Assessing Black Rat Population Abundance and Persistence at the Oceano Dunes State Vehicular Recreation Area

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Bachelor of Science in Animal Science
Bachelor of Science in Biological Sciences

By

Mars Lu & Julia Perez

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Abstract:

The black rat, *Rattus rattus*, is considered one of the most destructive and widespread invasive species around the world, with the ability to damage crops, kill native species, and spread disease. The Oceano Dunes State Vehicular Recreation Area (ODSVRA) is home to numerous at-risk species such as the Western Snowy plovers (*Charadrius nivosus nivosus*) and California Least Tern (*Sternula antillarum browni*). Black rats have been detected at the ODSVRA in studies conducted in 2015 and 2018, and may be a potential threat to nesting seabirds like the plover and the tern. In addition, they may also serve as competitors for native mammals, as well as pests for the locals. Black rats are considered commensal with humans, and are often associated with our properties, in particular trash. Semi-permanent human encampments were observed around the Dune Preserve area back in 2018, which may serve as a vector for black rats to spread. This study was developed to investigate if black rats remained at the site where they were detected back in 2015, and if there was a relationship between abundance of black rats and proximity to human encampments. Two plots were set-up with numerous camera stations, one following the same grid done in 2015 (called Dune Preserve 2), and one spanning part of the plot done in 2018 (called Dune Preserve Rattus Transect). Cameras were left at both sites for 3-4 days in April of 2022, and pictures of numerous species of rodents were collected. The rodent images were then identified by eye and evaluated for their respective hypothesis. The Dune Preserve 2 plot found that black rat populations have persisted at the site since their detection back in 2015, and may have potentially grown and spread. This is due to a higher number of black rats detected, as well as more stations detecting black rats than before. The Dune Preserve Rattus Transect did not find a significant relationship between black rat abundance and proximity to human encampments. However, rats were still captured at a majority of the stations. The results and data from this study could aid park personnel in making informed decisions on controlling this invasive species and developing their management plan.

Introduction:

Species of the genus *Rattus* are arguably one of the most destructive invasive species on the planet, with an immense potential to disrupt and destroy native ecosystems (Harris et al., 2022). Black rats (*Rattus rattus*) are especially abundant along coastal areas because of their long history and association with ships (Lack et al., 2013). Their opportunistic nature and omnivorous diet make them a threat to every new habitat that they occupy (Lack et al., 2013). Globally, they are associated with the greatest number of declines or extinctions of native island biota (Shiels et al., 2014). In addition, black rat behavior results in numerous negative interactions with humans including property damage, nesting around human dwellings, consuming food, and carrying diseases such as the bubonic plague (Shiels et al., 2014).

Black Rats were detected at the Oceano Dunes State Vehicular Recreation Area (ODSVRA) during studies conducted in 2015 and 2018 (Villablanca and Trunzo, 2018). Their presence as a predator and competitor is a potential threat to the native birds and mammals. The threatened Western Snowy plovers (*Charadrius nivosus nivosus*) and endangered California Least Tern (*Sternula antillarum browni*) in particular may be negatively affected by invasive rats. Oceano Dunes contain critical nesting habitat for these species, and the importance of this area will only increase as climate change continues and sea levels rise (Jacobson, 2012). Mammalian predators like black rats could be a major factor in the decline of seabird eggs and chicks, as an

Oregon study found the use of predator exclosures on Snowy Plover nesting habitats resulted in positive nesting success (Dinsmore et al., 2014). A population of black rats at Oceano could potentially impact the nesting success of these at-risk species, as well as other native birds. Black Rats could also be a threat to native Woodrats (*Neotoma macrotis*) due to competition for similar resources (Stokes et al., 2009). Black rats are very opportunistic and have been known to outcompete native small mammals in their native environment. In Australia, invasive Black Rats were discovered to limit the range of native rats, as those native species tended to avoid areas where Black Rats are abundant (Stokes et al., 2009).

Black Rats have a commensal relationship with humans, and they thrive in the presence of their belongings (Lack et al., 2013). The opportunistic and generalist nature of black rats make them highly effective at utilizing the food, water, and habitats that human societies provide, and so their distribution and abundance often reflect that of human societies (Puckett et al., 2020). This ability has facilitated their transport and establishment to countless places around the world, especially in places with high concentrations of humans.

A study in 2015 was conducted to detect the presence of Black Rats at Oceano Dunes. Park personnel and researchers conducting HMS2 small mammal monitoring live trapped rodents on two standardized plots, which were sampled for three days every three months. Trapped individuals were ear-tagged and released. Black rats were first captured at the Dune Preserve 2 plot in March of 2015, followed by numerous captures in June and one in September (Table 1). As a follow-up study, camera traps were placed in 2018 along a plot ranging from the Dune Preserve 1 plot up North towards the creek. 17 camera stations were placed at approximately 150m intervals and were used to look for the presence of black rats along the plot (Figure 1). At the end of the study, 8 cameras were missing from the stations up North, likely due to theft. The areas in the Northern part of the plots were observed to have numerous human encampments, which might have contributed to the high rates of theft there. 3 camera stations ended up with images of black rats, two in the North, and one in the South near where the Dune Preserve 2 plot was in 2015. It was also noted that there was a large trash pile near that Southern station, and it had more images of black rats than any other camera.

