Threats from Toxicants at Illegal Cannabis Cultivation Sites on Public and Adjacent Private Lands to Reintroduced California Condors in California

Final Report prepared for National Park Service
Agreement #P17AC01674

<u>Authors</u>

Dr. Greta Wengert[1]

Ivan Medel[2]

Dr. Mourad Gabriel[1,2]

Grant Administered to:

Integral Ecology Research Center

Integral Ecology Research Center

Affiliations

1. Integral Ecology Research Center
   239 Railroad Ave., P.O. Box 52, Blue Lake, CA 95525

2. United States Forest Service, Pacific Southwest Research Station, Arcata, CA 95521

Citation

Any and all data and project information contained within this final report shall be cited as:

Wengert, G.M., I.D. Medel and M.W. Gabriel (2020). *Threats from Toxicants at Illegal Cannabis Cultivation Sites on Public and Adjacent Private Lands to Reintroduced California Condors in California*. Final Report to National Park Service, Agreement # P17AC01674

Background

California condors (*Gymnogyps californianus*) are obligate scavengers and, as such, are reliant upon the remains of carcasses found across the landscape. Their highly endangered status is due, in part, to carcasses contaminated with lead fragments from spent ammunition (Church et al. 2006). Following detection of rodenticides in blood samples collected from prairie falcons nesting in Pinnacles National Park (hereafter, "Pinnacles"), resource managers conducted a preliminary assessment of liver tissue samples from deceased condors. Over half of the samples of birds released by Pinnacles had been exposed to at least one anticoagulant rodenticide (AR). This indicated that condor exposure to ARs may be widespread and could be a primary or a contributing mortality factor for some condors, in addition to lead exposure.

ARs are commonly used throughout California and pose risks to scavengers because they can easily be incorporated into the food web, which results in secondary, and even tertiary exposures and poisonings (Kelly et al. 2014, Rattner et al. 2014). They have been used for decades to manage rodent pest populations in urban and rural landscapes. Once consumed, they prevent blood clotting necessary for hemostasis (Rattner et al. 2014). Recent studies in California have found that exposure to ARs across a suite of avian scavengers ranged from 67 - 100% of birds sampled (Kelly et al. 2014). As the only obligate scavenger sampled in that study, 95% of the turkey vultures (*Cathartes aura*) of the 23 carcasses evaluated were exposed to ARs, with ARs as the proximate cause of mortality for four and contributing or ultimate cause of mortality for three vultures.

Recently emerging data document that many wildlife species have been poisoned by ARs and other pesticides at illegal cannabis grow sites (Wengert et al. 2017). Poisoned carcasses at these sites are left in the field, become food for scavengers, and decompose slowly. In some instances, the carcasses are contaminated enough that vultures have been found dead within the carcasses of bears and foxes, likely due to the consumption of poisoned tissue (Gabriel et al., unpublished data).

IERC is aware of approximately 300 existing illegal marijuana grow sites in California that overlap or are in proximity to the current condor range. The geographic data were collected by law enforcement, and the sites are not accessible to the public due to security concerns and law enforcement sensitive data clearance. Although each of those mapped was 'eradicated,' meaning plants were destroyed, they are not necessarily cleared of all grow site infrastructure, including toxicants like ARs or contaminated carcasses. National Park Service project cooperator and collaborator, IERC, is a leader in applied ecological research documenting the effects of ARs on wildlife and the ecological impacts associated with marijuana cultivation on public lands.

Anticoagulant rodenticides and other environmental contaminants impact all wildlife that contacts them, from rodents to large mammals such as bears and scavenging birds. These hazardous chemicals also negatively impact the environment in other ways by contaminating soil and water (Gabriel et al. 2017). Predicting and identifying where illegal cannabis cultivation sites are likely to occur enhances the ability to remove them from the landscape and remove the risk to condors and other scavengers.

The objectives of this project were to:

1. Identify areas with a high probability of illegal grow sites within central California condor range using Geographic Information Systems (GIS) and Maximum Entropy modeling efforts;
2. Identify areas with a high probability of illegal grow sites within a 100 km radius around a proposed California condor reintroduction site in Redwood National Park (REDW) using GIS and Maximum Entropy modeling efforts;
3. Ground-truth the GIS model through site visits in central and northern California to establish model accuracy;
4. Create GIS layers by overlaying California condor Global Positioning System (GPS) location data to determine high condor use areas coupled with high-risk areas for cultivation;
5. Create a GIS layer based on likely movements of newly released condors from a proposed northern California release site at REDW.

