Supplemental Material: Causes of Death of Female Cooper's Hawks in North Central New Mexico, USA

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Introduction and Methods

The objective of this analysis is to estimate the frequency and importance of different types of mortality in a population of female Cooper's hawks (*Accipiter cooperii*) in north central New Mexico, USA, between 2011 and 2021.

Methods

Field Methods

Methods for locating and monitoring Cooper's hawk nests on the study area are reported in Lien et al. (2013), Millsap (2018a, 2018b), and Millsap et al. (2019). Relative to this analysis, female Cooper's hawks were banded and color-banded, and a subset VHF radio- or GPS/GSM-tagged, on an urban study area in northeast Albuquerque, NM, from 2011 to 2020. Nearly all banding occurred during the breeding season, between 1 March and 30 July each year. Most VHF- and GPS-tagging was of fledged young between 25 June and 30 July. Tagged Cooper's hawks dispersed widely over a ~ 45 km radius area around the study area, with about 50% of tagged young settling outside of urban and suburban Albuquerque in exurban, rural, and wilderness landscapes (Millsap 2018a, 2018b). About 50% of fledged young migrated > 45 km in winter (Millsap 2018a), and we now know from GPS/GSM tags that most of these birds winter from the Trans-Pecos region of Texas south in central and western Mexico to the state of Jalisco. Individuals that migrate in their first year tend to continue to do so as adults (Millsap 2018a). We continued to monitor and collect data from individuals that settled on nests outside the study area, and those data are included in this analysis.

Re-encounters with VHF tagged hawks were attempted by ground crews weekly; missing hawks were searched for over a broad area from Espanola, NM, to the border with Mexico by fixed-wing aircraft twice per year. All breeding adult Cooper's hawks on the study area were checked for bands each year during the breeding season, and banded hawks were identified. Hawks that died both on and off the study area were subject to being found and reported to the USGS Bird Banding Laboratory. Finally, GPS/GSM-tagged hawks were constantly monitored via periodic (3 - 5 day) data downloads.

Analyses

We used the multistate cause-of-death model developed by Millsap et al. (2022) for the analysis of female Cooper's hawk survival and cause of death data. This model framework allows for the simultaneous use of VHF- and GPS/GSM-tagging data, color-band resighting data, and dead bird band recovery and reporting data to estimate annual survival rates. We only used deaths of hawks wearing functioning VHF or GPS/GSM tags for the cause-of-death portion of the analysis because there is minimal detection and recovery bias in these data; the proportions of deaths by cause in this sample can be expected to reflect true mortality frequencies better than band recovery data (Millsap et al. 2022).

Execution

The estimates reported in the Supplemental Material do not exactly match those in the published paper because this document was produced from a separate model run. The differences are a result of the MCMC process.

Read in the Data

```
# Set file path.
setwd("G:/My Drive/Cooper's Hawks NM/COD/COD/Last Run/")

# Read in data.
load("COD_COHA_PubV.Rdata")
y <- data[[1]]
z <- data[[2]]
n.ind <- data[[3]]
n.occassions <- data[[4]]
f <- data[[5]]

# Set number of release occasions.
nyears <- 12
```

Specify the Multistate Model