Due to the detection of black rats in 2018 near areas of human encampments and trash, we believe that these factors may be sustaining Black Rat populations. For this study, we hypothesize that populations of black rats will be present and in higher abundance near those areas with human encampments and trash. In addition, we also hypothesize that since black rats were detected at the Dune Preserve 2 plot in 2015, they have persisted and will still occur there. Our expectation is that 1) Black Rats have persisted and will be detectable at the 2015 Dune Preserve 2 site, and 2) Abundance of Black Rats will increase as proximity to human encampments increases. To test this, we set up two plots, each utilizing similar ones made in the 2015 and 2018 study. One of them will be conducted in the Dune Preserve 2 (DP2) plot, and will be used to see if black rats have persisted in that location since their detection in 2015. The second plot, called Dune Preserve Rattus Transect (DPRT) will utilize the 2018 study data, and will analyze if camera stations closer to the North, where there is a greater concentration of human encampments, will result in more black rat images.

In addition to confirming the presence and abundance of black rats, images of them captured in this study will be used in a separate study involving artificial intelligence. The AI is in the process of being trained to identify rodent species using the top-down images captured by these camera stations. Once the AI is developed to be highly accurate in rodent identification, it can be utilized in streamlining invasive rat detection in places like Oceano Dunes. Rather than evaluating thousands of images by eye, park personnel could speed up the process by simply feeding the images through the AI.

Figure 1. Map of camera stations used in 2018 study. Name in a red box arrow indicates that the camera was lost (presumed stolen). Pie charts indicate the proportion of images that were of black rats (in blue) (Villablanca and Trunzo, 2018). The current study replicates part of this plot, spanning Camera 9-13 and 17.

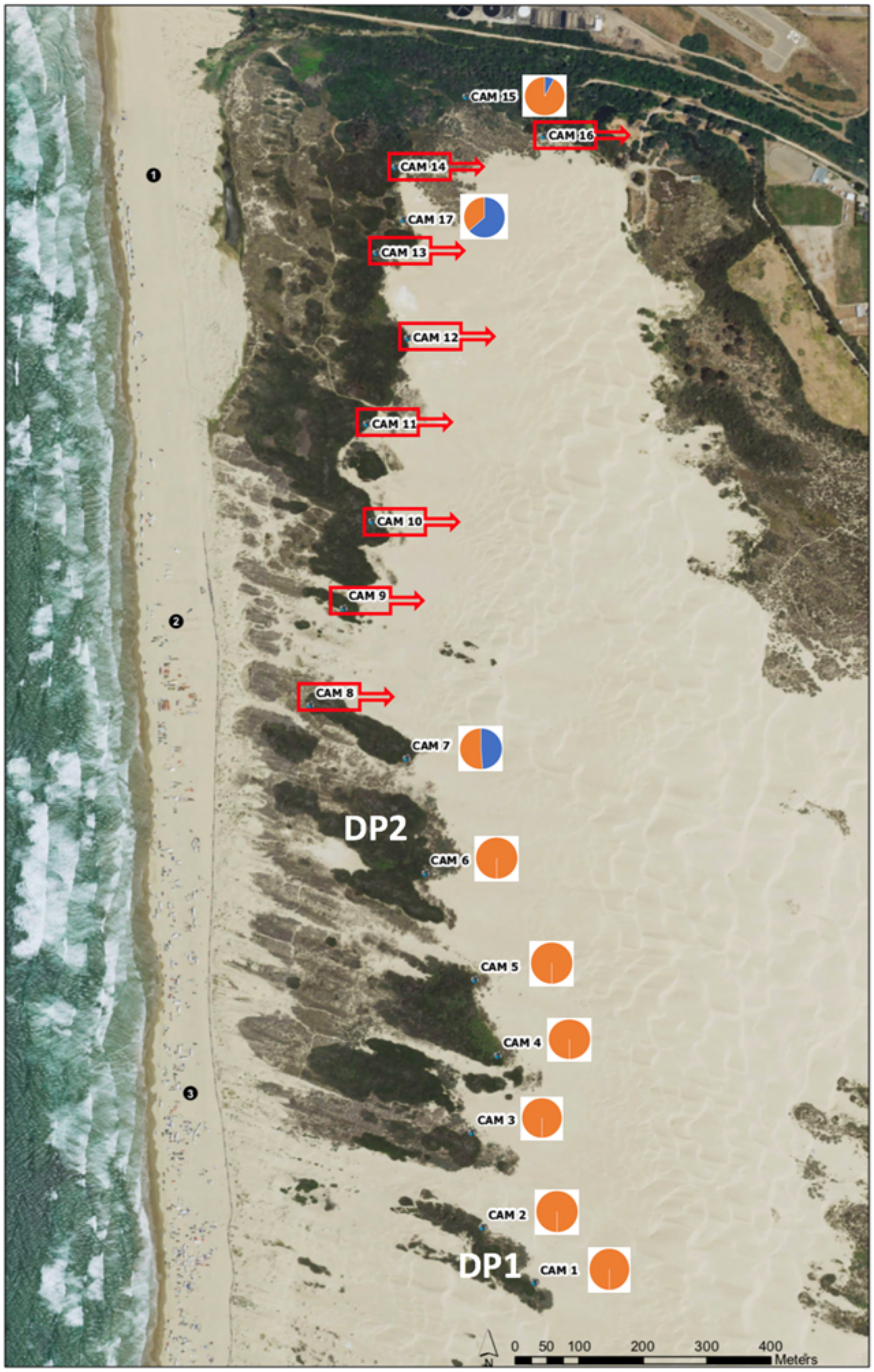


Table 1. Capture history for Black Rats at ODSVRA in 2015.