Methods

Objectives 1 and 2

We conducted modeling and ground-truthing efforts in two geographically distinct study areas. The extent of Study Area 1, covering 9,918.78 km^2, was defined by generating a 95% Minimum Convex Polygon for all locations recorded by 23 individual reintroduced condors affixed with Argos satellite GPS wing transmitters prior to release into central California from Pinnacles National Park (Figure 1). Study Area 2, covering 19,216.23 km^2, includes all California terrestrial areas within 100km of a proposed condor reintroduction release site in Redwood National Park (Figure 2). The distance of 100km is based on the distance reintroduced animals are expected to initially range.

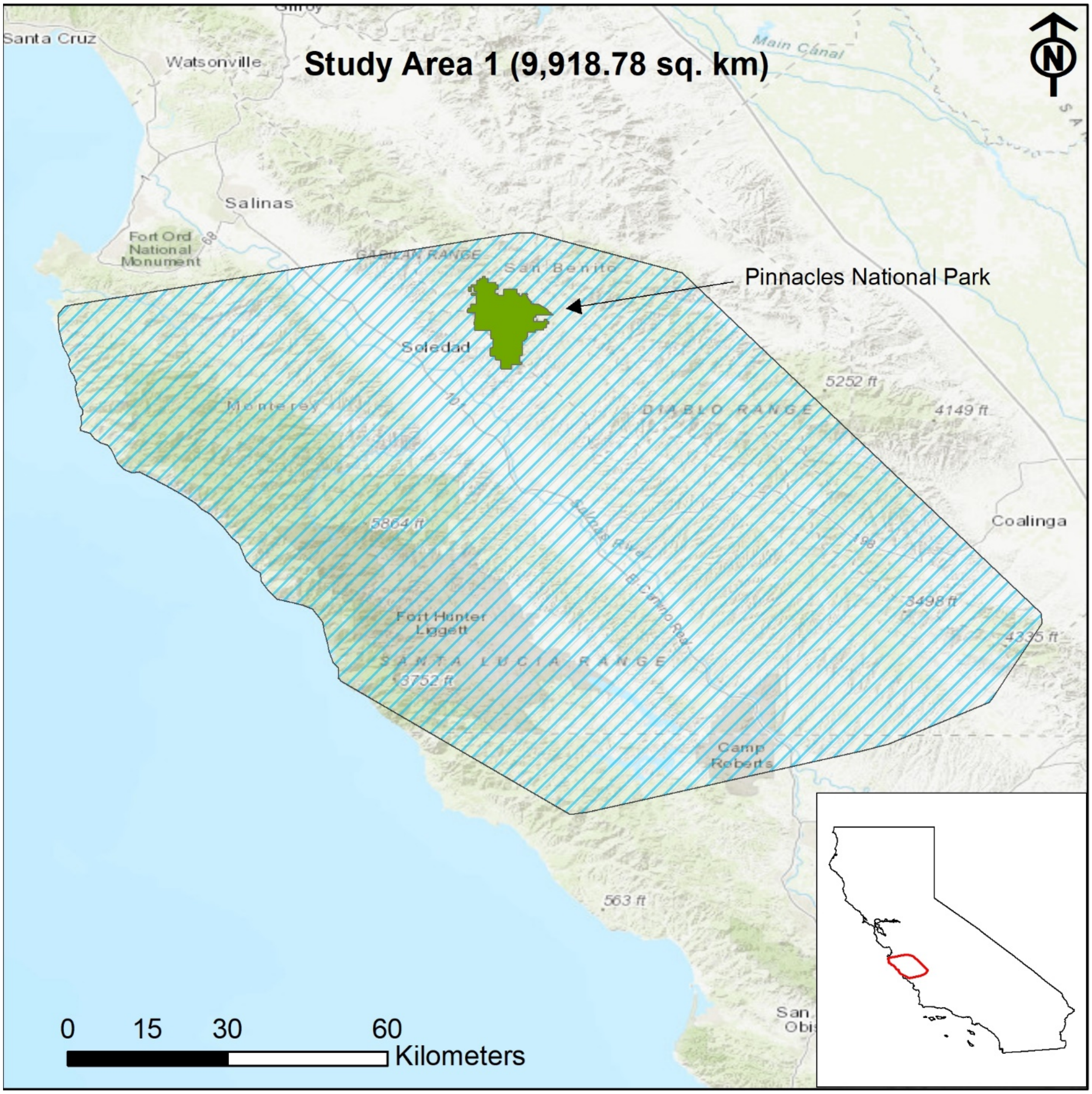

Figure 1. Overview map of the extent of Study Area 1 (blue hatch polygon) in central California and the location of Pinnacles National Park for a study on trespass cannabis cultivation risk on California condors, between 2016 – 2020.

