latitude	Longitude	Site	Camera	No. fox photos	
1	26 May	No handheld fox pictures this day						0
2	27 May	No handheld fox pictures this day						0
3	28 May	101	57.119361	-170.270584	Ruin of dock E of St. Paul City	X Y	2 14	
4	29 May	102	57.15476	-170.3229	Side of road to SW Point	X Y	1 13	
5	30 May	No handheld fox pictures this day						0
6	31 May	No handheld fox pictures this day						0
7	1 June	103	57.15215	-170.2488	Between USCG buildings	Y	7	
8	2 June	No handheld fox pictures this day						0
<b>TOTAL</b>							<b>37</b>	

The locations of these three waypoints are shown in the following Google Earth image. The exact location is at the base of the flag icon.





## Day 3

### Waypoint 101 Day 3

Camera X



Camera Y



## Day 4

### Waypoint 102 Day 4

Camera X (All five pictures same fox)



Camera Y





## Day 7

### Waypoint 103 Day 7

Camera Y (Both pictures same fox)

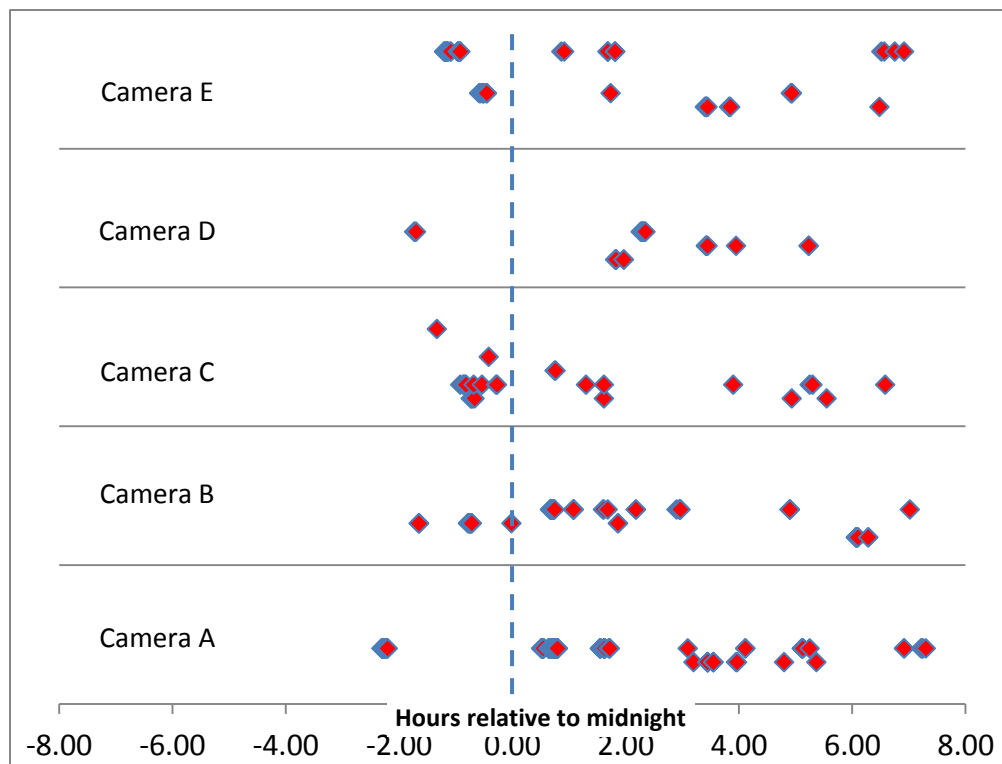


## Discussion

### Temporal distribution of the photos

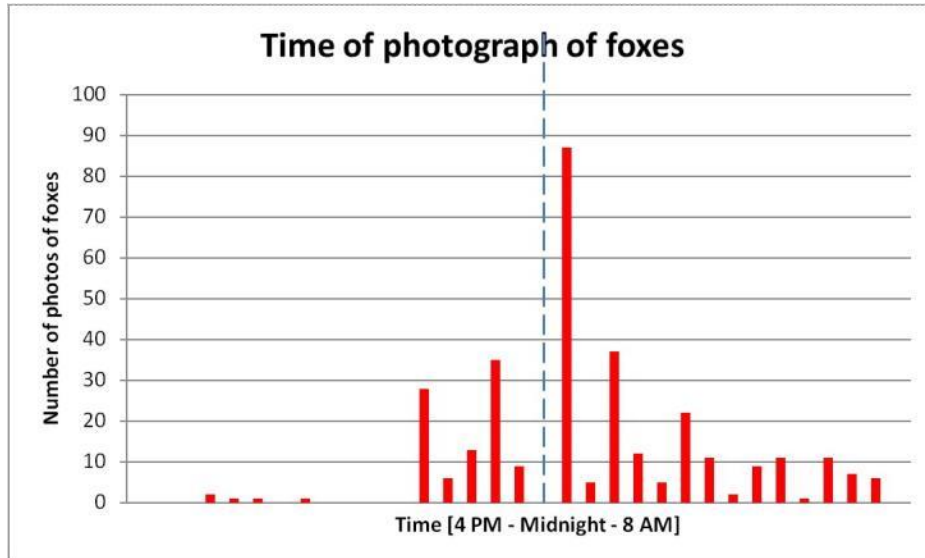
The trail camera photographs record the date-time the picture was taken. The cameras were deployed in the afternoon and collected the next morning, and then deployed again that afternoon in different places. They were deployed on five days (Days 2, 3, 4, 5, and 7); Days 1 was the day of arrival; Day 6 was at rest; and Day 8 was the departure day. Thus for the five cameras and five days, there was the potential for  $5 \times 5 = 25$  camera-days. In fact, fox pictures were obtained only on 16 days.