Island	Month	Captures	Individuals
Dune Preserve 1	March	0	0
	June	3	2
	Sept	0	0
	Dec	0	0
Dune Preserve 2	March	3	2
	June	13	10
	Sept	1	1
	Dec	0	0
Total		20	12

Methods:

To confirm the presence and extent of human encampments in the area, reconnaissance was conducted starting from the riparian area surrounding Arroyo Grande Creek and then heading South (Figure 3). Evidence of multiple semi-permanent encampments was found, due to the presence of trash, tents, and trails. Sightings appeared to be more concentrated towards the North. However, human activity and number of encampments appeared to have decreased compared to reconnaissance from the 2017 study (Pers. comm., F. Villablanca, California Polytechnic State University).

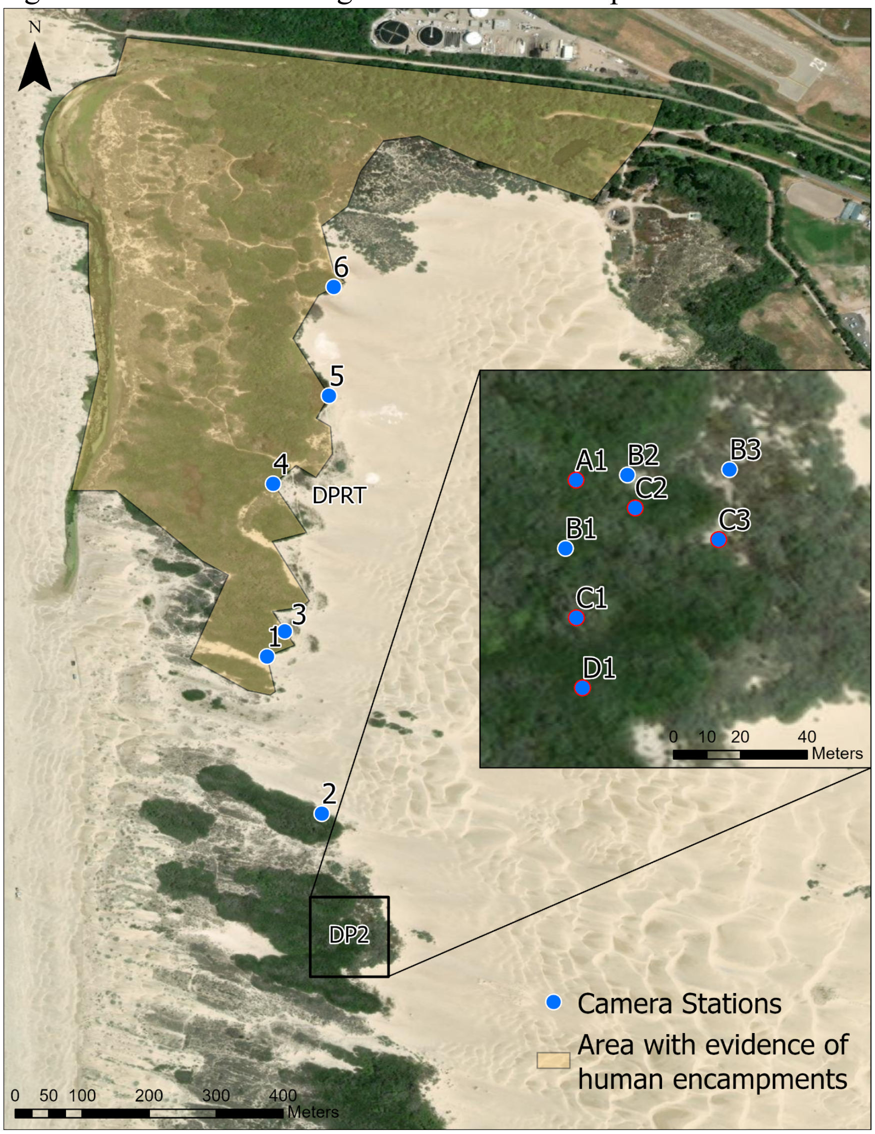
Camera stations for both DPRT and DP2 were set-up in the same fashion (Villablanca and Trunzo, 2018). The camera used was Bushnell Essential E3, an infer-red, hyper-motion-sensitive, low-intensity red light flash camera with a trigger speed of 0.3 sec. The cameras were set to take 3 pictures during every event followed by a 1 min lag. It was determined that the view from above the trap was best for getting a consistent view of the animal detected, and made it easier to determine species using relative sizes (Villablanca and Trunzo, 2018). To do this, cameras were attached, facing downwards, to a metal U-post at a height of 28 inches from the ground with a screw, wing nut, and washer. The post had a PVC pipe (1.5 inch diameter) strapped on (zip-tie) that was used as a bait reservoir (Figure 2). The pipe had its opening at the bottom a quarter inch above the ground, which allowed the pipe to act as a gravity feeder. The pipe was then filled with Trader Joe's brand old fashioned rolled oats. A flat 2 foot by 2 foot square area below the camera was cleared of large branches and other debris so that bare sand, dirt or leaf litter could be used as a background for the photos (Figure 2). The PVC pipe was spray painted in tans and greens for camouflage.

The DPRT station locations were based on the 2018 study. In contrast to that study, and because of camera theft, only 6 camera trapping stations were set-up (Figure 3). Minor adjustments were made to prevent theft, as 8 out of 17 cameras were stolen in the previous study. Due to this, camera stations were not placed all the way North as that was where there was the highest concentration of encampments. Cameras were placed 1-2 meters into the vegetation so that they were not visible from the dune trails. Human tracks were covered to keep the location of cameras discrete. Cameras for DPRT were deployed from Monday, April 11th to Friday April 15th, 2022. No cameras were determined to be stolen.