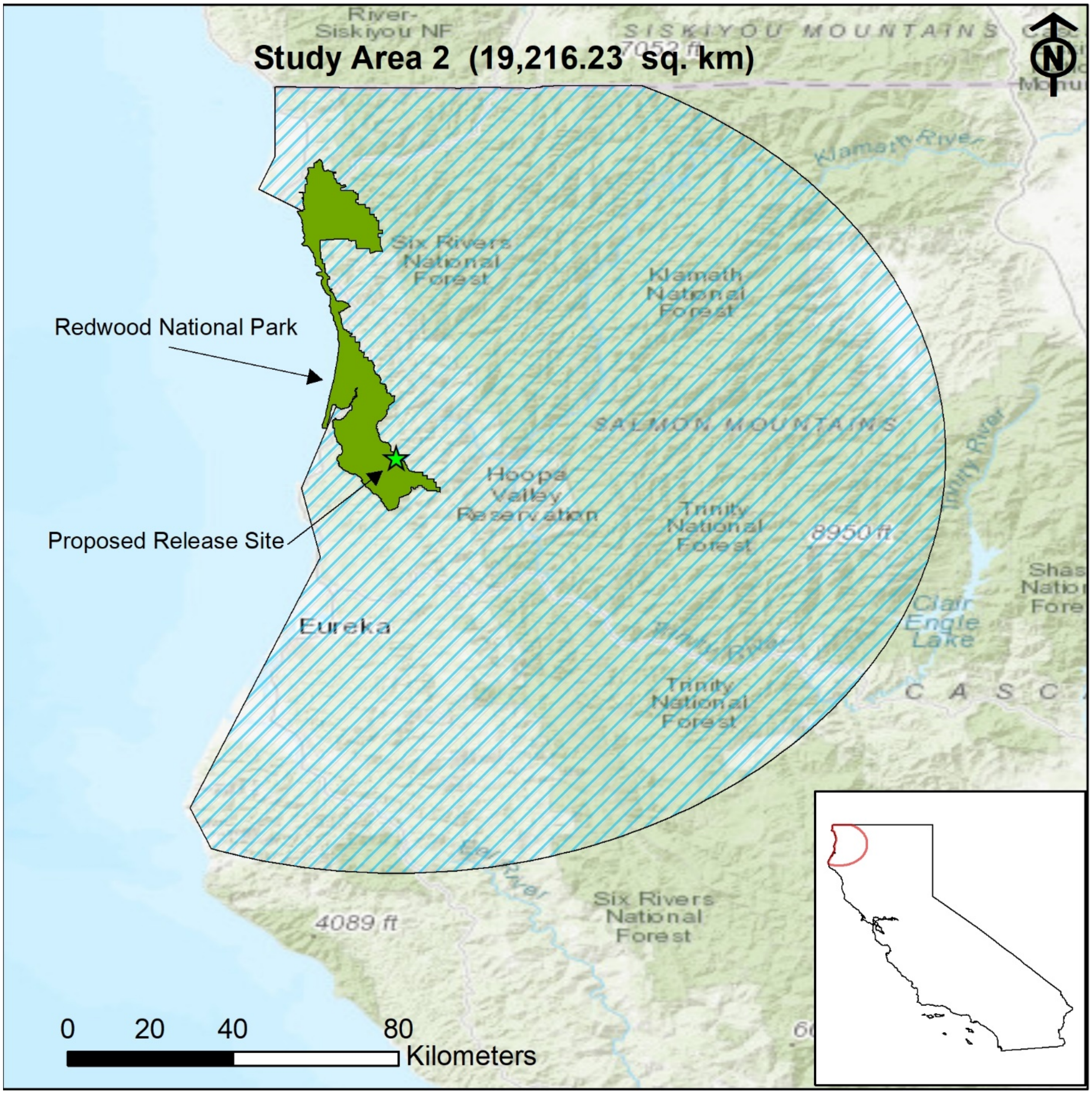

Figure 2. Overview map of the extent of Study Area 2 (blue hatch polygon) in northern California, the location of Redwood National Park, and the proposed release site, for a study on trespass cannabis cultivation risk on California condors, between 2016 – 2020.

We received data from local, state, and federal law enforcement agencies on the locations of 13 and 88 trespass cannabis cultivation sites active between 2016 and 2020 on public and nearby private lands within Study Area 1 and 2, respectively. We used the presence-only MaxEnt modeling system (Elith et al. 2006, Phillips et al. 2006, Ortega-Huerta and Peterson 2008), which is often used to model species distributions (sometimes interpreted as habitat quality) using species presence data and the values of environmental variables at these locations relative to random background points. For background (availability) points, we used a random selection of 10,000 points across the modeling extent. Because law enforcement does not keep records of areas searched, we were unable to limit background data selection to surveyed areas only (Phillips et al. 2009).

