Gobbling Up Habitat?
Impact of Wild Turkeys on Native Bird Habitat Selection

By

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April 2008

Masters project submitted in partial fulfillment of the
requirements for the Master of Environmental Management degree in
the Nicholas School of the Environment and Earth Sciences of
Duke University
2008

Abstract

The wild turkey (*Meleagris gallopavo*) is an invasive species currently causing heated debate in California. Not only is there a question as to whether or not the bird is actually invasive, as a very similar species of wild turkey was present in California about 10,000 years ago, but there is considerable dissent over whether or not turkeys actually cause any ecological damage. I conducted this study under the auspices of the California State Department of Parks and Recreation (DPR) in order to address the potential impact of wild turkeys on habitat selection in native ground-dwelling avifauna, using the California quail (*Callipepla californica*) as the basis for comparison. Results show that both turkeys and quail are significantly selective about their preferred habitat types ($p < 0.01$). Results also demonstrate that turkeys and quail are coexisting within the same macrohabitat types without significant detrimental effects on either bird. The birds utilize very different microhabitat types, and given the size difference between them, it is highly unlikely that turkeys will begin to occupy the dense, bushy vegetation preferred by quail. Turkeys also appear to have narrower preferences for both microhabitat and macrohabitat than quail, and are therefore limited in the areas they can colonize. There is a great deal of dietary overlap, however both birds have such diverse feeding preferences that barring any extraordinary environmental disasters, it is also unlikely that turkeys will monopolize available food sources.

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Introduction

Invasive species are one of the most prevalent and pressing ecological threats facing environmentalists today. Not all exotic species become invasive, in fact only a small percentage of the species transported daily around the world by humans actually take root in non-native ecosystems and become a problem (Mooney and Hobbs, 2000). Invasive species are almost exclusively introduced by anthropogenic means, and estimates of the total environmental damage and control costs in the United States alone approaches $140 billion (Pimentel *et al.*, 2000). The most well-known cases are those of exotics that have been transported from one far away continent to another, but what of species found within the same country? Neighboring states even? The wild turkey (*Meleagris gallopavo*) in California is a current controversial example of this phenomenon. Not only is there controversy as to whether or not *M. gallopavo* is actually an exotic species, but there is considerable dissent over whether or not turkeys actually cause any ecological damage. During the summer of 2007 I conducted a study under the auspices of the California State Department of Parks and Recreation (DPR) addressing the impact of wild turkeys on habitat selection in native ground-dwelling avifauna, using the California quail (*Callipepla californica*) as the basis for comparison. In addition to ecological impacts, DPR is notoriously under funded and I was concerned with whether current and future expenditure on turkey removal is money wisely spent or, if the damage caused by turkeys is minimal, the funding could be redirected to more pressing projects. The results of this study can be used by environmental managers in the region to evaluate turkey management efforts and expenditures as well as increase efficiency of resource allocation.

Turkeys can be hunted throughout much of the state, but within protected areas where hunting is prohibited the population of turkeys has grown exponentially in recent years and attracted attention to their potentially damaging presence. DPR is currently in the early, experimental stages of turkey management. DPR manages the turkeys as invasive species and is increasingly concerned that the birds are disrupting the ecology of the parks. Since 2006 the agency has been investing in research, monitoring, depredation, and translocation efforts in an attempt to develop a plan that is both scientifically sound and an efficient use of economic and personnel resources. In early 2007 three potential negative environmental impacts of turkeys were highlighted by DPR as being of the most immediate importance: that the turkeys are assisting with the spread of Sudden Oak Death (SOD) caused by the fungal pathogen *Phytophthora ramorum*, that turkeys are consuming endangered herpetofauna such as the California tiger salamander (*Ambystoma californiense*) and California red-legged frog (*Rana draytonii*), and that turkeys are out-competing other ground-dwelling birds for habitat and food (M. Hastings, California Department of Parks and Recreation, personal communication).

SOD has killed thousands of trees since its first appearance in California in 1995 (Henricot and Prior, 2004). The pathogen that spreads the disease can be transmitted through infected plant matter or soil, and humans are the main vector for the disease, picking up the infected matter in their shoes or bicycle tires and spreading it to new locations (Henricot and Prior, 2004). This is problematic in parks where numerous hikers and bikers come into contact with the pathogen on a daily basis. It has been hypothesized that turkeys have the potential to serve as vectors for *P. ramorum* as well, since they spend a great deal of time rooting in the dirt and detritus found at the base of oaks trees, and could potentially carry the pathogen under their nails. A 2005 study conducted in Annadel State Park on the diet of wild turkeys by Barrett and Kucera also collected turkey feet for *P. ramorum* sampling, but results were never published and no current scientific literature exists to support this hypothesis.

Turkeys are highly opportunistic feeders, and while their diet consists mainly of plant matter, seeds, and invertebrates, they have been known to consume vertebrates on occasion. Local biologists have begun to suspect that turkeys could be feeding on juvenile red-legged frogs and tiger salamanders, diminishing the populations of these species which are federally listed as threatened and endangered, respectively (CDFG, 2008). Both the red-legged frog and tiger salamander are large, charismatic amphibians, and have served as flagship species for efforts to conserve fragile ecosystems in northern California such as vernal pools, which are critical for juvenile survival. Barrett and Kucera (2005) sampled the crops of 163 turkeys and found the remains of only one salamander, the species of which was unconfirmed but was not believed to belong to a threatened or endangered species. The crop is a pouch-like organ in the avian digestive system used for storing food (Gerstenfeld, 1989).

The final area of concern is the potential impact of turkeys on native ground-nesting birds. Since turkeys are large, opportunistic feeders there is concern that they will over-utilize available food resources, particularly if their numbers continue to grow as they have been. They may also begin to dominate preferred nesting and feeding areas not only of other gallinaceous birds such as grouse and quail, but potentially for other ground-nesters such as thrushes and rails. Quail were selected as a basis of comparison for this study because they share a similar ecology and range with turkeys, are easily identifiable and numerous enough that they can be found without extraordinary effort, and the quail is California's state bird so, although not currently threatened, the recent decrease in population size has drawn attention from the state (Calkins *et al.,* 1999).

Study Objectives

My overall goal in this research is to determine if wild turkeys are displacing California quail from preferred habitat and evaluate whether or not turkey removal is an effective use of DPR funding. Combining the results of my research with the results of soon-to-be published studies on the spread of SOD and consumption of endangered herpetofauna (Glusenkamp, in prep.) will help to guide the development of a sustainable turkey management plan in northern California. Using this information, DPR and other environmental management agencies will be better able to prioritize and may choose to increase or decrease efforts to remove wild turkeys from protected areas.

Background

History of Wild Turkeys in California

A native species of turkey, *M. californica*, once roamed the hills of California. However the most recent evidence of its presence is a 10,000 year old skeleton found in the La Brea Tar Pits of Los Angeles County. Remains found scattered from Orange County through Los Angeles County and north into Santa Barbara County suggest that *M. californica* had a relatively small range size, although other unconfirmed sources indicate a wider range that may have spread outside of California (Bochenski and Campbell, 2006; CDFG, 2004). Osteological studies revealed that *M. californica* is more closely related to *M. gallopavo*, the species currently inhabiting a good portion of California, than to *M. ocellata*, the species native to Mexico and Central America (Bochenski and Campbell, 2006). It is hypothesized that the disappearance of *M. californica* was caused by a significant drop in precipitation which would have lead turkeys to concentrate heavily around water sources, rendering them easy targets for Paleo-Indians who may have hunted the remaining densely concentrated populations into extinction (Bochenski and Campbell, 2006).