The DP2 stations were based on a 4x4 grid developed in the 2015 study (Figure 3). Live trapping stations were set-up 20 meters apart within the two dominant habitat types - willow/ wax myrtle and mock heather/lupine scrubs. In the present study, eight stations were placed based on locations where black rats were previously found in 2015. In this study, an experimental error led to 4 of the stations being shifted one station over as shown by the mismatched names (Figure 3). In this plot, no measures concerning theft were needed as these were located out of the way of human traffic. Cameras for DP2 were deployed Monday April 18th to Thursday April 21st, 2022, with none stolen.

Figure 2. Image of the DP2 Station C1 set-up. Note that the sand was manually transferred to the station in order to cover up pine needles, which the AI could potentially detect as a tail.

Figure 3. Map of camera stations used to survey for black rats at the ODSVRA. DPRT stations are numbered 1-6 and are situated to the North. DP2 stations are arranged in a grid and labeled accordingly. DP2 stations that had previously captured black rats in 2015 are highlighted in red. Areas overlaid with yellow show locations with evidence of human encampments, with the highest concentration being towards the creek up North.

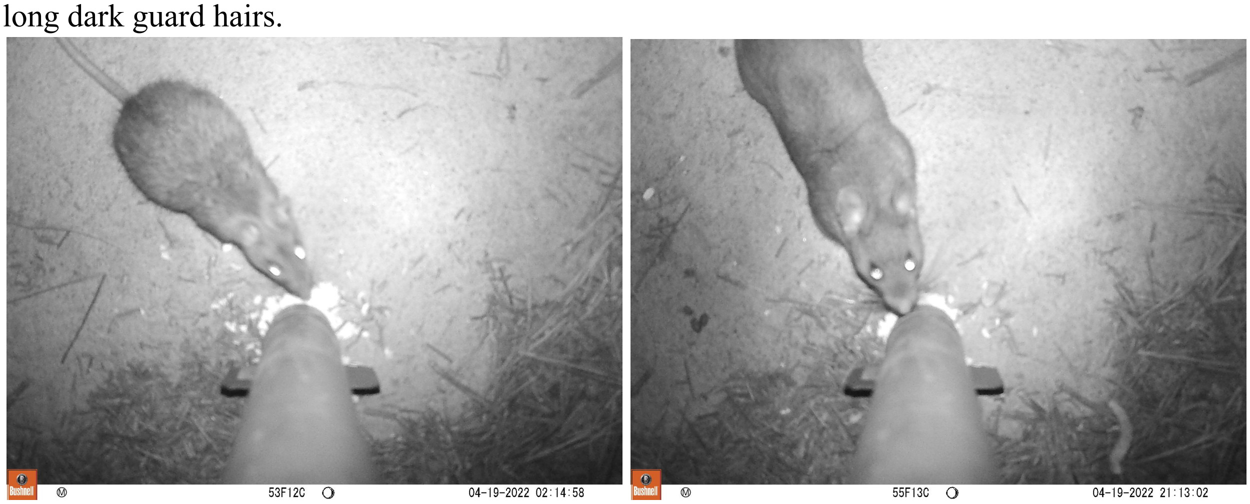


After retrieving the cameras from every station, images were downloaded and backed up. Both authors were trained by Villablanca on the identification of rodents in camera images. Once identifications were accurate and consistent, then the images collected were evaluated by eye to discriminate between the possible target species and to collect data on presence/absence and abundance. Primary rodent species besides Black Rats that were expected to be seen included the Monterey big-eared woodrat (*Neotoma macrotis*), the California Deer mouse (*Peromyscus californicus*), and the Deer mouse (*Peromyscus maniculatus*). A non-rodent data collection category was created for when species like brush rabbits, bobcats, or birds appeared in camera photos. A category was also created for empty pictures or pictures where it was too difficult to determine species. This includes instances where the individual in the image was too blurred or only had a non-distinguishing feature present. Being able to discriminate between black rats and woodrats was important, as they occupy the same habitats and are large-bodied. Characteristics, such as body and head shape, that were used to identify images as black rats or woodrats are listed in Table 2. Furthermore, we attempted to identify discernible individuals of Black Rats in Table 3 and Table 4. This was mostly done since a single individual rat may have spent a long duration eating, and thus will appear in numerous images. This was evaluated based on if a black rat, with the same size and shape, appeared in a narrow window of time. This gives us an estimate on how many distinct individuals there are at each station.

Table 2. Characteristics for Black Rats and Monterey big-eared woodrat (*Neotoma macrotis*) used during species identification of camera station images (Villablanca and Trunzo, 2018).

Species	Body Shape	Tail Shape	Ear Size	Head Shape	Fur	Scrotum
R. rattus	Slender	Pointed Tip Bare Longer than head and body	Small	Narrow from eyes to tip of rostrum	Longer dark hair along the mid-back, coarse in appearance	Visible
N. macrotis	Rounded	Rounded Tip Haired Shorter or equal to head and body	Large and round	Wide from eyes to tip of rostrum	Uniform	Not visible

Figure 4. Example of a black rat (left) captured at Station C1 compared to a woodrat (right) captured at Station C1. Note the narrower "triangle-shaped" head and smaller ears on the black rat compared to the wider "pear-shaped" head and larger ears of the woodrat. Woodrat pelage also appeared consistently "glossy" and smooth, while black rat pelage was often "spiky" with long dark guard hairs.