```
# Read in multistate cause-of-death model.
COD.txt = "
model{
  # Parameters:
  # Sfy: FY survival probability
  # Ssy: SY survival probability
  # Safy: AFY survival probability
  # psiFail: VHF/GSM failure rate
  # Pfyem: Probability of initially recruiting off the study area
  # Pafyem.mu : probability of AFY emigration
  # Pafyim.mu : probability of AFY return immigration
  # PdVHF: probability of re-encounter, VHF
  # PdBAND: probability of re-sighting, BAND
  # PdVID: probability of re-sighting, VID
```

```
  # rVHF: probabiity of dead recovery, VHF
  # rBnfy: probability of recovery, BAND, FY
  # rBnafy: probability of recovery, BAND, AFY
  # psiKNOWN: probability cause of death is known
  # psiFY[1]: probability FY cause of death was from collision with fence
  # psiFY[2]: probability FY cause of death was from collision with distribut
ion wire
  # psiFY[3]: probability FY cause of death was from collision with window
  # psiFY[4]: probability FY cause of death was from collision with vehicle
  # psiFY[5]: probability FY cause of death was from electrocution
  # psiFY[6]: probability FY cause of death was from entrapment
  # psiFY[7]: probability FY cause of death was from fighting
  # psiFY[8]: probability FY cause of death was from disease
  # psiFY[9]: probability FY cause of death was from poison
  # psiFY[10]: probability FY cause of death was from predation
  # psiFY[11]: probability FY cause of death was from shooting/killing
  # psiFY[12]: probability FY cause of death was from starvation
  # psiAFY[1]: probability AFY cause of death was from collision with fence
  # psiAFY[2]: probability AFY cause of death was from collision with distrib
ution wire
  # psiAFY[3]: probability AFY cause of death was from collision with window
  # psiAFY[4]: probability AFY cause of death was from collision with vehicle
  # psiAFY[5]: probability AFY cause of death was from electrocution
  # psiAFY[6]: probability AFY cause of death was from entrapment
  # psiAFY[7]: probability AFY cause of death was from fighting
  # psiAFY[8]: probability AFY cause of death was from disease
  # psiAFY[9]: probability AFY cause of death was from poison
  # psiAFY[10]: probability AFY cause of death was from predation
  # psiAFY[11]: probability AFY cause of death was from shooting/killing
  # psiAFY[12]: probability AFY cause of death was from starvation

  # States (S):
  # 1 FY, VHF or GSM (VHF)
  # 2 SY, VHF, on study area (SA)
  # 3 AFY, VHF, SA
  # 4 SY, VHF, not on study area (NSA)
  # 5 AFY, VHF, NSA
  # 6 FY, Band
  # 7 SY, Band, SA
  # 8 AFY, Band, SA
  # 9 SY, Band, NSA
  # 10 AFY, Band, NSA
  # 11 Recovered dead, VHF, unknown
  # 12 Recovered dead, VID/BAND, unknown
  # 13 Collision-Fence
  # 14 Collision-Wire
  # 15 Collision-Window
  # 16 Collision-Vehicle
  # 17 Electrocution
  # 18 Entrapment
```

```
# 19 Fight
# 20 Disease
# 21 Poisoned
# 22 Predation
# 23 Take
# 24 Starved
# 25 Long dead or dead but not found

# Observed as (O):
# 1 FY, VHF
# 2 SY, VHF, SA
# 3 AFY, VHF, SA
# 4 SY, VHF, NSA
# 5 AFY, VHF, NSA
# 6 FY, Band
# 7 SY, Band, SA
# 8 AFY, Band, SA
# 9 SY, Band, NSA
# 10 AFY, Band, NSA
# 11 Recovered dead, VHF, unknown
# 12 Recovered dead, VID/BAND, unknown
# 13 Collision-Fence
# 14 Collision-Wire
# 15 Collision-Window
# 16 Collision-Vehicle
# 17 Electrocution
# 18 Entrapment
# 19 Fight
# 20 Disease
# 21 Poisoned
# 22 Predation
# 23 Take
# 24 Starved
# 25 Not observed

# Constraints and uninformative priors
lmu1 ~ dnorm(0, 0.01)T(-10,10) # Logit-scale mean fy survival
lmu2 ~ dnorm(0, 0.01)T(-10,10) # Logit-scale mean sy survival
lmu3 ~ dnorm(0, 0.01)T(-10,10) # Logit-scale mean asy survival
lmu.emig1 ~ dnorm(0, 0.01)T(-10,10) # Logit-scale mean FY emig. prob.
