Population Decline Due to Drought in Northern Mojave Woodpeckers (*Melanerpes rubrifrons*): a Cause for Concern.

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The fictional species Mojave Woodpecker (*Melanerpes rubrifrons*) illustrated.

The Mojave Woodpecker is a (hypothetical) member of the genus Melanerpes. This species has a very large range throughout the Mojave and Sonoran deserts, with an Extent of Occurrence of more than 20,000 square kilometers, although populations within this area appear to have more localized dynamics. Another contiguous population can be found in central and southern Mexico. Although the northern population underwent a significant bottleneck during a prolonged drought in 2010-2014, it is not clear what its status is currently.

This species does not migrate. Its generation time is between five and six years, and females have between 1 and 3 female progeny each year. This species is a social breeder and it requires grassland, savanna, or forest that is not heavily disturbed by human development to persist. An annual survey undertaken by USFWS has provided data on the northern population from 1992 to 2012. These data can be found in "woodpecker.csv."

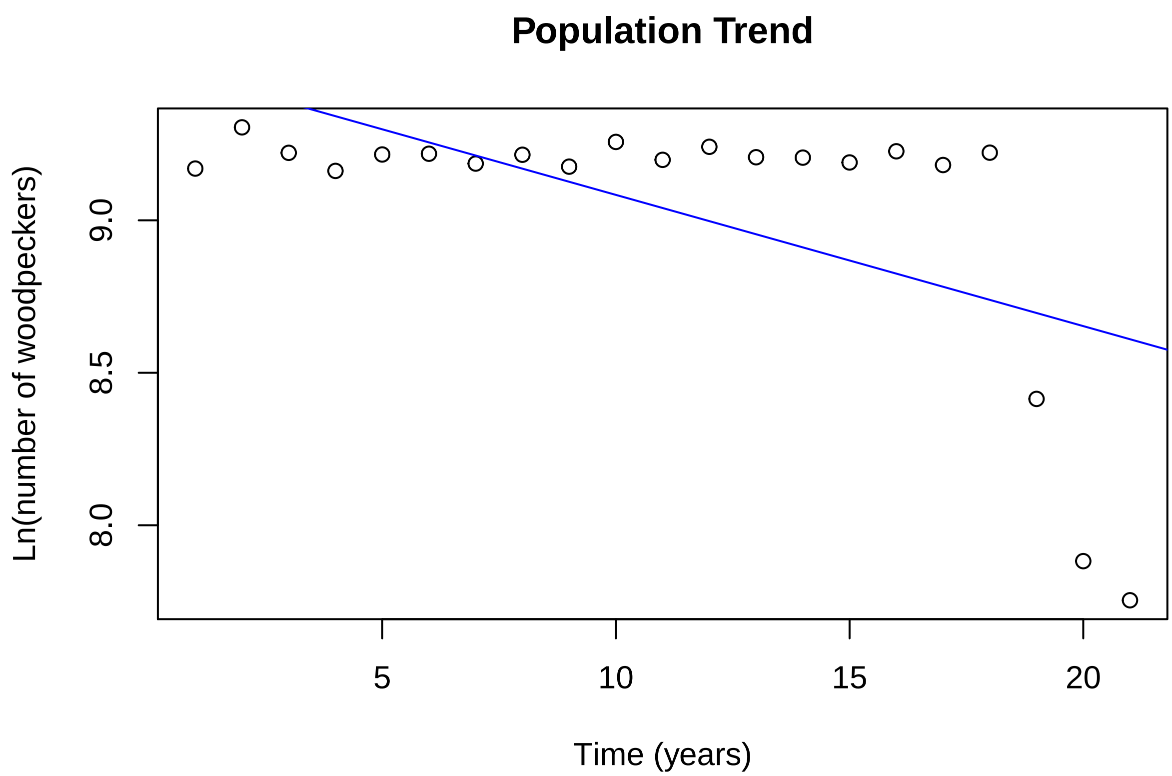
First, determine whether the population is increasing, decreasing, or stable, based on the trend data.