We selected candidate environmental variables for modeling at 30m resolution based on the highest resolution, except for precipitation, obtained for regional datasets (Table 1). In addition to variables derived from climate, terrain, and land cover data, we used an array of variables related to human influences, such as distance from roads, trails, and ownership boundaries. Because personal observations suggested that trespass growers often select forest stands that had been logged or burned in recent years, we also tested several variables derived from recent disturbance data layers (1-9 years prior) and the total number of years since the last fire. Ninety percent of the filtered cultivation site locations were used for model training, and 10% as test data. We implemented 10-fold cross-validated replication with 500 iterations. Area Under the Receiver Operating Curve (AUC) was used for model evaluation, ranging from 0.5 (random) to 1.0 (perfect discrimination). To identify related groups of variables, we created correlation matrices for all potential explanatory variables. No correlated variables ($|r| > 0.7$) were identified within either study area, with the strongest correlation calculated as 0.59.

Starting with the full model, we used step-wise variable reduction or jackknife approach, eliminating the variable causing the smallest decrease or largest increase in mean test AUC when removed to assess the importance of variables in the final model. The final logistic output of the model predictions was classified into binary suitability indexes based on the mean 'Maximum training sensitivity plus specificity Cloglog threshold' identified by MaxEnt based on ten replicate model runs. High suitability areas were identified as all pixel values above the mean values calculated at all training locations. A 5 x 5 pixel rectangular moving window was then used to smooth model outputs and account for suitability outputs at the spatial scales of grow sites instead of highly localized values within a single pixel.

Table 1. All environmental and anthropogenic variables used by independent study areas in California to develop complete models before removing variables through step-wise variable reduction for a study on trespass cannabis cultivation risk on California condors between 2017-2020.

Variable	Study Area 1 (Central CA)	Study Area 2 (Northern CA)
Aspect	x	x
California Habitat Wildlife Relationship	x	
Canopy cover (%)	x	x
Distance to 1 - 9 year old fire disturbance (m)	x	x
Distance to closest road (m)	x	x
Distance to closest spring or seep (m)	x	x
Distance to closest trail (m)	x	x
Distance to intermittent or perennial stream (m)	x	x
Distance to private property (m)	x	x
Elevation (m)	x	x
Mean 2016 - 2020 annual precipitation (mm)	x	x
Slope (%)	x	x
Time since last fire (years)		x

Objective 3

Due to the spatial bias inherent to the grow-site locality data due to non-random surveillance by law enforcement, we wanted to ensure our model accounted for characteristics of cultivation sites not previously found by law enforcement as well as those that were. Therefore, we used an unbiased method of finding cultivation sites previously undetected by law enforcement by ground-truthing randomly selected drainages within the two project areas. Because all cultivation sites require water, irrigation pipe always originates from some natural or modified water source, usually within a few hundred meters upslope of the cultivation site, but up to 3 km away according to our observations. Therefore, we performed ground-truthing by walking stream courses searching for irrigation pipe, water cisterns, refuse typically associated with trespass cultivation (e.g., fertilizer or pesticide containers, propane tanks, sleeping bags, tents, and other camping materials), or cannabis planting holes themselves (Wengert unpublished data). We described any evidence of cultivation we found and recorded a location with GPS. When possible, we identified the precise location of the cultivation site by following the irrigation pipe to its final destination. When we found other types of evidence but not irrigation pipes, we searched the immediate area for the actual location of the cultivation sites.

To select streams for ground-truthing, we overlaid the two pre-designated project areas, or modeling extents, with the CalWater coverage (CIWMC 2020). Our objective was to perform ground-truth surveys on 1% of total stream distance within each ground-truthing area. We did this by randomly selecting a single reach, then selecting all reaches within that HUC6 subwatershed with the same name, repeating this step until the total stream mileage added up to at least 1% of the entire CalWater stream distance within each project area. For Study Area 1 only, this process resulted in selecting many inaccessible streams due to private property or closures of particular areas; thus, we also selectively chose several additional public land stream reaches with a presumed high likelihood of access. These processes resulted in the selection of 8 streams in Study Area 1, of which we were able to survey 50.1 km, distributed mostly throughout public land (Pinnacles National Park, Los Padres National Forest, Bureau of Land Management properties, and a small portion on private land).