It was found that nearly all of the fox photographs were taken during the night (although in May the night didn't arrive until after 11 PM). The following figure plots the times of the photographs, arranged around midnight. The time runs from 4 PM to 8 AM (the next day). The data for each of the five cameras A,B,C,D,E are arranged in horizontal lines for each of the camera deployments. For instance, Camera E has time lines for days 3, 4, and 7 (but no data for days 1, 2, 5, 6, or 8. Thus, there are 16 lines of data, representing the 16 deployments.

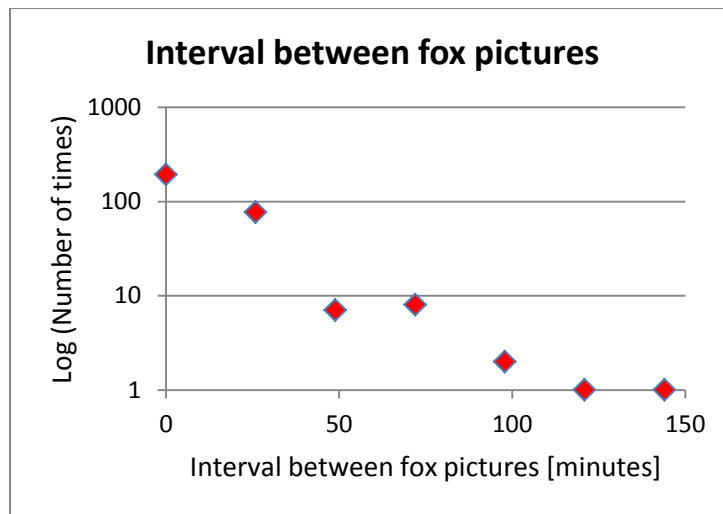


At first glance, these events appear to be quasi-randomly distributed in time. Looking more closely, certain regularities seem to be present. For instance, each day appears to have multiple fox photos separated by roughly a half-hour. That is, the photos don't seem to be randomly distributed through the night; rather, they are somewhat evenly spread out.

The following plot shows that the fox photos peak around midnight, with a width of about  $\pm 2$  hours.



The following plot shows the frequency distribution of the intervals between the fox photos (all 16 time lines are included in this plot). Note that this is a semi-log plot.



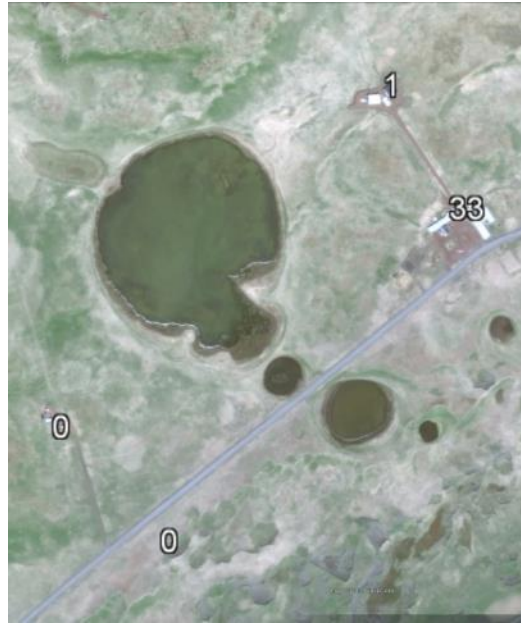
This plot shows an almost perfect decreasing exponential function. The exponential decay function is characteristic of a Poisson point process, i.e., a process in which events occur continuously and independently at a constant average rate. Independence of the events is the key characteristic of Poisson point processes, so we infer that the arrival of the foxes at each camera is independent of previous arrivals. In spite of appearing to prefer intervals of about a half-hour, it appears that *the intervals between visits are random*.