Sfysig ~ dunif(0,10)
Ssysig ~ dunif(0,10)
Safysig ~ dunif(0,10)
Semsig ~ dunif(0,10)
TaufyYr <- pow(Sfysig,-2)
TausyYr. <- pow(Sfysig,-2)
TauafyYr <- pow(Safysig,-2)
TauemYr <- pow(Semsig,-2)
for(t in 1:(n.occasions - 1)){
  SfyYr[t] ~ dnorm(0,TaufyYr)T(-10,10) # Temporal random effect Sfy
```

```
  SsyYr[t] ~ dnorm(0,TaufyYr)T(-10,10) # Temporal random effect Ssy
  SafyYr[t] ~ dnorm(0,TauafyYr)T(-10,10) # Temporal random effect Sasy
  PemYr[t] ~ dnorm(0,TauemYr)T(-10,10) # Temporal random effect FY emig.
  logit(Sfy[t]) <- lmu1 + SfyYr[t] # FY survival natual scale
  logit(Ssy[t]) <- lmu2 + SsyYr[t] # SY survival natual scale
  logit(Safy[t]) <- lmu3 + SafyYr[t] # ASY survival natual scale
  logit(Pfyem[t]) <- lmu.emig1 + PemYr[t] # Prob. FY emig. natural scale
  Pafyem[t] <- Pemafymu
  Pafyim[t] <- Pimafymu
  PdBAND[t] <- PdBANDmu
  PdVHF[t] <- PdVHFmu
  PdVID[t] <- PdVIDmu
  rVHF[t] <- rVHmu
  rBnfy[t] <- rBnfymu
  rBnafy[t] <- rBnafymu
  psiFAIL[t] <- Pfailmu
  psiKNOWN[t] <- mean.psiKNOWN
}#t
Pemafymu ~ dbeta(1, 1)  # Prior for mean AFY emigration probability
Pimafymu ~ dbeta(1, 1)  # Prior for mean AFY return immigration probability
PdVHFmu ~ dbeta(1, 1)   # Prior for mean detection probability, VHF
PdVIDmu ~ dbeta(1, 1)   # Prior for mean detection probability, VID
PdBANDmu ~ dbeta(1, 1)  # USGS BAND resight probability
rVHmu ~ dbeta(1, 1)     # Prior for mean recovery probability, VHF
rBnfymu ~ dbeta(1, 1)   # Prior for mean recovery probability, FY BAND
rBnafymu ~ dbeta(1, 1)  # Prior for mean recovery probability, AFY BAND
Pfailmu ~ dbeta(1, 1)   # Prior for VHF failure rate
mean.psiKNOWN ~ dbeta(1, 1) # Prior for probability cause of death is known

# Gamma random variables for Dirichlet priors - FY.
#   Used Dirichlet priors because it ensures coefficients are in the
#   interval 0 - 1 and the set sums to <1

for(i in 1:12){
  a[i] ~ dgamma(1, 1)
  psiFY[i] <- a[i]/sum(a[])
}

# Gamma random variables for Dirichlet priors - AFY.
for(i in 1:12){
  b[i] ~ dgamma(1, 1)
  psiAFY[i] <- b[i]/sum(b[])
}