In Study Area 2, the random selection process resulted in the survey of 18 streams in Study Area 2, of which we were able to survey 89.9 km, distributed on the Klamath, Six Rivers, and Shasta-Trinity National Forests, and Green Diamond Timber Company lands. We also used ground-truthing data from a previous, unrelated effort to boost our stream ground-truthing distance for more robust validation of the model. We did this by resurveying three of the 12 streams surveyed under that original project in 2016, thus ensuring that results did not differ from the original surveys' results. After the inclusion of these additional ground-truthing efforts, a total of 221.9 km were surveyed towards the ground-truthing effort.

Objectives 4 and 5

Once the cannabis cultivation risk model was generated for each of the two study areas, we used ArcGIS 10.6.1 to overlay the output with the high-use areas of the reintroduced condors in Study Area 1 to generate a risk map for condor interaction. A condor use zone was developed using the 95% kernel density estimate contours calculated from 2014 – 2017 occurrence records of 23 individual reintroduced condors through Argos GPS transmitters affixed to condors managed by Pinnacles National Park. The "use zone" was intersected with MaxEnt model outputs to calculate the proportion of the "use zone" within each relative cultivation likelihood.

For Study Area 2, we had no data on condors' movements except to estimate that the highest use areas would fall within 100km of the release point.

Results

The two modeling efforts resulted in two significantly different sets of variables contributing to illegal cannabis cultivation sites. In Study Area 1, five variables were included in the final model, while in Study Area 2, six variables were included (Table 2). Model output (mean AUC = 0.84) resulted in 8.19% of Study Area 1 classified as the high relative likelihood of cultivation, 5.88% for moderate, and 85.93% for the low likelihood (Figure 3). Within the condor use area, used as a proxy for suitable condor habitat, model outputs identified 8.83% as having a high relative likelihood of cultivation, 5.00% moderate, and 86.18% as low likelihood.

In Study Area 2, the mean AUC for the final model was 0.841, 7.12% was classified as high relative likelihood of cultivation, 18.71% was classified as moderate, and 74.17% was classified as low likelihood (Figure 4). Without information on condors' movements post-release, these percentages represent our best estimate of the spatial risk to condors within their likely movement range once released.

Table 2. List of environmental and anthropogenic variables used in the final MaxEnt models for both California study areas for a study on trespass cannabis cultivation risk on California condors, between 2017 – 2020.

Variable	Study Area 1 (Central CA)	Study Area 2 (Northern CA)
Aspect		
California Habitat Wildlife Relationship		
Canopy cover (%)		x
Distance to 1 -9-year-old fire disturbance (m)		
Distance to the closest road (m)		x
Distance to the closest spring or seep (m)		
Distance to the closest trail (m)	x	
Distance to intermittent or perennial stream (m)	x	
Distance to private property (m)	x	x
Elevation (m)	x	x
Mean 2016 - 2020 annual precipitation (mm)	x	
Slope (%)		x
Time since last fire (years)		x