M. gallopavo is native to 39 states but has not historically been found in any part of California. In its native range *M. gallopavo* once had a nationwide population exceeding 10 million birds (Schorger, 1966), but pressure from excessive hunting and land clearing began to dramatically reduce the number of turkeys. By 1940 turkeys inhabited only 19% of their original range (Boone and Rhodes, 1996). Efforts to reintroduce wild turkeys for hunting purposes in areas where populations were severely decimated, as well as areas not previously inhabited by turkeys, began in the late nineteenth century. The first documented Californian introduction occurred in 1877 on Santa Cruz Island and was orchestrated by private ranch owners (DFG, 2004; Burger 1954a). The California Department of Fish and Game observed this introduction and hypothesized that the range of the wild turkey was limited by geographic as opposed to habitat constraints, as *M. gallopavo* was common throughout Arizona and New Mexico in areas that were nearly identical to the environment in California. Fish and Game thought that the desert separating the states was the reason why the turkeys had not migrated north and west, even though they were perfectly suited to the environment in California. So in 1908 Fish and Game took over introduction of the wild turkey along with several other game species (DFG, 2004). Early introductions of wild-caught birds were unsuccessful, so between 1928 and 1949 Fish and Game began raising hybrid birds on game farms, a cross between the Mexican (*M. g. gallopavo*) and Merriam's (*M. g. merriami*) subspecies, for the purpose of introducing them throughout the state (Burger, 1954a). In 1951 the introductions were terminated pending the results of a survey conducted by Burger (1954a), who found that out of 118 introductions only four populations were successfully living and reproducing in their new environments. Interestingly, one of these populations, the birds introduced to Brush Creek in the Sierra Nevada, consisted entirely of wild caught Merriam's turkeys and proved to be the most successful. In the 1960s Fish and Game returned to the method of catching and translocating wild-caught turkeys and maintained a high success rate up until the most recent introductions in 1999 (DFG 2004). The majority of turkeys found in lowland California today are believed to belong to the Rio Grande subspecies (*M. g. intermedia*) while the Merriam's turkeys maintain a stronghold in higher elevations (DFG, 2004).

The public has, until now, generally supported these introductions because of the popularity of wild turkey as a game species; however, as the turkey population grows and they become increasingly habituated to humans, the number of complaints increases as well. Habituation has been partially facilitated by enthusiastic wildlife aficionados who enjoy feeding the birds and help establish permanent turkey populations in residential areas, particularly those that border wildlands or parks. Because of this, Fish and Game has included wild turkeys in their "Keep Me Wild" campaign (DFG, 2006), a campaign which seeks to educate California residents to secure their garbage and stop feeding wild animals to prevent potential human-wildlife conflict. Once turkeys settle near a neighborhood they can begin to root in gardens, roost on cars, decks, or fences and leave droppings and scratches, and become aggressive towards humans. Males in particular have been known to charge humans during breeding season. Residents then become angry and register complaints with Fish and Game or DPR, often seeking depredation permits to remove the turkeys from the area. Vintners have been particularly vocal amongst California residents, complaining that the birds root around in their fields and consume their grapes. Camera trap studies conducted in 2000 and 2001 by the National Wild Turkey Federation, an influential hunting group with chapters located across the nation, indicated that turkeys are not eating grapes, and are likely being blamed because the most common culprits – raccoons, opossums, and other small mammals – are nocturnal and less likely to be caught in the act (CDFG, 2004; Tempest, 2003). Vintners staunchly claim the opposite is true, and other studies have shown that wild turkeys do occasionally consume grapes, although the amount is believed to be relatively insignificant. A study based on a nationwide survey conducted in 2005 (California was not among the respondents) stated that grape farmers in the United States suffer mild to moderate crop damage, and the average statewide total monetary damage to all agricultural crops is less than $10,000 per annum (Tefft *et al.*, 2005). The same study showed that turkeys prefer corn by a significant margin, followed by wheat, alfalfa, and then grapes. Given the opportunistic nature of turkey feeding patterns, any food source, whether natural or cultivated, is a likely target.

M. gallopavo is currently found in every state except Alaska (Barrett and Kucera, 2005) and while this proliferation has been deemed a great conservation success story, there is considerable debate surrounding the presence of the turkeys in non-ancestral habitat. Turkey supporters such as the National Wild Turkey Federation, claim that the turkeys currently found in California are so genetically similar to the native *M. californica* that they fill the niche vacated by the extinct native species. Some of these supporters even suggest using the term "reintroduced" species as opposed to "introduced" (Roberson, 2001). While an ecosystem can arguably adapt and close a niche in 10,000 years, there is still the fact that skeletal remains have only been found in a few locations and turkeys now range over much of the state. Little scientific research has been published on the topic, although popular media in California has certainly caught on to the controversy and many articles have appeared on both sides of the issue from Wine Country in the north to Los Angeles in the south (Henley, 2003; Roberson, 2001; Tempest, 2003). While the issue of whether or not wild turkeys can be considered native to California is a big one, it is coupled with the more pressing question of whether or not they are causing ecological damage, what kind of damage they are causing, and what can be done to prevent it.

Turkey and Quail Ecology

Turkeys and quail are both gallinaceous birds, meaning they are ground-nesting game birds capable of flight but preferring to walk, and in California their ranges overlap significantly. Quail prefer edge habitat, utilizing open woodland and grassland areas for feeding, scrub, chaparral, and foothill brush for cover, and typically reside near a permanent water source (Alderfer, 2006; Brinkley, 2007; Leopold 1985). Turkeys also tend to congregate near permanent water sources, the roosting females in particular

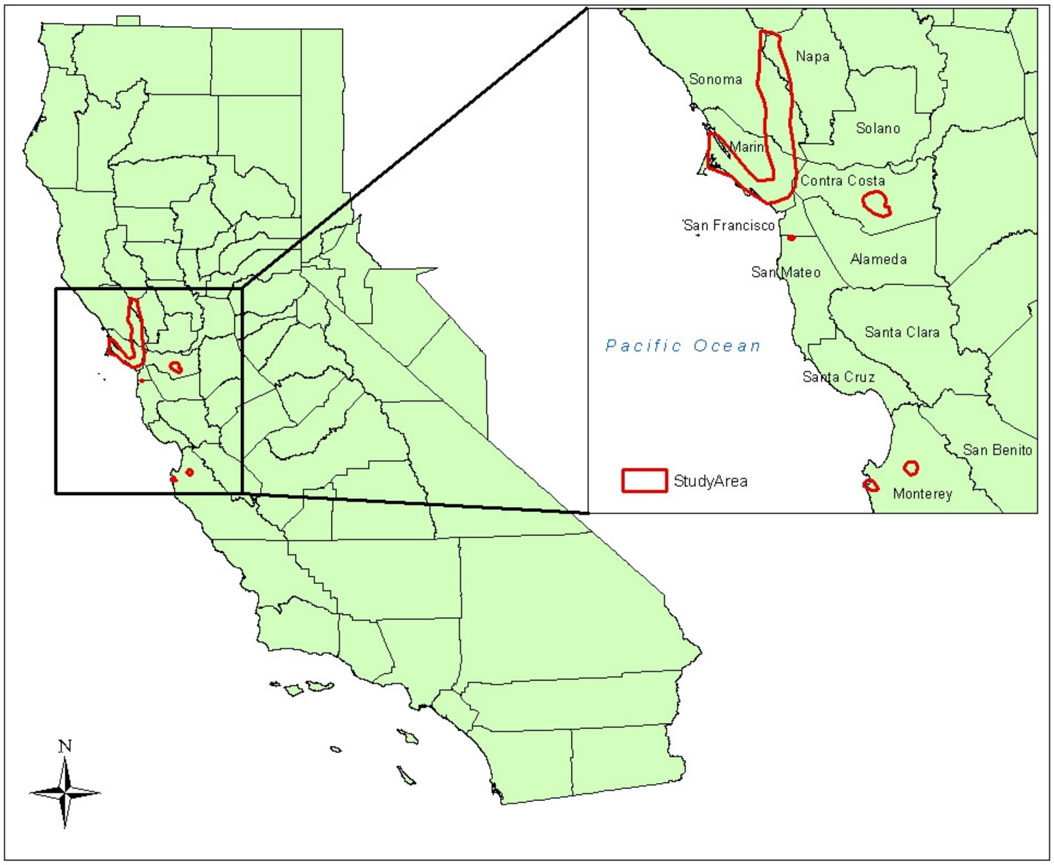
(Chamberlain *et al.*, 2000), and require a combination of open grassland and trees (DFG, 2004). Both birds roost in trees at night and forage on the ground during the day.