# Define state-transition matrix.
for (i in 1:n.ind){
  # Define probabilities of state S(t+1) given S(t)
  for (t in f[i]:(n.occasions-1)){
    ps[1,i,t,1] <- 0
```

```
      ps[1,i,t,2] <- Sfy[t] * (1 - psiFAIL[t]) * (1 - Pfyem[t])
      ps[1,i,t,3] <- 0
      ps[1,i,t,4] <- Sfy[t] * (1 - psiFAIL[t]) * Pfyem[t]
      ps[1,i,t,5] <- 0
      ps[1,i,t,6] <- 0
      ps[1,i,t,7] <- Sfy[t] * psiFAIL[t] * (1 - Pfyem[t])
      ps[1,i,t,8] <- 0
      ps[1,i,t,9] <- Sfy[t] * psiFAIL[t] * Pfyem[t]
      ps[1,i,t,10] <- 0
      ps[1,i,t,11] <- (1 - Sfy[t]) * (1 - psiKNOWN[t]) * rVHF[t]
      ps[1,i,t,12] <- 0
      ps[1,i,t,13] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[1]
      ps[1,i,t,14] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[2]
      ps[1,i,t,15] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[3]
      ps[1,i,t,16] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[4]
      ps[1,i,t,17] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[5]
      ps[1,i,t,18] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[6]
      ps[1,i,t,19] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[7]
      ps[1,i,t,20] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[8]
      ps[1,i,t,21] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[9]
      ps[1,i,t,22] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[10]
      ps[1,i,t,23] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[11]
      ps[1,i,t,24] <- (1 - Sfy[t]) * psiKNOWN[t] * rVHF[t] * psiFY[12]
      ps[1,i,t,25] <- (1 - Sfy[t]) * (1 - psiKNOWN[t]) * (1 - rVHF[t])

      ps[2,i,t,1] <- 0
      ps[2,i,t,2] <- 0
      ps[2,i,t,3] <- Ssy[t] * (1 - psiFAIL[t]) * (1 - Pafyem[t])
      ps[2,i,t,4] <- 0
      ps[2,i,t,5] <- Ssy[t] * (1 - psiFAIL[t]) * Pafyem[t]
      ps[2,i,t,6] <- 0
      ps[2,i,t,7] <- 0
      ps[2,i,t,8] <- Ssy[t] * psiFAIL[t] * (1 - Pafyem[t])
      ps[2,i,t,9] <- 0
      ps[2,i,t,10] <- Ssy[t] * psiFAIL[t] * (1 - Pafyem[t])
      ps[2,i,t,11] <- (1 - Ssy[t]) * (1 - psiKNOWN[t]) * rVHF[t]
      ps[2,i,t,12] <- 0
      ps[2,i,t,13] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[1]
      ps[2,i,t,14] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[2]
      ps[2,i,t,15] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[3]
      ps[2,i,t,16] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[4]
      ps[2,i,t,17] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[5]
      ps[2,i,t,18] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[6]
      ps[2,i,t,19] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[7]
      ps[2,i,t,20] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[8]
      ps[2,i,t,21] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[9]
      ps[2,i,t,22] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[10]
      ps[2,i,t,23] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[11]
      ps[2,i,t,24] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[12]