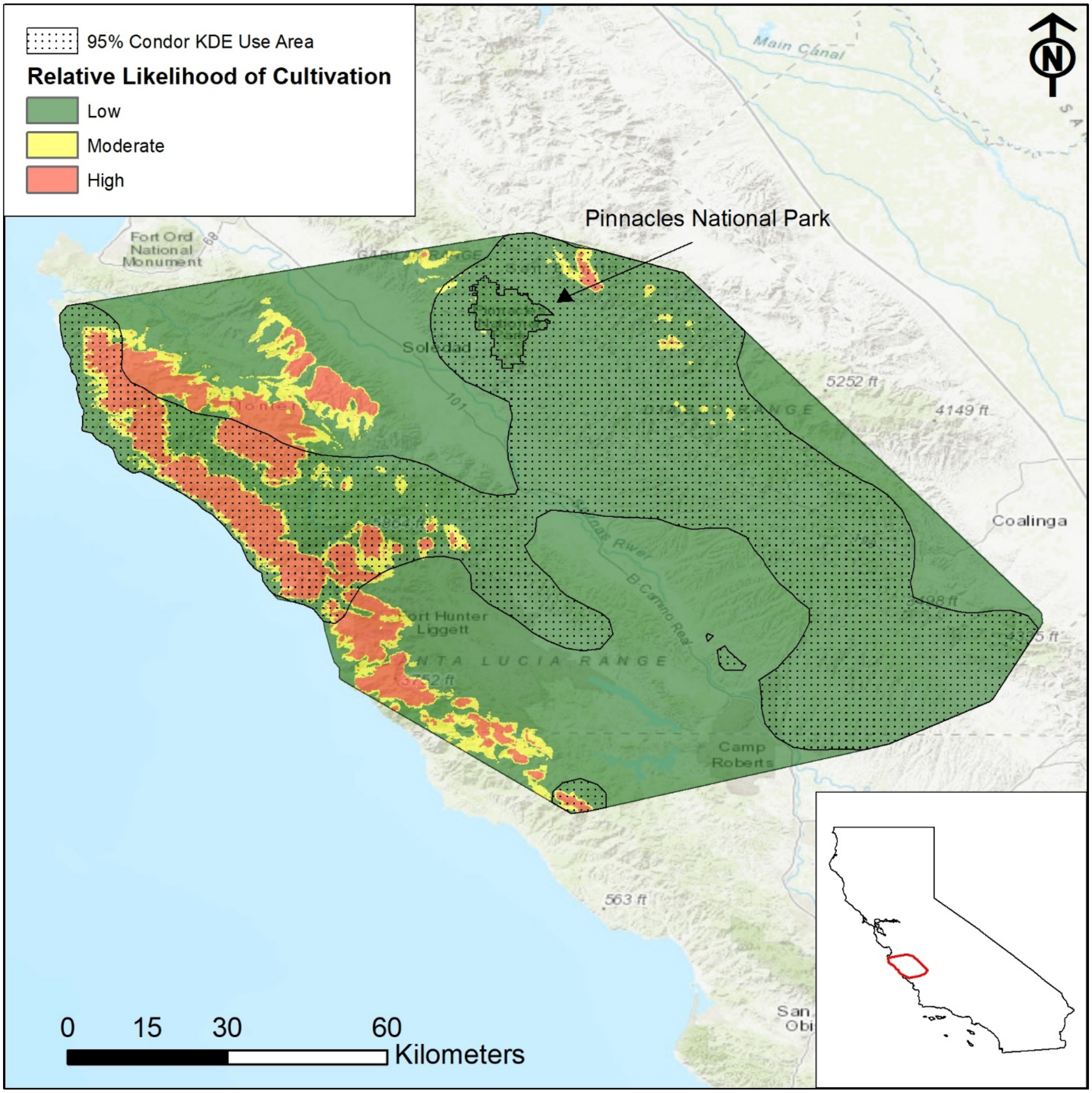

Figure 3. MaxEnt model output of the relative likelihood of cultivation within Study Area 1 overlaid on the condor use area determined by occurrence data from individuals from 2014 – 2017, for a study on trespass cannabis cultivation risk on California condors, between 2016 – 2020.