Quail subsist on a diet of green plant material, fruits, seeds, and a small invertebrate intake (Glading *et al.*, 1940). A 2005 study of 163 turkey crops found that the diet of turkeys consists of grasses, seeds, invertebrates, and commercial feed harvest (Barrett and Kucera, 2005). While poults were not sampled in this study, it is generally accepted that poult diets consist of a higher proportion of invertebrates than the adults (Hurst, 1992). As mentioned in the Introduction to this paper, the study did find the remains of one juvenile salamander, so there is documentation supporting DPR's concern that turkeys can and do on occasion consume amphibians; however, further studies are required to confirm that this is a regular occurrence that in fact has the potential to impact amphibian populations. Both birds consume the acorns of several species of oaks, but acorns comprise a much smaller percent of the quail diet and it has been suggested that they may be feeding on remnants of acorns already broken apart by other birds such as jays (Glading *et al.*, 1940).

Both turkeys and quail lay eggs in the spring and will lay one egg a day until desired clutch sized is reached – an average of 8 to 12 eggs for turkeys (Hubbard *et al.*, 1999; Vander Haegen *et al.*, 1988) and 12 to 16 for quail (Lewin, 1963; Zammuto 1985). Turkey poult survival rates have been recorded by various studies as varying between 23 – 62%, with the majority of mortalities occurring in the first two weeks after hatching (Hubbard *et al.*, 1999; Vander Haegen *et al.*, 1988; Vangilder *et al.*, 1987). Eggs and poults are quite vulnerable to predation, and studies have shown that predator avoidance is a significant factor in nest site selection (Badyaev and Faust, 1996; Vander Haegen *et* *al.*, 1988). Hawks, particularly the Cooper Hawk, are the main predators for adult quail (Leopold, 1985). Quail eggs and young are vulnerable to predation given their small size and accessibility to ground-dwelling predators such as snakes and rodents; however, studies have found that in the rare cases when communal brooding occurs, parental life span increases, hatch-success rates increase, and fledging survival rates increase (Lott and Mastrup, 1999). Given such similarities in breeding ecology one might imagine a similar rate of population increase, but in fact turkey numbers seem to be rapidly increasing while quail numbers have been on the decline (Calkins, 1999).

Study Area

This study took place in six counties in the North and East Bay areas of California – San Mateo, Sonoma, Napa, Contra Costa, San Francisco, and Marin – and in northern Monterey County. Five of these counties have top ten per capita incomes in California, and all contain a large percentage of California's agricultural lands, so are therefore influential voices when it comes to statewide concerns. Agriculture plays an enormous role in area politics as the industry produces a huge percentage of national and local produce, generates significant revenue, and employs a large number of California residents and, controversially, illegal aliens. Agriculture also causes a lot of environmental damage including habitat loss, soil and water quality issues, and active removal of wildlife species deemed pests. As both one of the area's most important industries and environmental degraders, agriculture is often at the center of political and environmental debate in California, and the turkey debate is no exception, especially given the perceived impact of turkeys on viticulture.



Map 1. The study area in northern California.

The majority of the area is dominated by annual grasslands, followed by urban areas, agriculture, and hardwood forests respectively (Figure 1). California hosts a large number of endemic species, and the California Floristic Province – which includes all six counties in the study area – is included in Conservation International's top 25 biodiversity hotspots (Myers *et al.*, 2000). Unfortunately, California is also host to a number of invasive species, some of the most well-known include yellow star thistle (*Centaurea solstitalis*), brown trout (*Salmo trutta*), and *P. ramorum*, the fungal pathogen that causes SOD (Pimentel *et al*., 2000; Jenkins *et al*., 1999). California tends to be a leader in the United States when it comes to conservation issues, and a large percentage of the state is currently protected under federal or state jurisdiction. The general public tends to be aware of and vocal about environmental issues which means that when issues arise, the public weighs in heavily as it has with the wild turkey debate.