      ps[2,i,t,25] <- (1 - Ssy[t]) * (1 - psiKNOWN[t]) * (1 - rVHF[t])
```

```
ps[3,i,t,1] <- 0
ps[3,i,t,2] <- 0
ps[3,i,t,3] <- Safy[t] * (1 - psiFAIL[t]) * (1 - Pafyem[t])
ps[3,i,t,4] <- 0
ps[3,i,t,5] <- Safy[t] * (1 - psiFAIL[t]) * Pafyem[t]
ps[3,i,t,6] <- 0
ps[3,i,t,7] <- 0
ps[3,i,t,8] <- Safy[t] * psiFAIL[t] * (1 - Pafyem[t])
ps[3,i,t,9] <- 0
ps[3,i,t,10] <- Safy[t] * psiFAIL[t] * Pafyem[t]
ps[3,i,t,11] <- (1 - Safy[t]) * (1 - psiKNOWN[t]) * rVHF[t]
ps[3,i,t,12] <- 0
ps[3,i,t,13] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[1]
ps[3,i,t,14] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[2]
ps[3,i,t,15] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[3]
ps[3,i,t,16] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[4]
ps[3,i,t,17] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[5]
ps[3,i,t,18] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[6]
ps[3,i,t,19] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[7]
ps[3,i,t,20] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[8]
ps[3,i,t,21] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[9]
ps[3,i,t,22] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[10]
ps[3,i,t,23] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[11]
ps[3,i,t,24] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[12]
ps[3,i,t,25] <- (1 - Safy[t]) * (1 - psiKNOWN[t]) * (1 - rVHF[t])

ps[4,i,t,1] <- 0
ps[4,i,t,2] <- 0
ps[4,i,t,3] <- Ssy[t] * (1 - psiFAIL[t]) * Pafyim[t]
ps[4,i,t,4] <- 0
ps[4,i,t,5] <- Ssy[t] * (1 - psiFAIL[t]) * (1 - Pafyim[t])
ps[4,i,t,6] <- 0
ps[4,i,t,7] <- 0
ps[4,i,t,8] <- Ssy[t] * psiFAIL[t] * Pafyim[t]
ps[4,i,t,9] <- 0
ps[4,i,t,10] <- Ssy[t] * psiFAIL[t] * (1 - Pafyim[t])
ps[4,i,t,11] <- (1 - Ssy[t]) * (1 - psiKNOWN[t]) * rVHF[t]
ps[4,i,t,12] <- 0
ps[4,i,t,13] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[1]
ps[4,i,t,14] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[2]
ps[4,i,t,15] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[3]
ps[4,i,t,16] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[4]
ps[4,i,t,17] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[5]
ps[4,i,t,18] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[6]
ps[4,i,t,19] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[7]
ps[4,i,t,20] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[8]
ps[4,i,t,21] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[9]
ps[4,i,t,22] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[10]
ps[4,i,t,23] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[11]
```

```
      ps[4,i,t,24] <- (1 - Ssy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[12]
      ps[4,i,t,25] <- (1 - Ssy[t]) * (1 - psiKNOWN[t]) * (1 - rVHF[t])

      ps[5,i,t,1] <- 0
      ps[5,i,t,2] <- 0
      ps[5,i,t,3] <- 0
      ps[5,i,t,4] <- 0
      ps[5,i,t,5] <- Safy[t] * (1 - psiFAIL[t]) * (1 - Pafyim[t])
      ps[5,i,t,6] <- 0
      ps[5,i,t,7] <- 0
      ps[5,i,t,8] <- Safy[t] * psiFAIL[t] * Pafyim[t]