The first thing we need to do is read our data into R and then determine the trend of the population. We do know that *Melanerpes* woodpeckers generally have one breeding event per year and experience discrete population growth.

```
#reading our file and importing our data
woodpecker <- read.csv("/cloud/project/woodpecker.csv")


#putting our population data into single vector
Population_data <- (woodpecker$Pop_size)

#creating a time vector with number of years (rather than year date)
Years <- 1:length(Population_data)

#making a linear regression line
reg_model <-lm(log(Population_data) ~ Years)
reg_model
```

```
##
## Call:
## lm(formula = log(Population_data) ~ Years)
##
## Coefficients:
## (Intercept)        Years
##     9.51364     -0.04303
```

```
#plotting our data and the line
plot(Years,log(Population_data), main="Population Trend",
    ylab="Ln(number of woodpeckers)", xlab="Time (years)")
abline(reg_model, col="blue")
```




```r
#setting r to be the second coefficient we found in our line (i.e. the slope)
r <- coef(reg_model) [[2]]
r
```

```
## [1] -0.04302674
```

```r
#r the instantaneous growth rate

#solving for lambda to find our current trend
lambda <- exp(r)
lambda
```

```
## [1] 0.9578858
```

The population is shrinking by ~4% a year.

Second, your assessment needs to include a projection of future status. This means you could calculate the instantaneous growth rate and calculate the time until the population reaches a critical threshold (see Assignment 2) or project the expected patch occupancy within a given time frame (see Assignment 3).You will have to use your judgment to determine what that critical threshold/time frame is. For example, you could calculate the time until the population is expected to recover to historic levels, or calculate the time until the population drops below 30% of current occupancy.

Using IUCN red list evaluation criteria for generation time (i.e. longer of ten years vs three generations), three generation times is the longer time span for this species. The generation time is 5-6 years – so 15 years will be our projection time.