Once images were evaluated and categorized, the two plots were analyzed using data from the previous studies. Capture data from the study in 2015 was evaluated for DP2 (Table 1). The presence of Black Rats at the stations back in 2015 compared to now was used to determine if Black Rats have persisted at this study site. Similarly, DPRT utilized the station data conducted by Villablanca and Trunzo in 2018. DPRT was analyzed to determine if there is a higher population or density of black rats closer to areas with higher concentrations of human encampments. A linear regression test was run in Rstudio to determine the significance of our results.

Results:

Prediction 1. Presence

All 8 cameras at DP2 remained by the end of the survey period. The bait reservoir was completely depleted in all stations with the exception of B3. The 8 cameras resulted in 11,449 images, with 2,426 of them containing empty or indiscernible pictures. These either contained no organisms, or were too blurry and had an unidentifiable part of an animal present such as the tip of the tail only. 19 images contained non-rodent animals that included brush rabbits, birds, and beetles. This left 9,004 images of rodent species, of which 14.5% were *Rattus rattus*, 29.4% were *Neotoma macrotis*, 9.6% were *Peromyscus maniculatus*, and 46.5% were *Peromyscus californicus* (Table 3). The camera station with the highest number of discernible individuals was C1 (37 distinct rats), followed by D1 (30 rats), and B2 (15 rats). These numbers are mostly associated with the total number of black rat images captured by the stations, with C1 having the most number of images followed by D1. However, B1 had more total images (135) compared to B2 (59), but had a lower number of discernible individuals (12) compared to (15) at B2. This is likely due to a few individuals at B1 sticking around the camera and setting off the trigger numerous times.

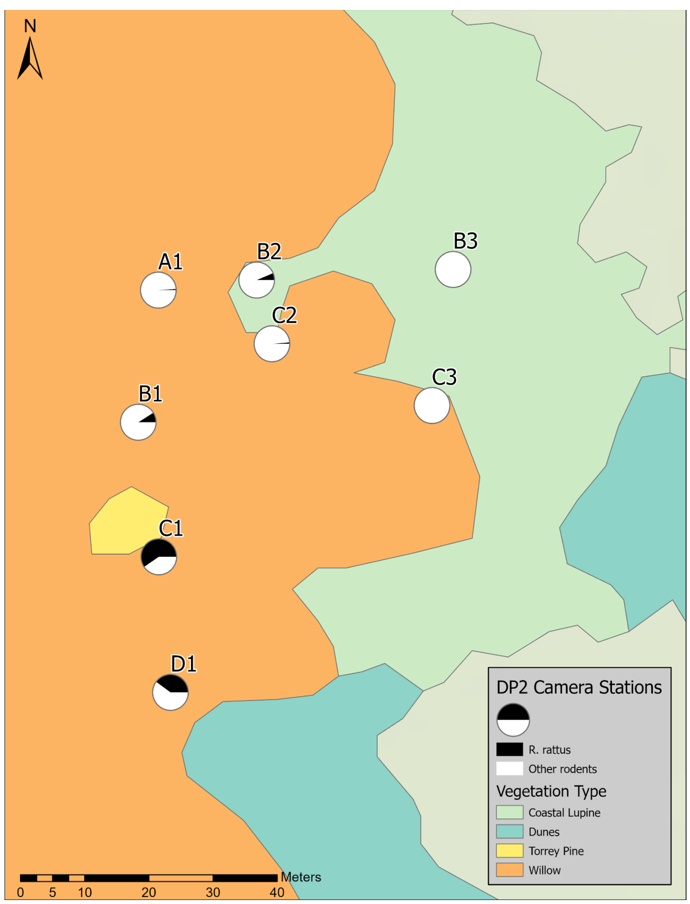
Table 3: Camera capture data for the Dune Preserve 2 camera stations. Stations highlighted in yellow captured black rats in both 2015 and the current study. Stations highlighted in green did not capture rats in 2015 but did in this study. Stations highlighted in red had captured rats in 2015, but did not in this study.

Camera Station	Total # pics	*R. rattus*	*R. rattus* (discernible individuals)	*N. macrotis*	*P. maniculatus*	*P. californicus*	Non rodent animals	Empty/ Unable to ID
A1	1173	9	3	503	0	392	1	268
B1	1881	135	12	147	0	1229	0	370
B2	1182	59	15	63	12	798	0	250
B3	880	0	0	0	675	57	9	139
C1	1305	575	37	361	0	30	3	336
C2	840	9	2	246	0	460	6	119

C3	2181	0	0	912	177	850	0	242
D1	2007	521	30	413	0	371	0	702
% Total Rodent Capture		14.5%		29.4%	9.6%	46.5%		

Black rats were previously detected in 2015 at stations A1, C1, C2, C3, and D1. Therefore, our hypothesis predicts that if the population has persisted over the past 7 years, black rats will be detected again at those same stations. Out of those stations with previous black rat captures previously, A1, C1, C2, and D1 (80%) captured black rats in the current study (Table 3). Additionally, B1 and B2, which did not detect any black rats in 2015, captured images of black rats. Since 80% of the total camera stations redetected or detected black rats at DP2, it suggests that our hypothesis was supported and that black rats have persisted at this study site. The addition of black rat detection at 2 other stations may also suggest that the population has increased or has expanded geographically.

Figure 5: Map of DP2 stations with pie charts indicating the proportion of images with black rats (in black) to images of all other rodents (in white). Vegetation type as an additional detail was added. Due to a spotty GPS signal, B2 appeared to be in coastal lupine while in actuality it was 1-2 meters into willow.