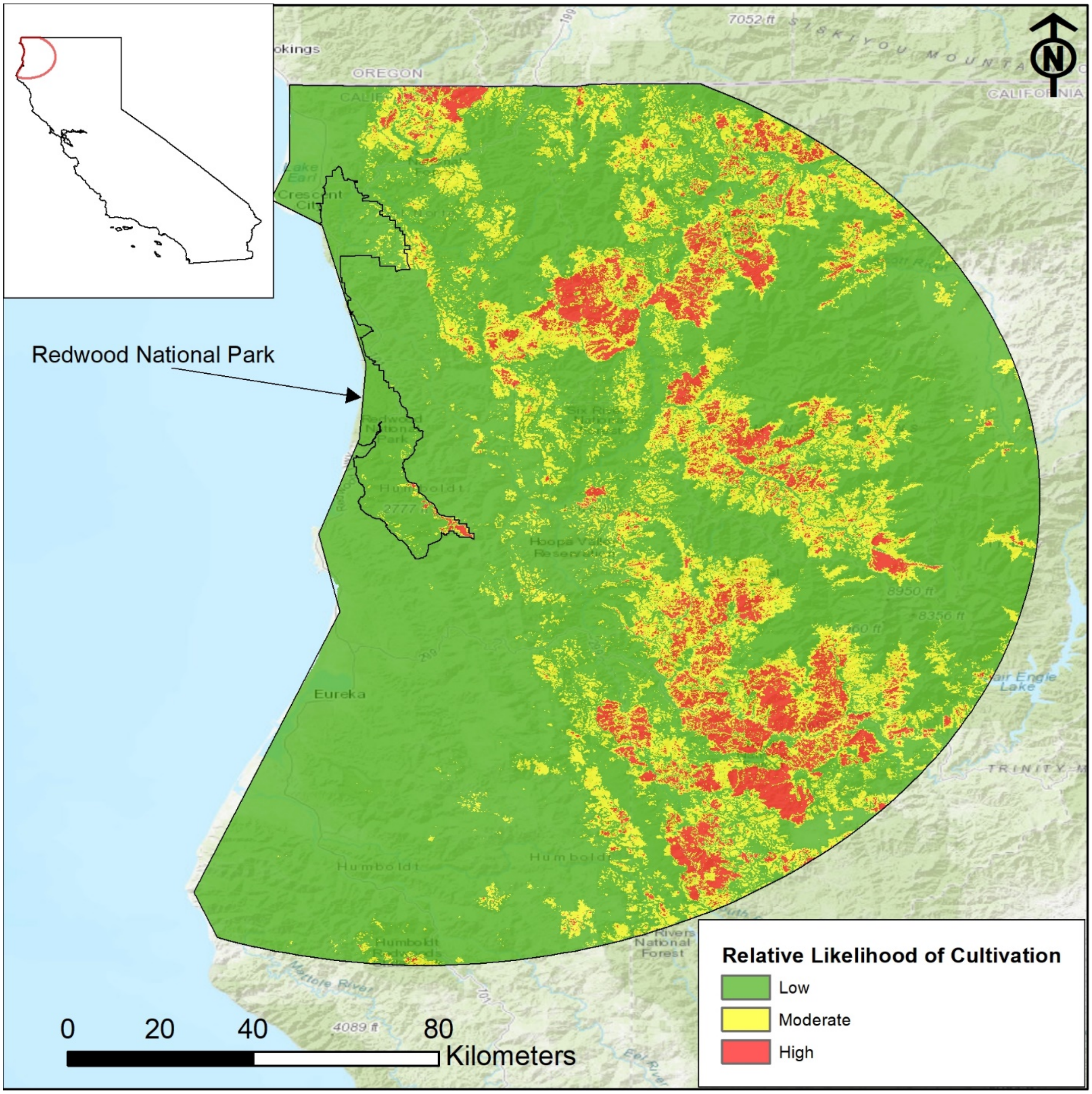

Figure 4. MaxEnt model output of the relative likelihood of trespass cultivation based on six predictor variables within Study Area 2 for a study on trespass cannabis cultivation risk on California condors, between 2016 - 2020.

In Study Area 1, the percentage of total stream kilometers surveyed through ground-truthing that fell into the high-risk likelihood category was 22.65%, and 26.65% and 50.70% for moderate and low likelihood, respectively. There were no detections of any infrastructure or plants suggesting illegal cannabis cultivation within any of the ground-truthing streams surveyed. These results suggest that the cannabis cultivation site dataset used to build the risk model was an accurate representation of environmental predictors for current (2016 - 2020) distribution of trespass cultivation sites within the localities for which data were available. However, available data within our time frame and condor use area were scarce and will require more comprehensive information across spatial and temporal parameters to strengthen the model's precision in properly modelling the distribution and magnitude of risk to condors from grow sites.

In Study Area 2, the percentage of total stream kilometers surveyed through ground-truthing that fell into the high-risk likelihood category was 5.3%, and 29.11% and 65.59% for moderate and low likelihood (Table 3), respectively. Surveys resulted in the detection of 17 trespass cannabis cultivation sites previously undetected by law enforcement. However, in all cases except one, evidence at the sites indicated that the last use of the infrastructure at the site for cannabis cultivation predated the time period of cultivation site locality data used to build the model. It is noteworthy to point out, however, that the single site detected that was dated within the time period of this study fell into the high likelihood category of cultivation risk, which incidentally supports the model. Overall, these results also lend support to the accuracy of the model, indicating that at least for the time period used (2016-2020) and that most relevant to condor movement, the model is a well-supported representation of current risk across the landscape based on available data.

Table 3. Proportions and total stream length of ground-truthing efforts listed by MaxEnt model likelihood category.

	% of Ground-truth efforts		Total Surveyed Stream Length (km)	
Likelihood	Study Area 1	Study Area 2	Study Area 1	Study Area 2
High	22.65	5.03	11.3	4.8
Moderate	26.65	29.11	13.4	26.2
Low	50.7	65.59	25.4	59.0
		Total	50.1	89.9

Conclusions and Recommendations

Access to water and sunlight are the primary limiting environmental conditions required for trespass *Cannabis* spp. production. Accordingly, the high-water availability within northern California likely results in larger total quantities of grow sites that may not be restricted to the highest likelihood model classifications. This is supported by the determination that all water-based model variables (e.g., stream locations, precipitation) were determined to be inconsequential within the northern study area. Thus, more ubiquitous adequate growing conditions result in a broader spatial distribution and the total number of grows within northern California, likely explaining the substantial difference in grow site detections during ground-truthing efforts (i.e., 17 in Study Area 1 vs. 0 in Study Area 2) with similar levels of effort. The ubiquity of grow sites, both historical and current, within the northern study area likely poses a risk to newly released condors, especially within the more distant regions of the expected range of condors. A more proactive surveillance program in these areas could accommodate quick eradication and removal of toxicants to lessen this risk. Alternatively, the areas adjacent to Redwood National Park and south through the private timberlands are at less risk and would likely provide habitat relatively free of the toxicants found at trespass grow sites.