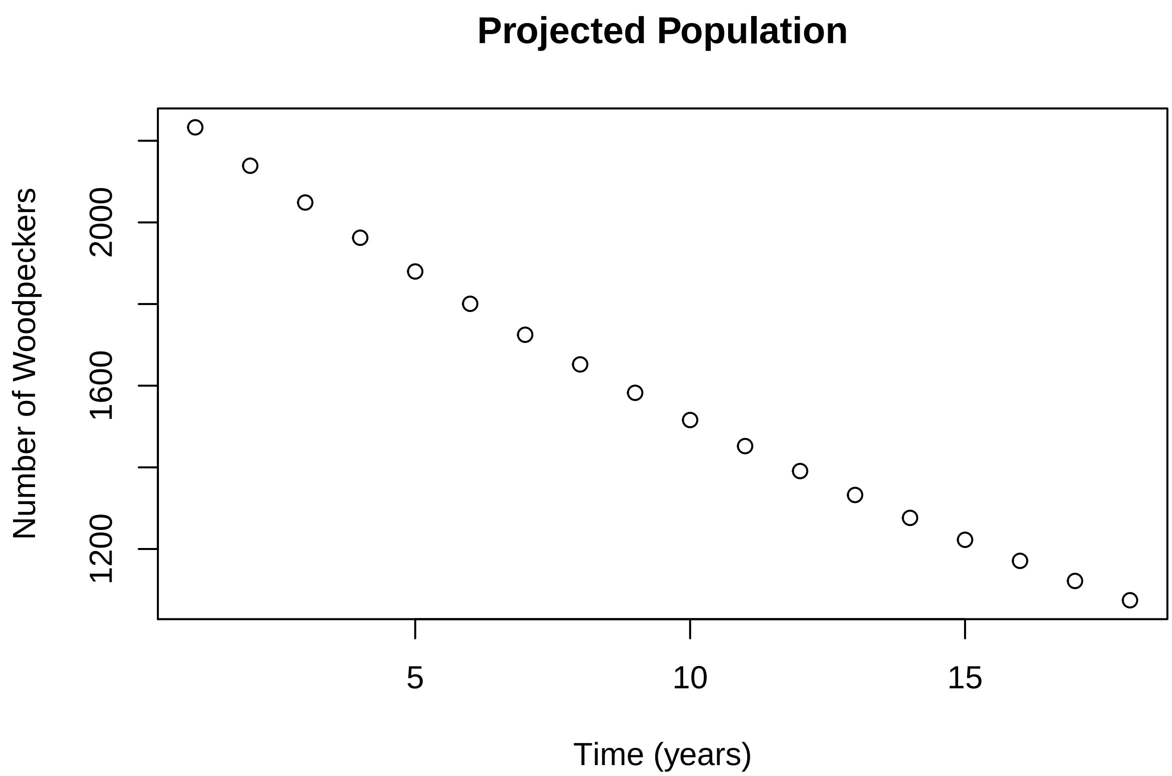
```r
#let's project the population using multiple measures to see the range of
#potential listing projections

#assuming K is close to the average population status prior to the fire
K <- sum(woodpecker$Pop_size, 1:18)/18
#setting our initial N value
N_2012 <- 2331
#creating a time vector out 15 years
t <- c(1:15)
#what is the population at year 15?
#we already know lambda, as coded above, so:
N_15 <- N_2012*lambda^t
#we projected the population out for 15 years
#but where is the population at 15 years?
N_15 [[15]]
```

```
## [1] 1222.498
```

```r
#For comparison, let's repeat this with the a higher generation time.
#(6 years, so 18 year range)

#creating a time vector out 18 years
t_18 <- c(1:18)
#what is the population at year 18?
#we already know lambda, as coded above, so:
N_18 <- N_2012*lambda^t_18
#we projected the population out for 18 years
#but where is the population at 18 years?
N_18 [[18]]
```

```
## [1] 1074.458
```

```r
#for fun, let's graph our data!
#we will plot only the 18 year data, since the first 15 years should be the same graphically
plot(t_18, N_18,
     main = "Projected Population",
     ylab="Number of Woodpeckers", xlab="Time (years)")
```




```r
#okay, so how is the population fairing?
#let's take our year 15-18 population projection and our last current projection
#and find out by how much the population has declined.
1 - 1222.498/2331
```

```
## [1] 0.4755478
```

```r
#it has declined by 48% in 15 years
1 - 1074.458/2331
```

```
## [1] 0.5390571
```

```r
#It has declined by 54% in 18 years.

#how does that compare to the real population drop on the data we already have?
#we will average the population from 15-18 years prior
#to our last real data point to get a rough estimate of that range.

Ave_Pop_18 <- sum(Population_data[c(3:21)]) / 18
Ave_Pop_15 <- sum(Population_data[c(6:21)]) / 15
Ave_Pop_18
```

```
## [1] 9394.778
```

```r
Ave_Pop_15
```

```
## [1] 9294.2
```

```r
1 - 2331/Ave_Pop_15 #decline over average years within 3 generations, low end
```

```
## [1] 0.7491984
```

```r
1 - 2331/Ave_Pop_18 #decline over average years within 4 generations, high end
```

```
## [1] 0.7518834
```

```r
#It has declined by 75% in 15-18 year window

#What about using K, which should average out year to year fluctuations?
#How as the population declined in response?
1- 2331/K
```

```
## [1] 0.7790161
```

```r
#The population has declined by 78%
```

Possible Listings

Using Real Observed Data

Using our real known observed data, the northern population of the Mojave Woodpecker can be classified as **A2a Endangered**. We have directly observed observation of decline (a), the population has declined by over 50% but not quite at 80% (Endangered), and fits the criterion for "Population reduction observed, estimated, inferred, or suspected in the *past* where the causes of reduction may not have ceased OR may not be understood OR may not be reversible." This is the best fit especially given we do not know if the trend is reversible – we have no given clear data or signs of recovery.

Using Real Data in Regards to K

Using our real known observed data but using K instead of three generation times, the northern population of the Mojave Woodpecker can be classified as **A2a Endangered**. We have directly observed observation of decline (a), the population has declined by 78% (Endangered), and fits the criterion for "Population reduction observed, estimated, inferred, or suspected in the *past* where the causes of reduction may not have ceased OR may not be understood OR may not be reversible." This is the best fit especially given we do not know if the trend is reversible – we have no given clear data or signs of recovery. While K may not be appropriate to calculate from it is an average of the population prior to drought and reflects both longer-term trends AND how far the population has fallen proportionally. While it combines a wider set of data than the 15-18 trend it is worth considering because that data is available.