Prediction 2: Abundance

All six cameras from DPRT were retrieved successfully as well. All camera bait was completely depleted. The total number of pictures captured at all six stations was 11,000; 1,315 of which were either empty or not usable for identification to species. 348 images contained non-rodent animals, mostly birds and one event of a bobcat. The remaining 9,351 images captured rodent species. Of these, 27.1% were images of *Rattus rattus.* 28.4% contained images of *Neotoma macrotis.* 30.5% contained images of *Peromyscus maniculatus* and 14.1% contained images of *Peromyscus californicus*. Percentages of Black Rats images to total rodent images varied widely across each camera station (Figure 7). Beginning from station 2, which was furthest from the area with highest evidence of human encampment, and moving closer (2, 1, 3, 4, 5, 6) percentages of Black Rats images are as follows, respectively: 0%, 0.2%, 45.7%, 65.2%, 0.5% and 38.6% (Figure 6).

A linear regression test was conducted to detect the correlation between distance from human encampments and the percentage of Black Rat activity to all other rodent activity at each station. We hypothesize that there will be a correlation between proximity to human encampments and Black Rat activity. The test resulted in a p-value of 0.4818. Since the p-value is greater than 0.05, we fail to reject the null hypothesis. There was not a significant correlation between distance from human encampments and Black Rat activity.

Table 4: Camera capture data for the Dune Preserve Rattus Transect camera stations.

Camera Station	Total # pics	*R. rattus*	*R. rattus* (discernible individuals)	*N. macrotis*	*P. californicus*	*P. maniculatus*	Non rodent animal s	Empty/ Unable to ID
1	1602	3	1	1017	189	237	2	146
2	1506	0	0	684	429	194	5	186
3	2424	946	5	473	313	340	0	349
4	2297	1256	5	0	231	440	202	205
5	2108	9	1	138	0	1631	21	305
6	1063	317	4	339	155	10	118	124
% Total Rodent Capture		27.1%		28.4%	14.1%	30.5%		

Figure 6: Percentage of Black Rat activity relative to distance from semi-permanent human encampments. Location of human encampment was chosen to be an estimated area of highest density of trash and human activity. Counted images of Black Rats are used to estimate activity. Percentages reflect Black Rat activity in proportion to all rodent activity.

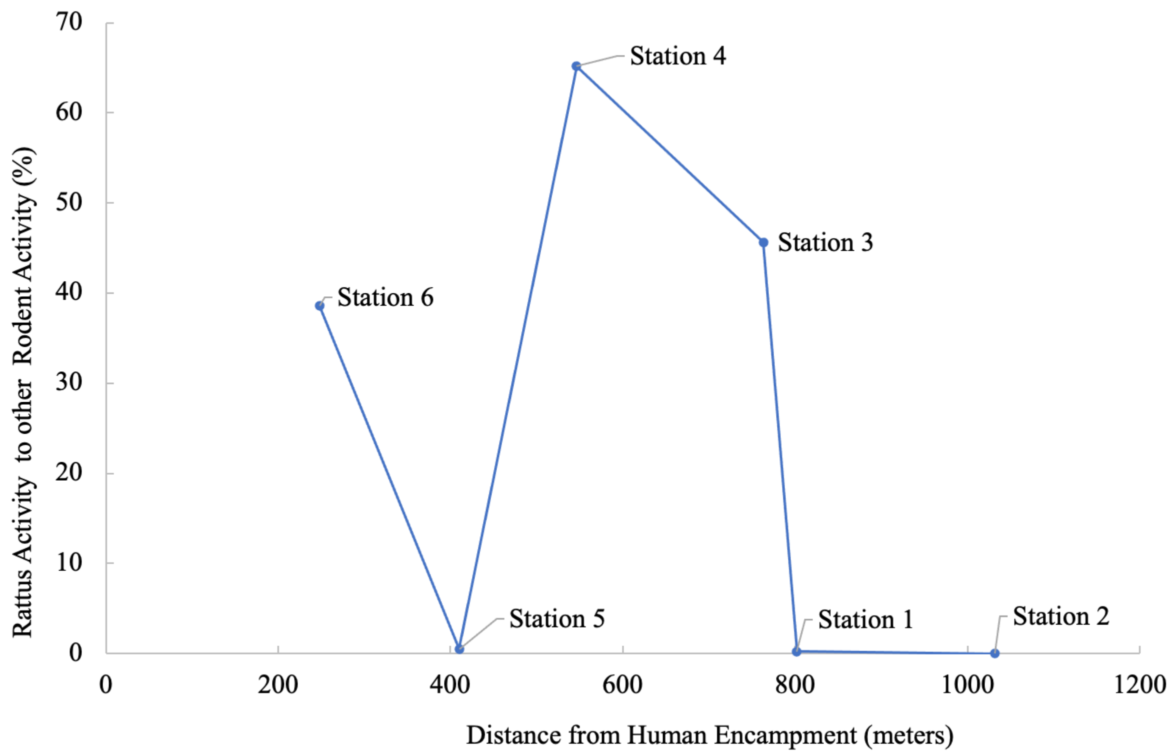
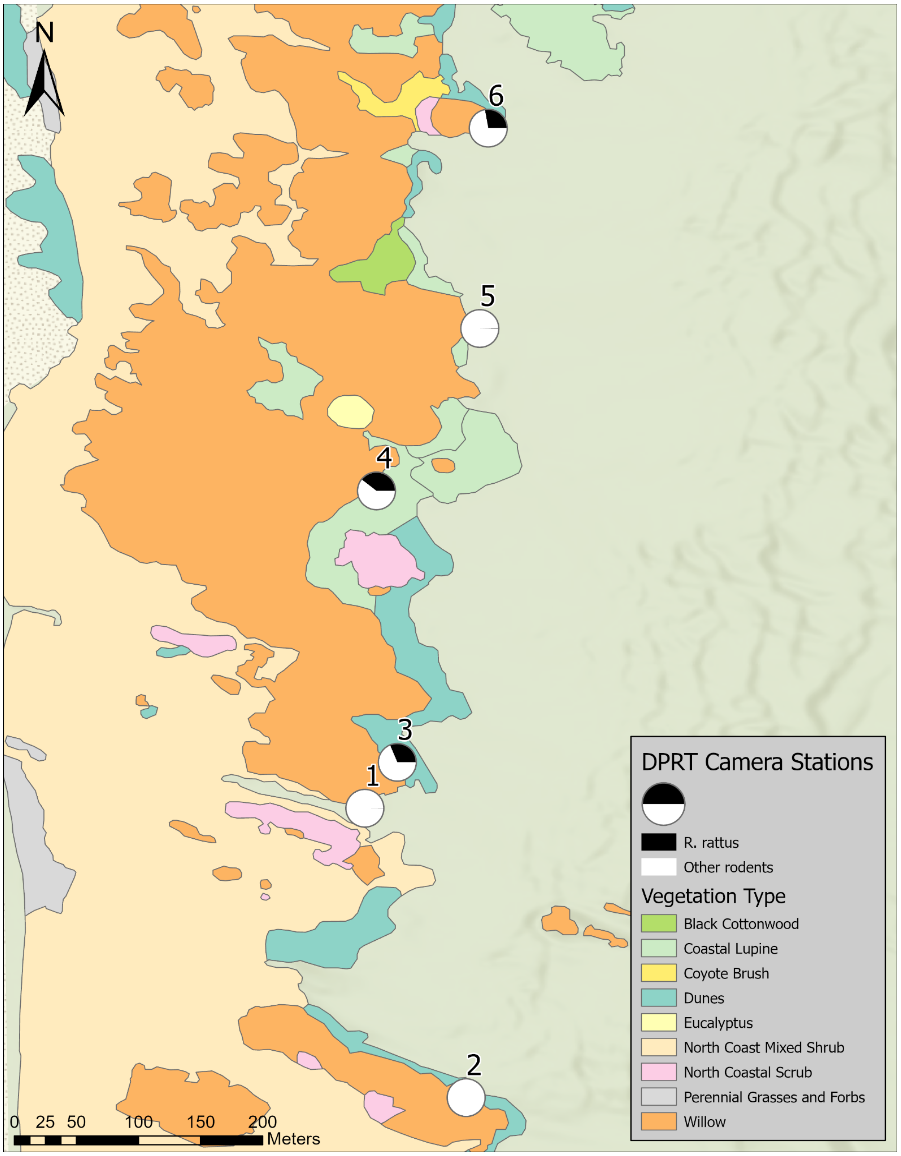