## Spatial distribution of the photos

The following figures show the number of fox photos at each location.



Beach



Utilities



Airport Hotel

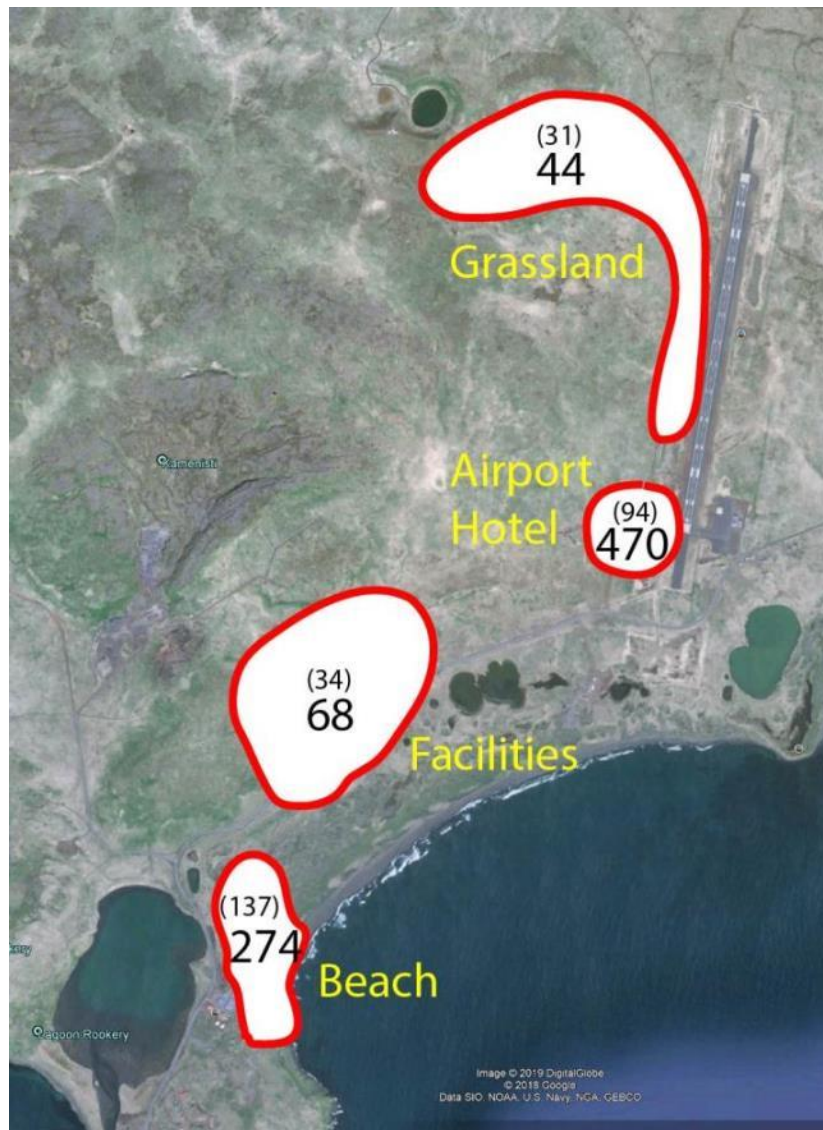


Grassland

The following table shows the number of fox photos in each of the four zones, an estimate of the area of the zones, and the ratio, i.e., the density of photos (photos/km<sup>2</sup>):

Zone	No. photos	Area [km <sup>2</sup> ]	No. fox photos/km <sup>2</sup>
Beach	137	0.5	<b>274</b>
Utilities	34	0.5	<b>68</b>
Airport Hotel	94	0.2	<b>470</b>
Grassland	31	0.7	<b>44</b>

The following figure shows (# photos) and density photos/km<sup>2</sup> of the four zones. For instance, in the Facilities zone (F), there were 34 fox photographs with implied density 68 fox photos/km<sup>2</sup>. It is clear that more trail camera photos were obtained in the more populated zones; e.g., the airport/hotel zone is more than 10 times the fox density than the grassland zone.