Using Projected Data

The northern population of the Mojave Woodpecker can be classified as **A4b Endangered (18 year span) OR A4b Vulnerable (15 year span).**

Under the A4b listing, the IUCN guidelines state "An observed, estimated, inferred, projected or suspected population reduction where the time period *must include both the past and the future* (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible." We used both future projection and past data to calculate the population dynamics. Like the A2a listing, we do not know if the trends are reversible nor do we fully understand the situation. The b criterion states that the abundance appropriate for the taxon must be used as evidence – because it is such a huge drop, we consider it significant and appropriate for the taxa.

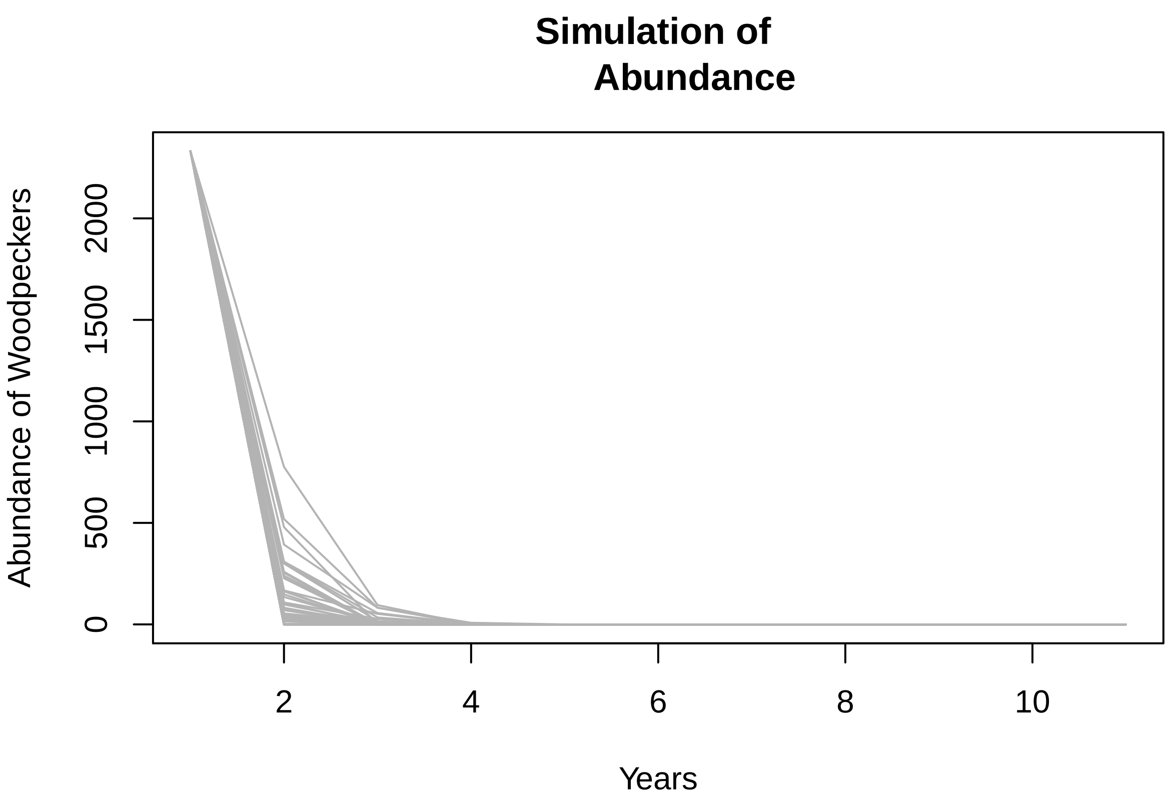
The 18 year span of data shows the population should be listed as Endangered as it has declined by over 50% but less than 80% (54%). The 15 year span of data shows the population should be listed as Vulnerable as it has declined by over 30% but less than 50% (48%).

Probability of drought

Because this population declined likely due to a prolonged drought, let us model environmental stochasticity and see what happens to the population.