Figure 7: Map of DPRT stations with pie charts indicating the proportion of images with black rats (in black) to images of all other rodents (in white). For stations 2, 1, 3, 4, 5, 6, the percentages of *R. rattus* images are as follows: 0%, 0.2%, 45.7%, 65.2%, 0.5% and 38.6% (respectively).Vegetation type as an additional detail was added.



Discussion:

The presence and persistence of black rats at the ODSVRA could lead to numerous potential problems, both for park management and the native wildlife. The destructive nature of black rats threaten the native biota, especially threatened or endangered seabirds that may nest near the Dune Preserve area. Expansion of rat populations to the South and West may start overlapping with nesting areas of those seabirds. The presence of semi-permanent human encampments are a potential vector of black rat immigration and spread, as it would not be surprising for commensal black rats to thrive in close proximity to humans. For thousands of years, rats have been unintentionally transported as humans move around the globe (Harris, 2009). It has been known that Black Rats have occurred in Oceano Dunes since at least 2015. Residents reported that it was trash in abandoned lots that resulted in "rat-infested" properties (Leslie, 2016). According to the 2018 study, all of the human encampments that were surveyed in Oceano Dunes had trash associated with them (Villablanca, 2018). When we surveyed the area 4 years later, we found that they were still present, albeit at a lower density. Trash was also still present at the site, in the highest density at the northernmost area of the map (Figure 5).

Our hypothesis predicted that if black rats have persisted at DP2 since 2015, then those same stations would also capture black rats in this study. Our results show that black rats were detected at 4 out of 5 of the camera stations that had previously captured rats in 2015. Additionally, 2 stations that hadn't captured rats in 2015 were able to detect black rats in this current study. This suggests that not only did the population of black rats persist at DP2, but it may have also spread to more areas. All stations with the exception of B3 were located within willow thickets (Figure 4). This may explain why B3, which was placed in a fairly open area in coastal lupine, had no detection of both black rats or woodrats. C3 was the one station that did not detect black rats although it had in 2015. This may be explained by its placement on the edge of the willows (1-2 meters in) compared to other camera stations. Based on these findings, we predict that black rats are more closely associated with dense willow thickets, and are less common in more open vegetation like coastal scrub. This could imply that at least in this area of Oceano Dunes, black rats are unlikely to venture out into open areas where ground nesting birds may potentially nest. However, a lot more research would need to be conducted to see: if this preferred habitat occurs in other parts of the Dunes, how close are seabird nesting sites to willow thickets where black rats may live, if the presence of bird nests could cause rats to begin exploring out of their preferred habitat, and more. This could play an important part in management plans, such as not restoring certain open areas of the preserve to prevent the creation of corridors for black rats to expand more.