      ps[5,i,t,9] <- 0
      ps[5,i,t,10] <- Safy[t] * psiFAIL[t] * (1 - Pafyim[t])
      ps[5,i,t,11] <- (1 - Safy[t]) * (1 - psiKNOWN[t]) * rVHF[t]
      ps[5,i,t,12] <- 0
      ps[5,i,t,13] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[1]
      ps[5,i,t,14] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[2]
      ps[5,i,t,15] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[3]
      ps[5,i,t,16] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[4]
      ps[5,i,t,17] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[5]
      ps[5,i,t,18] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[6]
      ps[5,i,t,19] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[7]
      ps[5,i,t,20] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[8]
      ps[5,i,t,21] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[9]
      ps[5,i,t,22] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[10]
      ps[5,i,t,23] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[11]
      ps[5,i,t,24] <- (1 - Safy[t]) * psiKNOWN[t] * rVHF[t] * psiAFY[12]
      ps[5,i,t,25] <- (1 - Safy[t]) * (1 - psiKNOWN[t]) * (1 - rVHF[t])

      ps[6,i,t,1] <- 0
      ps[6,i,t,2] <- 0
      ps[6,i,t,3] <- 0
      ps[6,i,t,4] <- 0
      ps[6,i,t,5] <- 0
      ps[6,i,t,6] <- 0
      ps[6,i,t,7] <- Sfy[t] * (1 - Pfyem[t])
      ps[6,i,t,8] <- 0
      ps[6,i,t,9] <- Sfy[t] * Pfyem[t]
      ps[6,i,t,10] <- 0
      ps[6,i,t,11] <- 0
      ps[6,i,t,12] <- (1 - Sfy[t]) * rBnfy[t]
      ps[6,i,t,13] <- 0
      ps[6,i,t,14] <- 0
      ps[6,i,t,15] <- 0
      ps[6,i,t,16] <- 0
      ps[6,i,t,17] <- 0
      ps[6,i,t,18] <- 0
      ps[6,i,t,19] <- 0
      ps[6,i,t,20] <- 0
      ps[6,i,t,21] <- 0
```

```
      ps[6,i,t,22] <- 0
      ps[6,i,t,23] <- 0
      ps[6,i,t,24] <- 0
      ps[6,i,t,25] <- (1 - Sfy[t]) * (1 - rBnfy[t])

      ps[7,i,t,1] <- 0
      ps[7,i,t,2] <- 0
      ps[7,i,t,3] <- 0
      ps[7,i,t,4] <- 0
      ps[7,i,t,5] <- 0
      ps[7,i,t,6] <- 0
      ps[7,i,t,7] <- 0
      ps[7,i,t,8] <- Ssy[t] * (1 - Pafyem[t])
      ps[7,i,t,9] <- 0
      ps[7,i,t,10] <- Ssy[t] * Pafyem[t]
      ps[7,i,t,11] <- 0
      ps[7,i,t,12] <- (1 - Ssy[t]) * rBnafy[t]
      ps[7,i,t,13] <- 0
      ps[7,i,t,14] <- 0
      ps[7,i,t,15] <- 0
      ps[7,i,t,16] <- 0
      ps[7,i,t,17] <- 0
      ps[7,i,t,18] <- 0
      ps[7,i,t,19] <- 0
      ps[7,i,t,20] <- 0
      ps[7,i,t,21] <- 0
      ps[7,i,t,22] <- 0
      ps[7,i,t,23] <- 0
      ps[7,i,t,24] <- 0
      ps[7,i,t,25] <- (1 - Ssy[t]) * (1 - rBnafy[t])

      ps[8,i,t,1] <- 0
      ps[8,i,t,2] <- 0
      ps[8,i,t,3] <- 0
      ps[8,i,t,4] <- 0
      ps[8,i,t,5] <- 0
      ps[8,i,t,6] <- 0
      ps[8,i,t,7] <- 0
      ps[8,i,t,8] <- Safy[t] * (1 - Pafyem[t])
      ps[8,i,t,9] <- 0
      ps[8,i,t,10] <- Safy[t] * Pafyem[t]
      ps[8,i,t,11] <- 0
      ps[8,i,t,12] <- (1 - Safy[t]) * rBnafy[t]
      ps[8,i,t,13] <- 0
      ps[8,i,t,14] <- 0
      ps[8,i,t,15] <- 0
      ps[8,i,t,16] <- 0