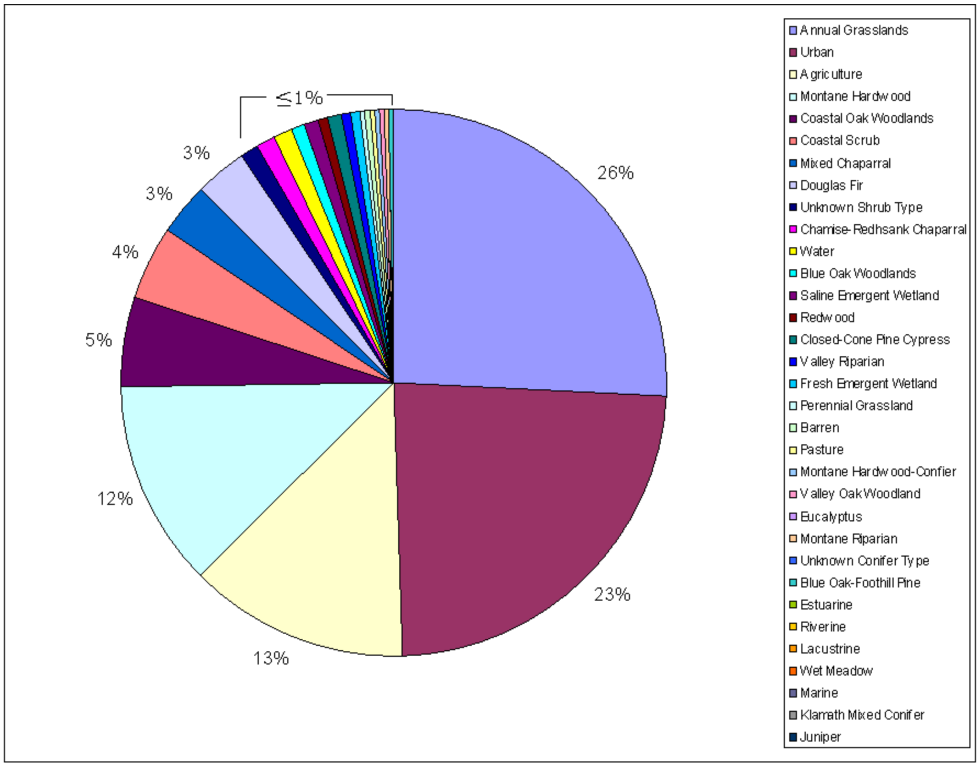
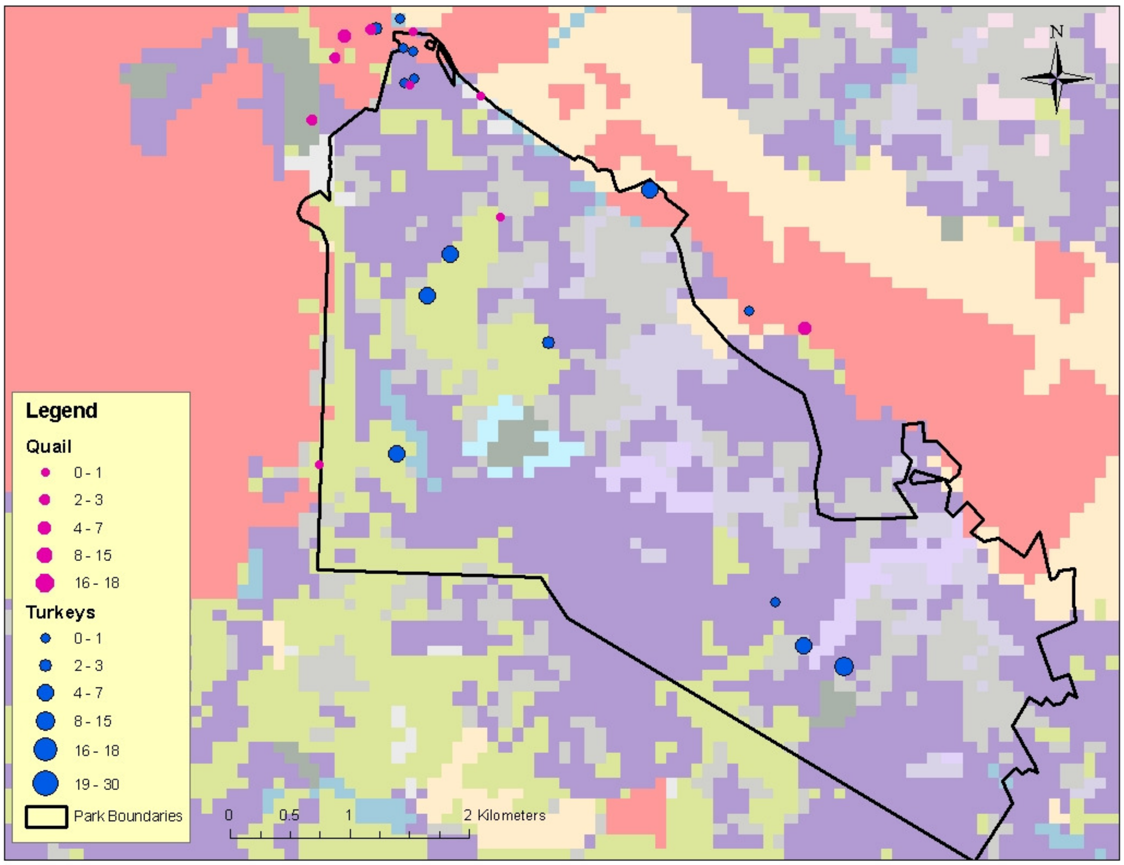


Figure 1. Percent cover of all habitat types found in the study area.

Methods

Data Collection

During the months of May through August of 2007 I collected data in 21 different protected areas in California. While the majority of these areas were state parks or state recreation areas, as this study was conducted under the auspices of DPR, I also surveyed three regional parks and two nature reserves managed by a non-profit organization called Audubon Canyon Ranch. Surveys were conducted in each park at least twice, although a few parks were surveyed more intensely. I conducted surveys at various times of day, which lasted between one and two hours, and utilized existing park trails. If I surveyed a park more than twice, each trail or set of connected trails selected was surveyed at least twice. Surveys were either conducted alone or in the company of DPR staff. I recorded all turkey and quail sightings and audible calls within approximately 300m of the trail and up to 300m from the park boundary. I did not select trails at random, but chose them in order to maximize representation of habitat types in the area. Among the 21 sites all but three of the terrestrial habitat types found within the study area were represented: juniper forest, wet meadows, and Klamath mixed conifer forest. The three types not represented together comprised less than 1% of the study area. I used the Wildlife Habitat Relationship (WHR) habitat classification scheme for this analysis, which is an adaptation of the CalVeg land cover classification scheme used by state agencies (California Department of Fish and Game, 2008), but with animal species taken into account as opposed to just plant communities. To record the GPS location of each sighting I used a mobile mapping device equipped with ArcPad (ESRI, Redlands, CA) software and for each point I documented WHR type, species, individual count, group composition, and microhabitat type along with other variables. The term micohabitat refers to the type of vegetation or substrate within the macrohabitat that the bird was located on or near when sighted. For example, in a montane hardwood forest a bird could be in or under a tree, hidden in a thicket or bush, or sitting on the park boundary fence. If a sighting occurred in a transition zone between two WHR types, I recorded both types indicating one as the primary habitat type and the other as the secondary habitat type. For sightings that occurred in one distinct habitat type I recorded the primary and secondary types as identical. Each point collected represented one sighting, regardless of the number of birds present. I then assigned a turkey establishment rank on a scale of one to three to each site. The highest rank indicates a large, well-established turkey population and the lowest indicates sporadic appearances of a few birds or no known occurrences. These rankings were developed by consulting parks staff and local biologists familiar with the local turkey population.



Map 2. Turkey and Quail sightings at Annadel State Park. The legend does not include the WHR types in the background, but the most important to note are urban (red), annual grasslands (green), and montane hardwood forest (dark purple).

Data Analysis

I first uploaded the data recorded in the field into ArcGIS 9.2 (ESRI, Redlands, CA) software for analysis. I obtained elevation, hydrology, and transportation data layers from the United States Geological Survey's National Elevation Dataset (USGS, 2006). Prior to beginning analysis I filtered the hydrology layer to include only fresh water that would be potable and accessible to the birds. For example marine areas, salt marshes, and below ground water sources were removed, among others. I then sampled each quail and turkey point elevation, nearest distance to potable water, and nearest distance to roads. I also calculated distance from each quail sighting to the nearest turkey sighting, and vice versa for points representing turkey sightings. I converted the WHR layer provided by the State of California into a binary raster separating urban areas from all other habitat types, and calculated the distance from each sighting to the nearest urban area for both species. All distances were calculated using Euclidean distance.

In order to create a habitat model it is necessary to include absence points as well as presence points, and since I only recorded presence points during the field portion of the study, I generated pseudo-absence points in ArcGIS as random samples of the study area and then sampled each point to assign the same environmental attributes as the presence points. Points falling in the ocean were removed since they fall in unsuitable habitat. I considered primary and secondary habitat type at each pseudo absence point identical. Microhabitat and turkey establishment rank were assigned randomly.

In order to determine whether or not turkeys and quail are selective when it comes to habitat I performed a Chi-square goodness-of-fit test, weighting habitat for the percent of the study area covered by each WHR type. A Chi-square test is used to determine if an observed set of sample values differ from what the expected values would be if the sample was truly random. If the test is significant, it indicates that the sample taken is not random and, in this case, that the birds are showing a preference for specific habitat. In order to develop a habitat model and evaluate which factors are most significant in turkey and quail habitat selection, I created classification and regression tree (CART) models for both species using R statistical software as well as a maximum entropy model using Maxent software (Phillips *et al.*, 2006). I included presence and pseudo absence points in all models. CART analysis is a form of binary recursive partitioning that divides variables into the two categories that best describe the dataset (Lewis, 2000). The output resembles a tree with nodes and branches; each node represents a variable and the two branches are the two categories within the variable that are most useful. A second variable may be found at the end of one or both branches and this variable will also be divided into two categories and so on and so forth. CART is useful for providing output that is easily decipherable and provides a clear, visually descriptive model of the data. However, CART does not provide significance values for the variables included in the model. Maxent is useful for small samples like mine because it uses only presence points to actually create the model and, unlike CART, provides the explanatory value of each variable. Maxent is an abbreviation of maximum entropy, and is a method of modeling the probability distribution of a species using entropy to generalize observations of presence of a species (Phillips *et al*., 2006). I ran both CART and Maxent models twice for each species – the first time including the presence of the other species as an explanatory variable, and the second time including only the environmental variables. I then generated confusion matrices to compare the classification success of each of the models, and compared results between models generated with and without the presence of the other species included.