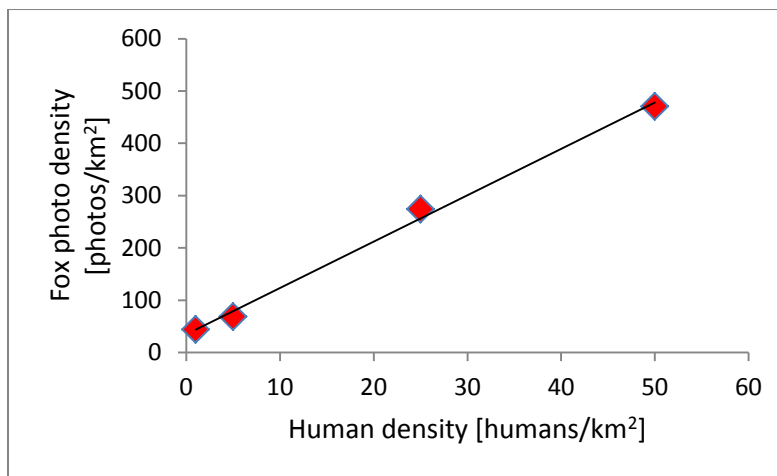




We can in fact take one more step to understand these densities. The next table lists our estimates of the human population density for the four zones, and the fox photos densities (from the previous table).

Zone	Human density [humans/km <sup>2</sup> ]	No. fox photo density [photos/km <sup>2</sup> ]
Grassland	1	44
Utilities	5	68
Beach	25	274
Airport	50	470

The plot below shows the fox photo density as a function of human density, which shows an apparently linear relationship between these densities.



Although the linear trend is probably artificially precise, the data are convincing that the trend is at least monotonic: more human density produced more fox photo density. This is, of course, entirely consistent with the notion that the foxes are human-dependent: they live in the vicinity of humans because that is where they find easiest sustenance. It is not known whether the human inhabitants on St. Paul deliberately provide food and shelter for the foxes, or whether it is opportunistic on the part of the foxes.

Do the photo densities reflect the actual fox densities? While we have no real data on this direct question, it seems reasonable that it should be (at least approximately) true. Thus, we feel provisionally confident of the following: *Greater human density means greater fox density, and the relationship is approximately linear.*

## All the foxes on St. Paul Island

We believe that each of the foxes seen in the trail and handheld cameras was unique; that is, we never photographed the same fox in more than one location. Here are all the different foxes from the various photographs. There are 19 fox pictures: 16 from the trail cameras and 3 from the handheld cameras. We believe these are 19 different foxes.



## Number of foxes on St. Paul

One additional statistical inference can be made from our data: the total number of foxes on St. Paul. The grassland zone **G** appears to be well-separated from human populations hence might be representative of the open grassland of St. Paul Island as a whole. We obtained 31 trail camera fox photos from 2 out of 5 sites in this zone, about 44 fox photos/km<sup>2</sup>. The area of St. Paul Island is 110 km<sup>2</sup>, implying a total of up to 5000 foxes for the island. However, not all of the island is covered with grassland favorable to the foxes. If we assume the area of favorable grassland is 70 km<sup>2</sup> we find that the number of foxes on St. Paul is around 3000±1000.

## Limitations of the study

Probably the most important limitation of this study is the limited number of locations and observing days. Thus, the statistics of the data are just able to reveal some trends, such as the presence (or absence) of foxes at each site.

In addition, we could not distinguish every individual fox, although some were made unique by their patterning because they were shedding their winter coats. The quality of even the best of the trail photographs was marginal for individual identification.

In the statistical analysis, we made extremely rough guesses as to the human densities in the zones, hence the correlation of fox densities and human densities is correspondingly weak.

## Conclusions

In spite of the limitations described above, we believe that this study provides clear support for the idea that the fox density increases monotonically with human density, and in fact the relationship might well be linear. This relationship is not a surprise; indeed, it is well-known that the foxes (just as with feral cats, rats, and other scavengers) tend to be more numerous around human habitation than in more remote unoccupied areas. Because the great majority of the area of St. Paul is open grassland, we believe the total number of foxes is probably about 3000.

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