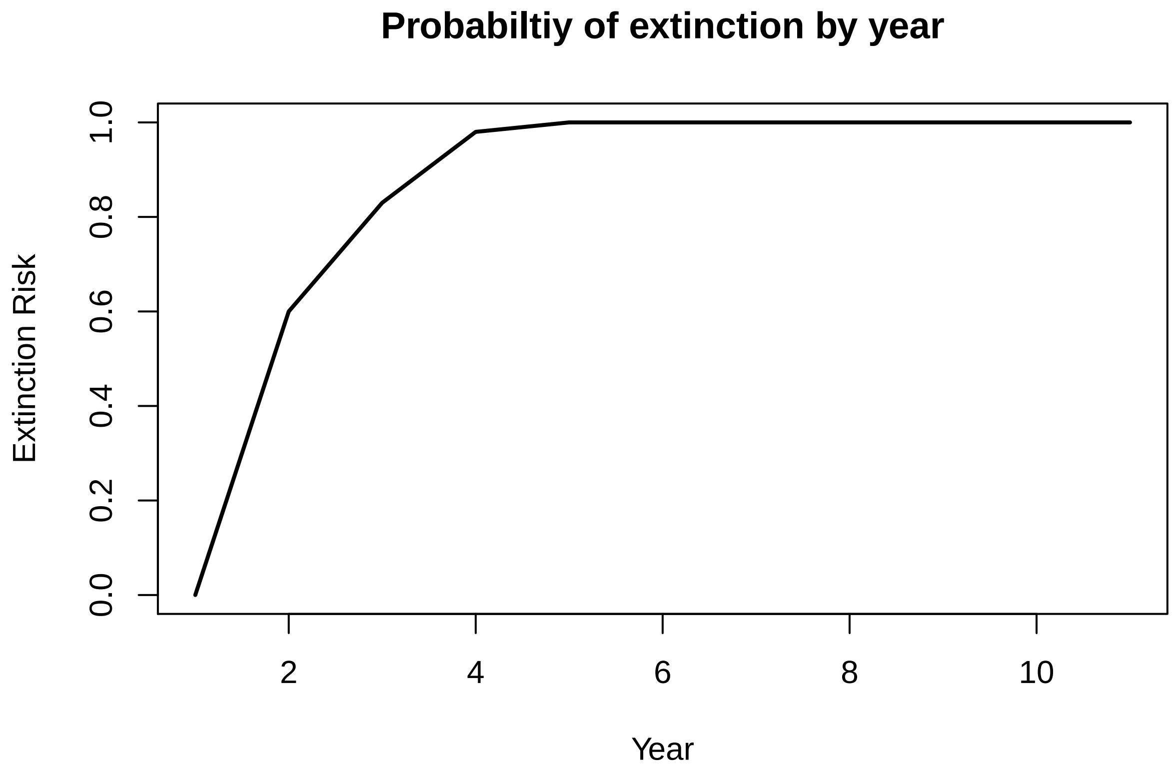
```
Init_N <- 2331 #this is our current population
Drought_prob <- 0.01 #1% risk of a drought occurring
#overall, we had a 88% mortality rate in the year of the drought
Drought_lambda <- 0.22
R_Max <-log(Drought_lambda) #finding r
nyears <- 10 #let us look 10 years from now
nreps <-  100 #let us look at 100 situations, of which there is a 1% chance of a drought.

#this is our N(t+1) data
Popdata_1 <- c(10991, 10110,  9528, 10055, 10080,
               9760, 10046, 9662, 10478,  9880, 10312,
               9965,  9952,  9796, 10161, 9714, 10115,
               4511,  2650,  2331)
#this is our (Nt) data
Popdata_0 <- c(9601, 10991, 10110,  9528, 10055,
               10080,  9760, 10046, 9662, 10478,
               9880, 10312,  9965,  9952,  9796,
               10161, 9714, 10115,  4511,  2650)

#Lambda = N(t+1)/(N(t)) for annual mortality/growth
Dr_Lambda <- c(Popdata_1/Popdata_0)

SD_anngrowth <- sd(Dr_Lambda) #standard deviation of our annual lambda

#this is a function for computing next-year abundance
#including environmental stochasticity
Logistic <- function(prev_abund){
  prev_abund * (rnorm(1,r,SD_anngrowth))*(1-(prev_abund/K))}

#we are building our model
VAdemo <- function(nreps,nyears,Init_N,R_max,K,Drought_prob,Drought_lambda){
  #browser()
  PopArray2 <- array(0,dim=c((nyears+1),nreps))   # set up storage array

#start looping through replicates, i.e setting up our trials to see what happens
#in an event of no drought/drought factoring in that chaos

  for(rep in 1:nreps){

    # we're setting the population's initial point the same at our initial abundance
    PopArray2[1,rep] <- Init_N

    #we are going to set hte loop through the years
    for(y in 2:(nyears+1)){
      #factoring in stochasticity and density dependence
      nextyear <- max(0,trunc(Logistic(PopArray2[y-1,rep])))
```

```
      # this is what happens in a drought year
      if(runif(1)<Drought_prob) nextyear <- nextyear*Drought_lambda
      PopArray2[y,rep] <- nextyear
    }
  }

  return(PopArray2)
}

#Running the simulation based on our parameters-- what is it projected to be?
Projection <- VAdemo(nreps,nyears,Init_N,R_max,K,Drought_prob,Drought_lambda)

#Let's plot the 100 simulations of abundance of woodpeckers versus years
PlotCloud <- function(simdata){
  plot(c(1:11),simdata[,1],col=gray(0.7),type="l",ylim=c(0,max(simdata)),
       xlab="Years" ,ylab="Abundance of Woodpeckers", main = "Simulation of
       Abundance")

  for(r in 2:ncol(simdata)){
    lines(c(1:11),simdata[,r],col=gray(0.7),type="l")
  }
}

PlotCloud(Projection)
```




```
Extinction_byyear <- function(simdata){
  apply(simdata,1,function(t)  length(which(t==0)))/ncol(simdata)
}
```

```r
#Let's plot the probability of extinction by year given our model
#factoring all of our trials.
plot(c(1:11),Extinction_byyear(Projection),type="l",lwd=2,xlab="Year",
     ylab="Extinction Risk", main = "Probabiltiy of extinction by year")
```