Results

I observed wild turkeys in nine of the 21 research sites and quail in 13. Both birds were spotted in five of the parks, four of which I ranked as having the highest level of turkey establishment. In 12 of the sites I recorded sightings of a single species and four sites had no sightings of either species. Table 1 provides a comparison of species seen with level of turkey establishment at the site. I recorded sightings in 12 of the 33 possible WHR types; turkeys in seven types and quail in 11. Douglas fir forest was the only habitat type lacking quail sightings. Turkey sightings occurred nearly 44% of the time in annual grasslands followed by montane hardwood forest at 18.75%. Quail sightings were distributed a bit more evenly with the birds exhibiting a slight preference for urban areas (25%) over annual grassland (22.5%) followed by montane riparian areas (15%) (Figure 2). Of the six microhabitat types I spotted birds in, quail were found in all of them, but showed a clear preference for dense vegetation including scrub, shrubs, and bushes (Figure 3). On the other hand I recorded turkeys almost exclusively in fields and under trees, which were almost exclusively oak trees. The results of the Chi-square test showed that both turkey and quail are not distributed randomly but are significantly selective about the habitat they reside in ($p < 0.01$).

Table 1. Number of sites where either one, both, or neither species was seen; broken down by establishment rank and number of sites where only turkey were seen.

Species seen	Rank	Sites	Turkey only
Both	3	4	-
	2	1	-
One	3	4	3
	2	6	0
	1	2	1
Neither	3	2	-
	2	1	-
	2	1	-

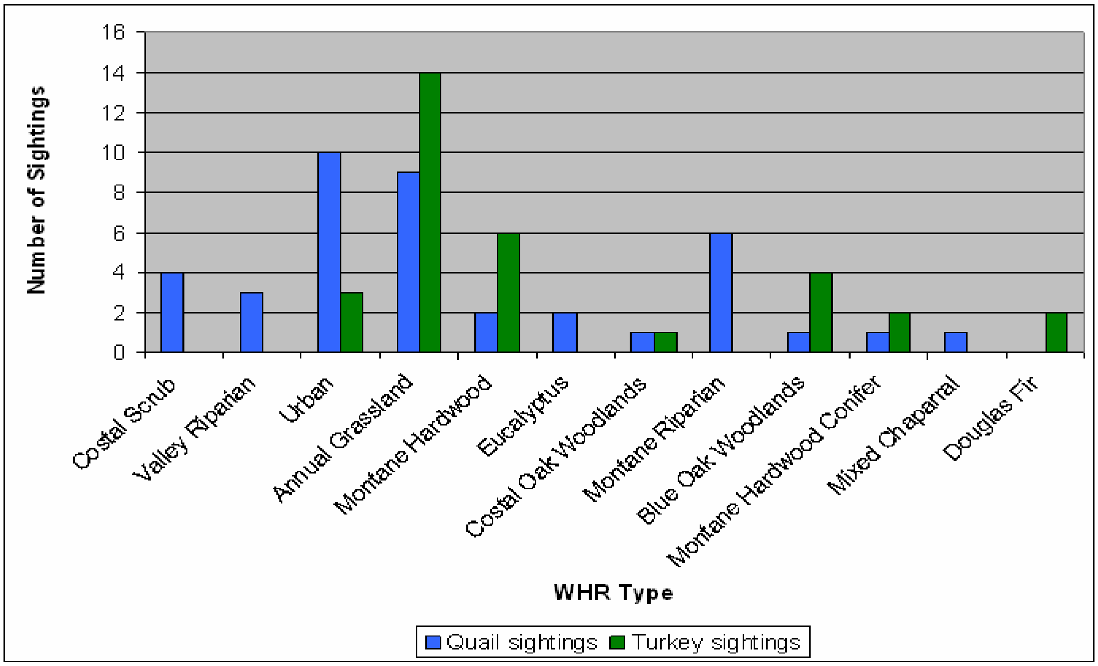


Figure 2. Number of turkey and quail sightings recorded in each WHR type.

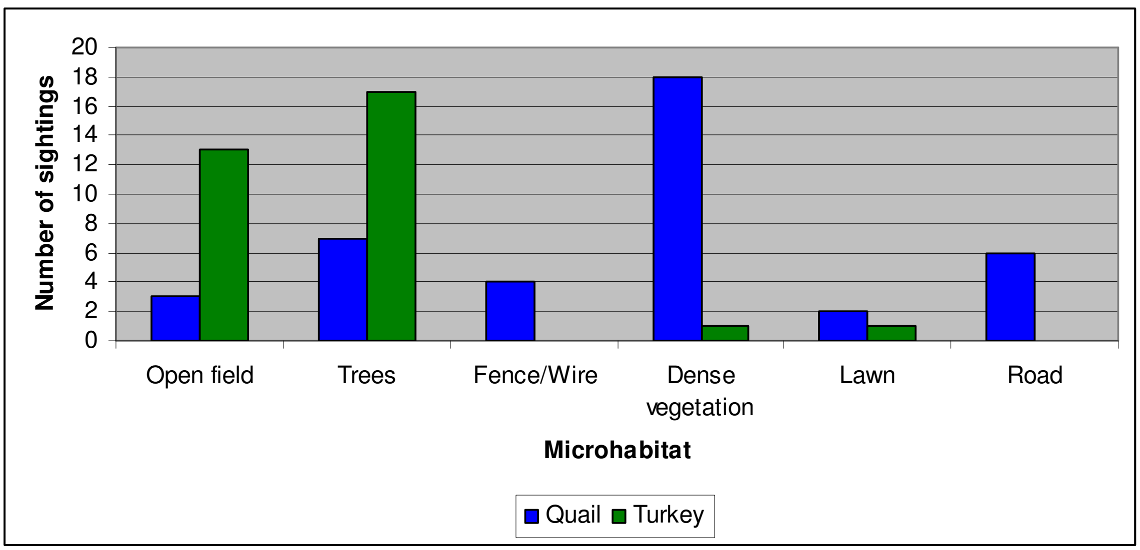


Figure 3. Number of turkey and quail sightings recorded in each microhabitat type.

The results of the CART models including the distance from one species to the other as a variable show that both turkey and quail are highly influential predictors of habitat for each other (Figure 4). Both models indicate that the two species exhibit a preference for close proximity to one another. The quail model had a 70% true positive success rate and the turkey model was slightly lower at 56.25%. The accuracy rates of the models including only the environmental dropped slightly, with the quail model dropping to 57.5% and the turkey model to 50% (Table 2). The true negative rate remained constant at around 99% (Table 3). Proximity to roads was by far the most influential variable in the quail model while primary WHR type and proximity to water were most influential in the turkey model (Figure 5).

Table 2. Confusion matrices of the accuracy of CART model outputs for turkeys and quail including distance from the other species as a variable.

Quail		
	TRUE	FALSE
POSITIVE	28	3
NEGATIVE	269	12
Turkey		
	TRUE	FALSE
POSITIVE	18	3
NEGATIVE	269	14

Table 3. Confusion matrices of the accuracy of CART model outputs for turkeys and quail including only environmental variables.