      ps[8,i,t,17] <- 0
      ps[8,i,t,18] <- 0
      ps[8,i,t,19] <- 0
```

```
      ps[8,i,t,20] <- 0
      ps[8,i,t,21] <- 0
      ps[8,i,t,22] <- 0
      ps[8,i,t,23] <- 0
      ps[8,i,t,24] <- 0
      ps[8,i,t,25] <- (1 - Safy[t]) * (1 - rBnafy[t])

      ps[9,i,t,1] <- 0
      ps[9,i,t,2] <- 0
      ps[9,i,t,3] <- 0
      ps[9,i,t,4] <- 0
      ps[9,i,t,5] <- 0
      ps[9,i,t,6] <- 0
      ps[9,i,t,7] <- 0
      ps[9,i,t,8] <- Ssy[t] * Pafyim[t]
      ps[9,i,t,9] <- 0
      ps[9,i,t,10] <- Ssy[t] * (1 - Pafyim[t])
      ps[9,i,t,11] <- 0
      ps[9,i,t,12] <- (1 - Ssy[t]) * rBnafy[t]
      ps[9,i,t,13] <- 0
      ps[9,i,t,14] <- 0
      ps[9,i,t,15] <- 0
      ps[9,i,t,16] <- 0
      ps[9,i,t,17] <- 0
      ps[9,i,t,18] <- 0
      ps[9,i,t,19] <- 0
      ps[9,i,t,20] <- 0
      ps[9,i,t,21] <- 0
      ps[9,i,t,22] <- 0
      ps[9,i,t,23] <- 0
      ps[9,i,t,24] <- 0
      ps[9,i,t,25] <- (1 - Ssy[t]) * (1 - rBnafy[t])

      ps[10,i,t,1] <- 0
      ps[10,i,t,2] <- 0
      ps[10,i,t,3] <- 0
      ps[10,i,t,4] <- 0
      ps[10,i,t,5] <- 0
      ps[10,i,t,6] <- 0
      ps[10,i,t,7] <- 0
      ps[10,i,t,8] <- Safy[t] * Pafyim[t]
      ps[10,i,t,9] <- 0
      ps[10,i,t,10] <- Safy[t] * (1 - Pafyim[t])
      ps[10,i,t,11] <- 0
      ps[10,i,t,12] <- (1 - Safy[t]) * rBnafy[t]
      ps[10,i,t,13] <- 0
      ps[10,i,t,14] <- 0
      ps[10,i,t,15] <- 0
      ps[10,i,t,16] <- 0
      ps[10,i,t,17] <- 0
```

```
      ps[10,i,t,18] <- 0
      ps[10,i,t,19] <- 0
      ps[10,i,t,20] <- 0
      ps[10,i,t,21] <- 0
      ps[10,i,t,22] <- 0
      ps[10,i,t,23] <- 0
      ps[10,i,t,24] <- 0
      ps[10,i,t,25] <- (1 - Safy[t]) * (1 - rBnafy[t])

      ps[11,i,t,1] <- 0
      ps[11,i,t,2] <- 0
      ps[11,i,t,3] <- 0
      ps[11,i,t,4] <- 0
      ps[11,i,t,5] <- 0
      ps[11,i,t,6] <- 0
      ps[11,i,t,7] <- 0
      ps[11,i,t,8] <- 0
      ps[11,i,t,9] <- 0
      ps[11,i,t,10] <- 0
      ps[11,i,t,11] <- 0
      ps[11,i,t,12] <- 0
      ps[11,i,t,13] <- 0
      ps[11,i,t,14] <- 0
      ps[11,i,t,15] <- 0
      ps[11,i,t,16] <- 0
      ps[11,i,t,17] <- 0
      ps[11,i,t,18] <- 0
      ps[11,i,t,19] <- 0
      ps[11,i,t,20] <- 0
      ps[11,i,t,21] <- 0
      ps[11,i,t,22] <- 0
      ps[11,i,t,23] <- 0
      ps[11,i,t,24] <- 0
      ps[11,i,t,25] <- 1

      ps[12,i,t,1] <- 0
      ps[12,i,t,2] <- 0
      ps[12,i,t,3] <- 0
      ps[12,i,t,4] <- 0
      ps[12,i,t,5] <- 0
      ps[12,i,t,6] <- 0
      ps[12,i,t,7] <- 0
      ps[12,i,t,8] <- 0
      ps[12,i,t,9] <- 0
      ps[12,i,t,10] <- 0
      ps[12,i,t,11] <- 0
      ps[12,i,t,12] <- 0
      ps[12,i,t,13] <- 0
      ps[12,i,t,14] <- 0
      ps[12,i,t,15] <- 0
```

```
      ps[12,i,t,16] <- 0
      ps[12,i,t,17] <- 0
      ps[12,i,t,18] <- 0
      ps[12,i,t,19] <- 0
      ps[12,i,t,20] <- 0
      ps[12,i,t,21] <- 0
      ps[12,i,t,22] <- 0
      ps[12,i,t,23] <- 0
      ps[12,i,t,24] <- 0
      ps[12,i,t,25] <- 1

      ps[13,i,t,1] <- 0
      ps[13,i,t,2] <- 0