Let's interpret the results.

Given current trends, even with a 1% chance of a drought occurring, the northern population of the Mojave Woodpecker has a 100% extinction rate in 6 years. There is no scenario in which this population recovers.

Density of the species in northern population.

```r
#Density <- population / square kilometers of land, one pop

#Historical Density
Hist_Dens <- K/20000 #use k for ease
Hist_Dens
```

```
## [1] 0.5274139
```

```r
#So historical density was 0.53 woodpeckers km^2

#Current Density
Cur_Dens <- 2331/20000
Cur_Dens
```

```
## [1] 0.11655
```

```r
#So current density 0.12 woodpeckers km^2
```

Final Assessment, Life History Considerations, and Management Plan.

Overall the Mojave Woodpecker 1. needs to be listed in some capacity and 2. management is needed to ensure the survival of the species. No projections calculated found that the species could continue to survive with current trends.

Life History Considerations: Past and Present

The Mojave Woodpecker is understudied (because it is fictional). *Melanerpes* woodpeckers have a wide range of characteristics but given the Mojave Woodpecker's fictional range and life history traits (i.e. social breeder), we will look at Acorn Woodpeckers (*Melanerpes formicivorus*, henceforth ACWO) and Red-cockaded Woodpeckers (*Dryobates borealis*, henceforth RCWO). Although RCWO is not in *Melanerpes* their life history traits are similar and this species has undergone notable declines unlike ACWO.

Both ACWO and RCWO have highly developed social systems and rely on cavities for nesting. ACWOs are generally social and live in cohesive family units of 1-8 males and 1-4 egg-laying females, including up to 10 non-breeding helpers (Stacey 1979, Koenig and Stacey 1990). ACWOs occasionally go on forays up to 15 km away (Hooge 1995, Barve et al. 2019). However, mean territory size for a Californian population is 0.06 km^2 (MacRoberts and MacRoberts 1976). In good acorn mast years the species may breed twice – this scenario has a 33% chance of occurring in any given year (Koenigand and Stahl 2007). The most important factor for ACWO reproductive success was the previous year's acorn mast – breeding groups with acorns cached produce twice as many offspring than those without (Stacey and Ligon 1987).