Quail		
	TRUE	FALSE
POSITIVE	23	2
NEGATIVE	270	17
Turkey		
	TRUE	FALSE
POSITIVE	16	3
NEGATIVE	269	16

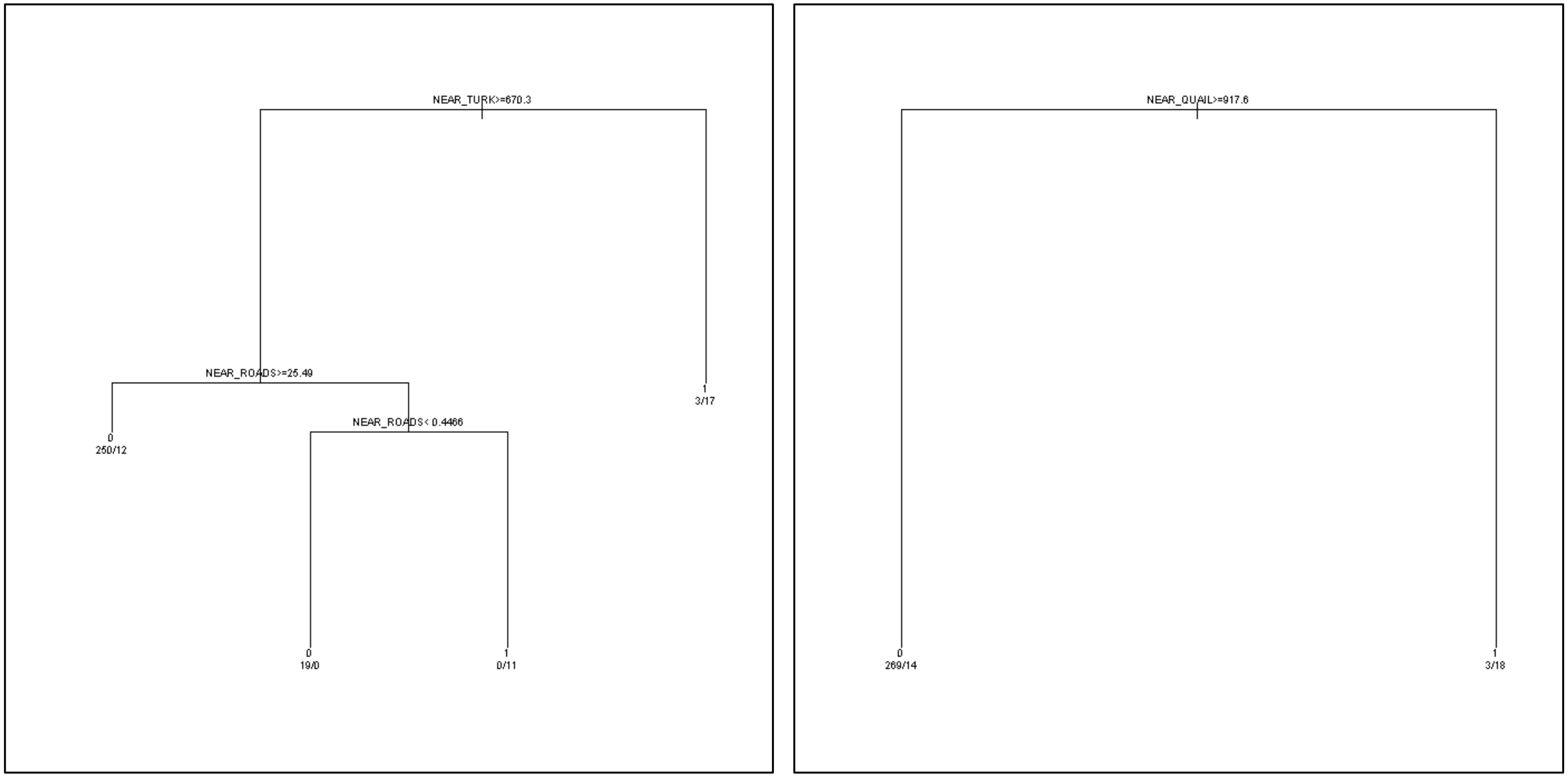


Figure 4. CART model output for quail (left) and turkey (right). Quail habitat selection is described by proximity to turkeys and roads while turkey habitat selection is entirely explained by proximity to quail.

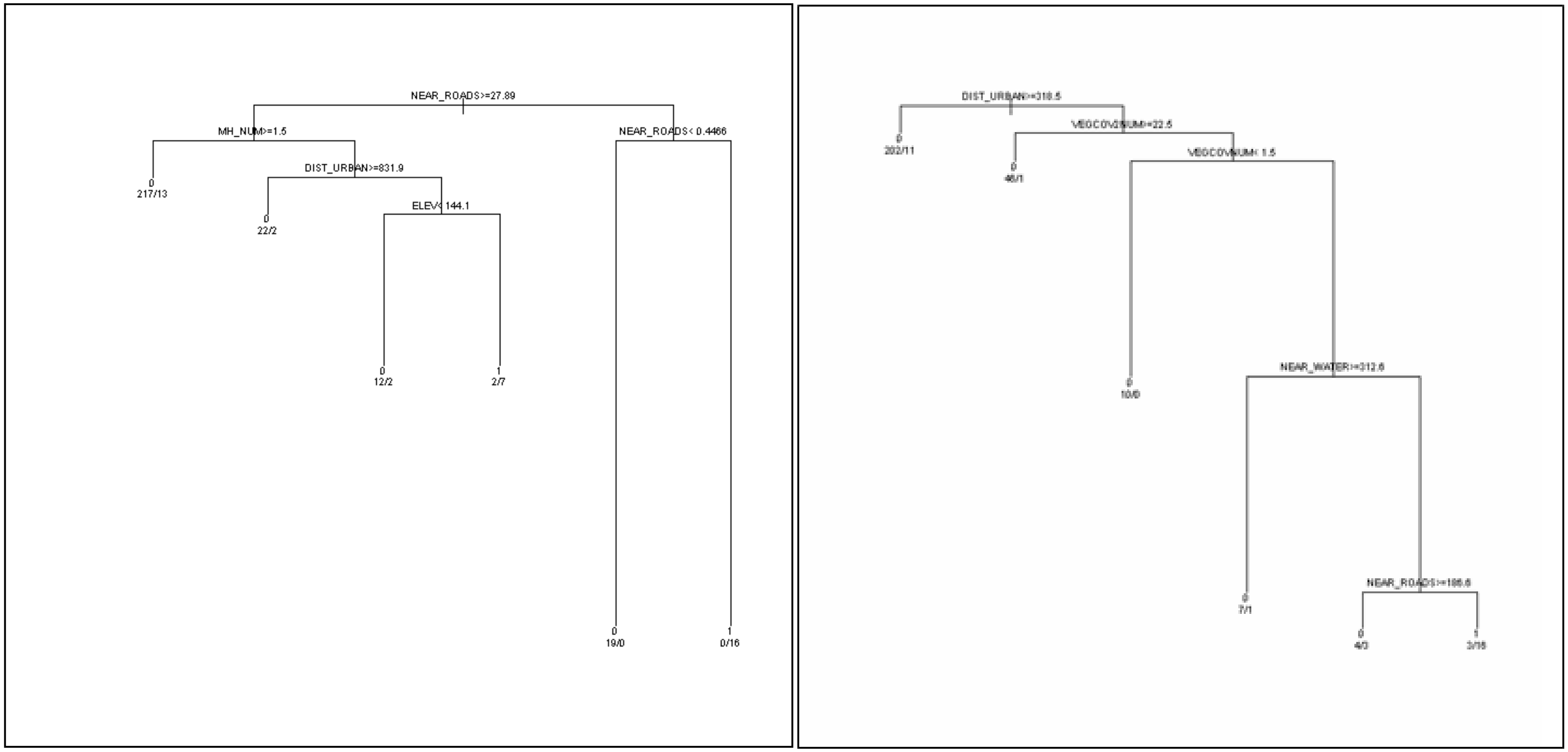


Figure 5. CART model outputs for quail (top) and turkey (bottom) models including only the environmental variables. Quail habitat selection is most influenced by proximity to roads while turkeys are most influenced by proximity to water and habitat type.