Conversely, low quantities of training data within Study Area 1 may not be completely representative of all grow site locations allowing highly precise extrapolation to regional condor risk. Limited recent data preliminarily indicate cultivators may be more willing to travel further off roads, likely in search of remote water sources, to establish sites. As a result, reconnaissance, investigation, and assessment efforts are likely missing collections of sites within remote wilderness areas situated near dispersed water sources. Additional efforts should be undertaken to identify and assess these locations so they may be evaluated for the presence of toxicants and provide additional data points to improve modelling efforts and improve the risk assessment for California Condors, and ultimately to implement a more proactive reclamation program to reduce risks.

Citations

California Interagency Watershed Mapping Committee [CIWMC]. N.d. Layer:CalWater hydrological Areas (ID:0). https://gispublic.waterboards.ca.gov/arcgis/rest/services/webmap/CalWater_HydrologicAreas/MapServer/0. Accessed Oct 28, 2020.

Church, M.E., R. Gwiazda, R.W. Risebrough, K. Sorenson, C. Chamberlain, S. Farry, W. Heinrich, B.A. Rideout, and D. R. Smith. 2006. Ammunition is the principal source of lead accumulated by California condors reintroduced to the wild. Environmental Science & Technology 40: 6143-6150

Elith, J., C. H. Graham, R. P. Anderson, M. Dudı´k, S. Ferrier, A. Guisan, R. J. Hijmans, F. Huettmann, J. R. Leathwick, A. Lehmann, J. Li, L. G. Lohmann, B. A. Loiselle, G. Manion, C. Moritz, M. Nakamura, Y. Nakazawa, J. M. Overton, A. T. Peterson, S. J. Phillips, K. Richardson, R. Scachetti-Pereira, R. E. Schapire, J. Sobero´n, S. Williams, M. S. Wisz and N. E. Zimmermann. 2014. Novel methods improve prediction of species' distributions from occurrence data. Ecography 29:129-151.

Gabriel M.W., G.M. Wengert, J.M. Higley, D.L. Clifford, R.H. Poppenga, L.W. Woods, S. McMillian and S. Torres (2017) Science with Solutions: Documentation, Reclamation and Monitoring of the Ecological Impacts of Marijuana Cultivation on Endangered Species, Final Performance Report, Grant #F14AP00021, USFWS: Endangered Species Act (Section-6) Grant-in-Aid.

Kelly, T. R., R. Poppenga, L.A. Woods, Y.Z. Hernandez, W.M. Boyce, F.J. Samaniego, S.G. Torres, and C.K. Johnson. 2014. Causes of mortality and unintentional poisoning in predatory and scavenging birds in California. Veterinary Record Open 0:e000028. doi:10.1136/vropen-2014- 000028

J. Grantham, D. George, A. Welch, J. Brandt, J. B. Burnett, K. J. Sorenson, M. Johnson, , D. Moen, J. Rasico, J. W. Rivers, C. Battistone, and C. K. Johnson. 2014. Spatiotemporal patterns and risk factors for lead exposure in endangered California condors during 15 years of reintroduction. Conservation Biology 00:1-10.

MaxEnt model version 3.3.3k: https://biodiversityinformatics.amnh.org/open_source/maxent/) to model grow-site distribution.

Ortega-Huerta, M. and A. T. Peterson. 2008. Modeling ecological niches and predicting geographic distributions: a test of six presence-only methods. Revista Mexicana de Biodiversidad 79:205-216.

Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling 190:231-259.

Phillips, S. J., M. Dudik, J. Elith, C. H. Graham, A. Lehmann, J. Leathwick, and S. Ferrier. 2009. Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. Ecological Applications 19:181-197.

Rattner, B. A., R. S. Lazarus, J.E. Elliott, R. F. Shore, and N. Van Den Brink. 2014. Adverse outcome pathway and risks of anticoagulant rodenticides to predatory wildlife. Environmental Science and Technology 48:8433–8445.

Wengert, G.M., Gabriel, M.W., Thompson, C, J.M. Higley. 2017. Ecological impacts across the landscape from trespass marijuana cultivation on western public lands. In Where There's Smoke: The Environmental Science, Public Policy, and Politics of Marijuana. C. Miller editor, University Press of Kansas.