A large portion of the population may die due to starvation if acorn production fails over a large geographic area (Hannon et al. 1987). Oak (*Quercus*) diversity plays a role in reproductive success as different species produce acorns at different times of the year on different boom-bust cycles. Areas with high oak diversity are not observed to be abandoned by ACWOs during mast failure years unlike areas with low oak diversity (Hannon et al. 1987).

RCWO have smaller family units of 2-5 individuals with one breeding pair and non-breeding helpers from previous generations. Moving unestablished females from their natal home area to RCWO groups lacking females has reduced the chance of extinction for isolated groups (Defazio et al. 1987). Nest excluders help reduce threats from other cavity dwellers (Carter, Walters, and Doerr 1989). A notable nest threat is the invasive European Starling (*Sturna vulgaris*) (Troetschler 1976).

The scenario and final IUCN determination

A possible scenario is the drought year (2009) severely hampered mast production and depleted existing acorn stores. This event lead to suppressed breeding in the population the following year (2010). Widespread starvation and death throughout the population likely have made it difficult for family groups to survive in subsequent years. Although Mohave Woodpeckers occur over a large geographic area resources are likely scattered/scarce in the desert which results in patchy distribution rather than being uniform across range. Due to their non-uniform distribution and the Mohave Woodpecker's group-oriented lifestyle, we assume 1. it is difficult for groups to continue surviving, in part because 2. suitable patches are few and far apart and 3. the current low population size makes it difficult for groups to "reconnect" with others. The Allee effect is likely present in the Mojave Woodpecker and if individual groups are under the critical population threshold they will not continue to survive. If each individual Mohave Woodpecker needed 0.06 km^2 (like similar real species), the current population would use 120km^2 of land if individuals did not overlap. Given the range for the northern population was 20,000 km^2 before the drought 120km^2 would only be 0.06% of the total former range. Surviving individuals could be so far apart they cannot easily find each other. All of the aforementioned considerations paint a grim picture.

We only have three year's worth of data after the drought period. In good breeding years the species may behave like ACWOs and breed twice. However, given there is only a 33% chance that a given year will be good is not improbable that there has not been a good breeding year since the drought which has contributing to their decline. If in the years following the drought oaks have had poor mast production that could also be another strike against an already struggling population. Additionally if the survey data reflects individuals and not breeding groups then some individuals counted do not breed given the Mohave Woodpecker's social structure. This means that the population is even worse off as not all of the remaining individuals will breed.

Given our mathematical projections and our knowledge of natural history this species needs management now. Listing it as endangered under A2b or A4b would be reasonable and difficult for anyone to object to given our projections given all but one analysis gave us endangered predictions.

Recommendations

Several recommendations exist. We know that ACWO populations are supported through supplemental feeding and hindered by artificial scarcity. Artificially supplying acorns to living populations may prevent starvation in bad years while also promoting second breeding attempts in some years. Trying to connect distant populations through habitat corridors or by relocation may be needed if some existing populations are too small to self-sustain or all the same sex. Artificially introducing young females into new areas without females may prevent against genetic isolation and boost population growth. Additionally, translocating family groups from the southern population may prevent against genetic bottlenecking and increase the population. Since the Mojave Woodpecker is considered non-migratory it is unlikely individuals would return back to their natal regions if relocated.

Protecting good quality existing habitat where birds survived will help both short term and long term. Existing habitat can be improved by increasing oak diversity to create plasticity in the case of environmentally stochastic events. In addition new habitat could be created by planting different oaks and supplementing food. If there is a lack of suitable cavities for breeding artificial nest boxes and guards barring certain species could boost breeding efforts.

While the mathematical protections seem grim good management practices can ensure the survival of the northern population. More information is needed to effectively manage what remains (we need habitat data, where the remaining birds are, etc.) but wildlife managers have successfully recovered low populations of social breeding woodpeckers before. Intervention is needed to save the Mojave Woodpecker's northern population from extinction but we are not without hope.

Citations

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