Maxent delivered similar results for both models. Distance from quail had the highest percent contribution to the turkey model at 63.3% (Table 4). As also indicated by the CART model results, the turkey habitat was concentrated near quail locations (Figure 6). Distance from turkeys was far less influential on the quail model, contributing 39.5% followed by distance from roads at 14.5% (Table 5). The distribution pattern also differed from that of the turkey with the highest concentration of quail found near turkeys but then dropping off steeply and steadily inclining again as distance increases (Figure 7). The models including only environmental variables showed proximity to roads (31.5 %) and WHR type (27.7%) to have the highest percent contribution to the quail model (Table 7). Microhabitat type and distance from urban areas were the top two contributors to the turkey models at 35.7% and 20.2% respectively (Table 6) with the turkeys exhibiting a preference for fields and tree cover (Figure 8). All Maxent models had 100% true positives which is very high and indicates that this model may be overfitted. Models including distance from turkey and quail had very high false positive rates of 43.4% for turkeys and 62.5% for quail (Table 9). The models including only environmental variables also had very high false positive rates 38.8% for turkeys and 59.9% for quail (Table 10).

Table 4. Maxent output for explanatory power of variables on turkey habitat selection, including presence of quail.

Variable	Percent contribution
Distance from quail	63.3
Microhabitat	14.6
Primary habitat type	7
Secondary habitat type	6.8
Distance from urban areas	4
Distance from water	3.1
Elevation	0.8
Distance from roads	0.5

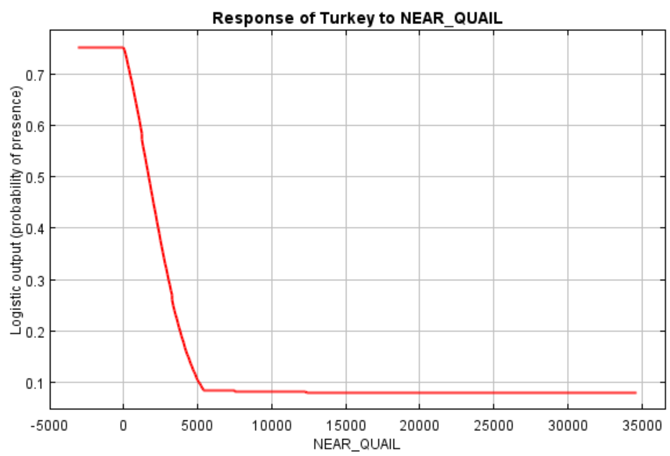


Figure 6. Graph of probability of turkey presence given the distance from quail.

Table 5. Maxent output for explanatory power of variables on quail habitat selection, including presence of turkeys.

Variable	Percent contribution
Distance from turkeys	39.5
Distance from roads	14.5
Microhabitat	12.0
Primary habitat type	11.7
Turkey establishment rank	9.2
Secondary habitat type	7.9
Distance from urban areas	3.8
Distance from water	1.3
Elevation	0.1

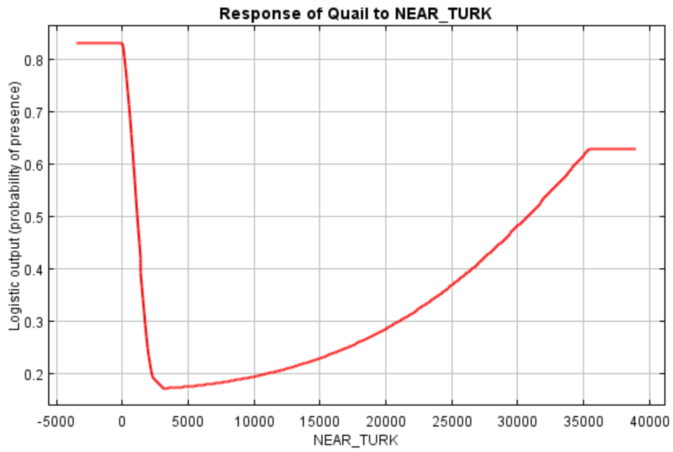


Figure 7. Graph of probability of quail presence given the distance from turkeys.

Table 6. Maxent output for explanatory power of variables on turkey habitat selection, including environmental variables only.

Variable	Percent contribution
Microhabitat	35.7
Distance from urban areas	20.2
Primary habitat type	15.2
Secondary habitat type	13.4
Distance from water	8.4
Distance from roads	4
Elevation	3.2

Table 7. Maxent output for explanatory power of variables on quail habitat selection, including environmental variables only.

Variable	Percent contribution
Distance from roads	31.5
Primary habitat type	27.7
Microhabitat	15.2
Secondary habitat type	10.6
Distance from urban areas	8.5
Distance from water	6
Elevation	0.6

Table 9. Confusion matrices of the accuracy of Maxent model outputs for turkeys and quail including distance from the other species as a variable.

Quail		
	TRUE	FALSE
POSITIVE	40	195
NEGATIVE	77	0
Turkey		
	TRUE	FALSE
POSITIVE	32	132
NEGATIVE	140	0

Table 10. Confusion matrices of the accuracy of Maxent model outputs for turkeys and quail including only environmental variables.

Quail		
	TRUE	FALSE
POSITIVE	40	187
NEGATIVE	85	0
Turkey		
	TRUE	FALSE
POSITIVE	32	118
NEGATIVE	154	0

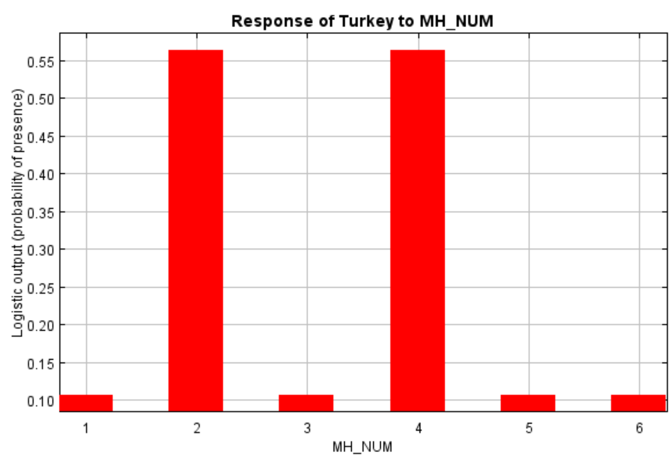


Figure 8. Graph of turkey microhabitat preferences. Types 1 – 6 are, in order, Lawn, Field, Bushes, Trees, Fences/Wire, Roads.