Comparing the relative abundance of black rats between the 2015 study and this current study is a bit difficult. The methods differed, as the 2015 study utilized live captures over the course of 3 days every 3 months. This study set up camera traps to take images over the course of 3 nights, and this was done only once. Live captures are useful in that researchers are able to take measurements, look at life history stages, and ear tag rats for future studies. However, it's also limited by the number of traps set up. For example, even if there were black rats present, other rodents could set off the trap before the rats got to it, and thus the findings would be no rats detected. For camera traps, far more data is able to be collected since the "capture" process is automatic and runs throughout the entire night. However, it also has a fair share of potential problems. Identification is more difficult when looking at a black and white image by eye. This could potentially lead to human error and bias when identifying rodents. Abundance could also be skewed, as a singular black rat could stay at a camera station for an extended duration and take up a large portion of the images. The bloated number of black rat images in this case wouldn't necessarily mean a larger number of individual black rats. Because of this, we also tried to identify discernible individuals when going through camera images. This was done by seeing if a rat of similar shape and size appeared with relatively close timestamps. This could still lead to a lot of potential errors since an individual rat may return an hour later, and it would be too difficult and time-consuming to go back and check all previous black rats for size and shape. This resulted in a rough estimate of distinct black rat individuals for both DP2 and DPRT (Table 3, Table 4). Comparing the current study's estimated individuals found at DP2 and the number of individuals caught at DP2 in 2015, we can see a far larger number in this current study. In March of 2015, 10 individuals were captured out of 16 stations over the course of 3 days (Villablanca and Trunzo, 2018). In this study, an estimated 99 individuals were caught out of 8 stations over the course of 3 days. Once again, because the methods differed, a comparative statement about black rat abundance is difficult to make. However, this still suggests that black rat populations remain at the DP2 site, and may potentially have grown in size.

Future iterations of this plot could be conducted yearly in order to analyze population trends for black rats at this site. This could also be used to track the populations of native rodent species, and perhaps how they respond to an increase or decrease of black rats. Improvements that could be made include developing a more successful method of determining individual rats, and more identifying characteristics of black rats to make distinguishing by eye easier for student researchers. Finally, a marker such as a post could be set up on the grid to ensure that camera stations are placed in the exact same location every year. In this current study, Villablanca had to use landmarks and a potentially spotty GPS signal to determine where the stations were placed back in 2015.

The initial hypothesis for the DPRT was that Black Rats activity would increase in closer proximity to the highest density of human encampments. The results did not support this hypothesis. A linear regression test comparing distance from the North (which had the highest concentration of human encampments and trash) and percentage of black rat images resulted in a p-value of 0.4818, and so we failed to reject the null hypothesis. The data also did not show an obvious trend consistent with our hypothesis (Figure 6). The plot resulted in an increasing number of Black Rat images with decreasing proximity to human encampments only for stations 2, 1, 3 and 4. Station 2, which was the furthest from the area with the most human encampment, showed the lowest amount of Black Rats activity, with zero images captured. Activity increased to station 1, 3 and 4. Station 1 had 3 images of Black Rats, station 3 had 946 images, and station 4 had 1,256 images. However, at station 5 there was interestingly very little evidence of black rats, with only 9 images total of black rats. At this station there was a surprisingly high amount of *P. maniculatus* activity, with 1,631 images making up 91.3% of total rodent images. Since *P. maniculatus* was such a dominating species, we considered it could be possible that this camera was not stationed in what we hypothesized to be rat habitat, and that this is the reason why Black Rats activity drops off so sharply. To support this thought, Station B3 at the DP2 plot was intentionally placed in an open coastal scrub habitat and found that 92.2% of rodents detected there were *P. maniculatus* (Table 3). However, after running a second linear regression test excluding station 5, the p-value changed to 0.2615, which is still insignificant. The area of high trash presence could also be distributed differently than previously anticipated. Other human encampments were seen along the central part of the plot, the placement of station 6 was even moved because it was too proximate to a human encampment area. Station 6 showed a moderate amount of Black Rats activity, when it was expected to show the most. There were 317 black rat images, the third most of all stations.

The DPRT plot was overall not conclusive on if Black rats are sustaining their population from trash accumulating in human encampments. The results from this may indicate other factors such as proximity to individual camps, differences in trash present, surrounding vegetation types, and non-human factors. Further studies may require more intense surveying and mapping of the area to determine exact locations of human encampments. In addition, future replicants of this plot should ensure that cameras are located within rat habitat, which we determined to be in willow thickets. More stations could also be set-up if necessary precautions are taken to prevent theft. Examples that appeared successful in this study included covering tracks leading to camera stations, ensuring that cameras and posts are invisible from open areas, and spray painting the posts to blend in with the surroundings. We also found success with deploying camera traps for only a few days, to limit potential discovery.

This study found some significant results looking at persistence of black rat populations at a previous study site, but was not able to find a significant link between black rat abundance and proximity to human encampments. Overall, we still conclude that since their detection in 2015 and 2018, black rats have maintained and potentially expanded their distribution at the ODSVRA. This data could be used to make informed management plans on these invasive rats in order to protect native wildlife and human property. Now that their populations appear established in areas like DP2, further studies should be conducted to investigate their effects on ynative seabird populations. Additionally, projects monitoring Black Rat and native rodent activity should continue in order to better understand the dynamic of competition. The relative abundance of each rodent species from this study could serve as an important baseline in tracking potential population change.

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