Discussion

Results for the models created using only environmental variables confirm known information about turkey and quail ecology. Quail habitat selection in both models was based heavily on proximity to roads. Most roads in this area are lined with shrubs and hedges which offer the kind of dense, covered protection that quail prefer. An overwhelming number of sightings occurred in blackberry bushes, both the native (*Rubus ursinus*) and Himalayan (*Rubus discolor*) varieties. Blackberry is a popular form of roadside vegetation in the study area and provides quail with both dense cover and a convenient source of food. The Maxent model also ascribed high explanatory power to habitat type. The CART model showed proximity to water as having the highest explanatory power in predicting turkey habitat while the Maxent model indicated microhabitat. Since a large portion of California, including the study area, has an extremely dry climate, it is not surprising that remaining close to a source of drinking water is vital. Since the turkeys were only seen in fields and under trees, it is likely the model is slightly overfitted, but these are the two types most suitable for their dietary ecology. The models also differed on selection of the second most influential variable, with the CART model indicating WHR type and Maxent indicating distance from urban areas. While many studies have proposed that turkeys are not highly habitat selective, these results as well as the results of other studies have shown that turkeys actually show a clear preference for areas with both open grasslands and tree cover, particularly oak tree cover (CDFG, 2004). With suburban sprawl increasing and turkeys habituating themselves to humans and the easy food sources we provide – whether by intentional feeding, gardens, or agriculture – the results of the Maxent model are logical as well.

The results for the models including distance from one species to the other are less easily interpretable. Both the CART and Maxent models showed turkeys have a very strong preference for habitat common with quail. This could be due to sampling bias or to the fact that quail habitat and turkey habitat preferences are so similar that 'quail presence' describes the suite of environmental conditions preferred by turkeys and is acting as a confounding variable. This could be true for quail as well, as the models including only environmental variables ranked proximity to water as highly explanatory, while the model including distance from turkeys did not. This could be due to the fact that turkeys exhibit such a strong preference for water that distance from turkeys acts as a confounding variable for distance from water. The importance of water could also be due in part to the time of year the study was conducted. Summer in California is very dry, and studies have shown that turkeys will move out of upland areas down into the lowlands to congregate near water sources (Burger, 1954b).

The model results for quail habitat also indicated a preference for habitat located near turkeys but, unlike the turkey models, showed a sharp decline and then gradual increase in preference for habitat located farther from turkeys. This could potentially be due to the fact that quail are able to utilize more habitat types than turkeys and have a larger range size. Turkeys are introduced, meaning they cannot inhabit an area unless they were translocated there or have managed to expand their territory that far. This would mean that wherever turkeys are present, quail are likely to be present as well, but that the presence of quail does not necessarily indicate turkey presence.

While the Maxent models appear to be more accurate than the CART models, the Maxent model results of 100% true positives mean that the model may be overfitted.

There was no difference in accuracy given the inclusion of turkeys or quail in the Maxent model, but the inclusion of the other species improved the results of the CART model. As I mentioned before, this is likely due to the fact that the habitat preferences are so similar that presence encompasses a suite of variables. The high false positive rates in the Maxent model were interesting and given that the majority of the study area contains habitat suitable for both turkeys and quail, the model probably did a good job of identifying places where the birds were likely to occur but simply had not been seen. The rates for quail were much higher, which is likely due to the fact that quail can utilize a broader range of both macrohabitat and microhabitat types.

Between 2005 and 2007 DPR invested in research and monitoring efforts, trapping and translocation efforts, and depredation by shooting. A depredation permit was issued in 2006 for Sugarloaf State Park, and a contractor was paid about $5,000 to shoot 40 turkeys in the park. The same year a trapping and translocation effort took place in Annadel State Park in conjunction with the National Wild Turkey Federation. NWTF and DPR staff removed 121 turkeys from the park, an estimated 60% of the total population at the time (Hastings and Shafer, 2006). NWTF covered the majority of the cost, approximately $37,900, in order to encourage DPR to translocate turkeys to areas where they can be hunted as opposed to culling them. However, DPR still had a total expenditure of nearly $11,800 in contract, survey, and manpower costs and staff invested 702 hours into the project. This works out to about $410 per bird, as opposed to $125 per bird for the depredation effort at Sugarloaf. The 2005 Barrett and Kucera study mentioned throughout this paper received approximately $95,000 in funding from DPR, and offered a few management recommendations. Due to the high costs associated with obtaining permits and shootings, they suggest trapping and translocation as the most efficient and cost effective method. Thus far this has not proved to be the case, although this was only DPR's first effort at translocating the birds and, with practice, time and manpower necessities should decrease. According to Hastings and Shafer (2006) the average cost of trapping in California is typically closer to $35 per bird. Barrett and Kucera also recommend increased monitoring in the parks, perhaps by having parks staff record any incidental sightings, in order to provide a more efficient and cost effective method of surveying. The survey component of the trapping and translocation effort cost $5,000, a prohibitive cost if a survey must be performed prior to every trapping effort.

There are a few caveats to this study, the principal one being that all conclusions are based on current turkey population levels. Turkeys are reproducing quickly and spreading throughout the state. This study can only account for current levels and the models generated are not predictive models. It is plausible that should turkey populations reach a certain threshold, they may have a clear negative impact on quail populations. In addition, the results from the amphibian and sudden oak death studies have not yet been published, and could indicate that while turkeys may not impact native birds, they do cause environmental damage in other ways. There could also be impacts in addition to the three major areas of concern that are not yet on the radar, perhaps even to taxa not yet considered such as reptiles or mammals. It also must be observed that this study was only a short term study, and it is difficult to evaluate competition without manipulation or direct observation of its occurrence.

Conclusion

The results of this study indicate that turkeys and quail are coexisting within the same macrohabitat types without significant detrimental effects on either bird. Quail and turkeys utilize very different microhabitat types, and given the size difference between the birds, it is highly unlikely that turkeys will begin to occupy the dense, bushy vegetation preferred by quail. Turkeys also appear to have narrower preferences for both microhabitat and macrohabitat than quail, and are therefore limited in the areas they can colonize. There is a great deal of dietary overlap, however both birds have such diverse feeding preferences that barring any extraordinary environmental disasters, it is also unlikely that turkeys will monopolize available food sources. Given the lack of evidence provided by this study or another to conclude definitively that turkeys are causing significant environmental damage, it would be prudent for parks to continue to pursue improving trapping and translocating efficiency, as both a more cost effective and humane method of removal. Allocating funding to turkey research and continuing to allow researchers to conduct studies in the parks is recommended in order to better understand the ecology and potential impacts of turkeys in California. Monitoring effort by current DPR staff should be initiated or increased in order to provide comprehensive information at little to no additional economic burden to DPR.

The debate as to whether or not the wild turkey is an invader or a reintroduced native - and if a reintroduced native can still be considered native after 10,000 years - may continue for some time to come. What is important at this time is to establish conclusively the extent to which turkeys do or do not cause damage to the environment so that managers can adjust priorities accordingly. This study contributes to expanding current knowledge and providing some basis for development of a wild turkey management plan, but is only the beginning. While many studies have been conducted in areas where the turkeys are native, there is a distinct paucity of information on areas where the birds have been introduced, and further studies are needed in order to make sustainable, well-founded managerial decisions.

Acknowledgements

I am extremely indebted to the staff at State Parks who provided me with guidance, equipment, and support throughout the course of this study particularly Marla Hastings, Cyndy Shafer, Christina Freeman, and Chuck Bancroft. Thanks to Jim Suero for all the critical GIS help. Thanks to Dan Glusenkamp, Gwen Heistad, and Jeanne Wirka at Audubon Canyon Ranch for providing me with information and permitting me to survey the reserves. Thanks to Jules Evans at Avocet Research for helpful suggestions on survey locations and research avenues. My sincere gratitude to the Doris Duke Charitable Foundation for providing funding, to my advisor at the Nicholas School Stuart Pimm, and most of all to Nicholas School professor Dean Urban, whose patience and surreal ability to do everything all at once made this paper possible.

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