      ps[13,i,t,3] <- 0
      ps[13,i,t,4] <- 0
      ps[13,i,t,5] <- 0
      ps[13,i,t,6] <- 0
      ps[13,i,t,7] <- 0
      ps[13,i,t,8] <- 0
      ps[13,i,t,9] <- 0
      ps[13,i,t,10] <- 0
      ps[13,i,t,11] <- 0
      ps[13,i,t,12] <- 0
      ps[13,i,t,13] <- 0
      ps[13,i,t,14] <- 0
      ps[13,i,t,15] <- 0
      ps[13,i,t,16] <- 0
      ps[13,i,t,17] <- 0
      ps[13,i,t,18] <- 0
      ps[13,i,t,19] <- 0
      ps[13,i,t,20] <- 0
      ps[13,i,t,21] <- 0
      ps[13,i,t,22] <- 0
      ps[13,i,t,23] <- 0
      ps[13,i,t,24] <- 0
      ps[13,i,t,25] <- 1

      ps[14,i,t,1] <- 0
      ps[14,i,t,2] <- 0
      ps[14,i,t,3] <- 0
      ps[14,i,t,4] <- 0
      ps[14,i,t,5] <- 0
      ps[14,i,t,6] <- 0
      ps[14,i,t,7] <- 0
      ps[14,i,t,8] <- 0
      ps[14,i,t,9] <- 0
      ps[14,i,t,10] <- 0
      ps[14,i,t,11] <- 0
      ps[14,i,t,12] <- 0
      ps[14,i,t,13] <- 0
```

```
      ps[14,i,t,14] <- 0
      ps[14,i,t,15] <- 0
      ps[14,i,t,16] <- 0
      ps[14,i,t,17] <- 0
      ps[14,i,t,18] <- 0
      ps[14,i,t,19] <- 0
      ps[14,i,t,20] <- 0
      ps[14,i,t,21] <- 0
      ps[14,i,t,22] <- 0
      ps[14,i,t,23] <- 0
      ps[14,i,t,24] <- 0
      ps[14,i,t,25] <- 1

      ps[15,i,t,1] <- 0
      ps[15,i,t,2] <- 0
      ps[15,i,t,3] <- 0
      ps[15,i,t,4] <- 0
      ps[15,i,t,5] <- 0
      ps[15,i,t,6] <- 0
      ps[15,i,t,7] <- 0
      ps[15,i,t,8] <- 0
      ps[15,i,t,9] <- 0
      ps[15,i,t,10] <- 0
      ps[15,i,t,11] <- 0
      ps[15,i,t,12] <- 0
      ps[15,i,t,13] <- 0
      ps[15,i,t,14] <- 0
      ps[15,i,t,15] <- 0
      ps[15,i,t,16] <- 0
      ps[15,i,t,17] <- 0
      ps[15,i,t,18] <- 0
      ps[15,i,t,19] <- 0
      ps[15,i,t,20] <- 0
      ps[15,i,t,21] <- 0
      ps[15,i,t,22] <- 0
      ps[15,i,t,23] <- 0
      ps[15,i,t,24] <- 0
      ps[15,i,t,25] <- 1

      ps[16,i,t,1] <- 0
      ps[16,i,t,2] <- 0
      ps[16,i,t,3] <- 0
      ps[16,i,t,4] <- 0
      ps[16,i,t,5] <- 0
      ps[16,i,t,6] <- 0
      ps[16,i,t,7] <- 0
      ps[16,i,t,8] <- 0
      ps[16,i,t,9] <- 0
      ps[16,i,t,10] <- 0
      ps[16,i,t,11] <- 0
```

```
      ps[16,i,t,12] <- 0
      ps[16,i,t,13] <- 0
      ps[16,i,t,14] <- 0
      ps[16,i,t,15] <- 0
      ps[16,i,t,16] <- 0
      ps[16,i,t,17] <- 0
      ps[16,i,t,18] <- 0
      ps[16,i,t,19] <- 0
      ps[16,i,t,20] <- 0
      ps[16,i,t,21] <- 0
      ps[16,i,t,22] <- 0
      ps[16,i,t,23] <- 0
      ps[16,i,t,24] <- 0
      ps[16,i,t,25] <- 1

      ps[17,i,t,1] <- 0
      ps[17,i,t,2] <- 0
      ps[17,i,t,3] <- 0
      ps[17,i,t,4] <- 0
      ps[17,i,t,5] <- 0
      ps[17,i,t,6] <- 0
      ps[17,i,t,7] <- 0
      ps[17,i,t,8] <- 0
      ps[17,i,t,9] <- 0
      ps[17,i,t,10] <- 0
      ps[17,i,t,11] <- 0
      ps[17,i,t,12] <- 0
      ps[17,i,t,13] <- 0
      ps[17,i,t,14] <- 0
      ps[17,i,t,15] <- 0
      ps[17,i,t,16] <- 0
      ps[17,i,t,17] <- 0
      ps[17,i,t,18] <- 0
      ps[17,i,t,19] <- 0
      ps[17,i,t,20] <- 0
      ps[17,i,t,21] <- 0
      ps[17,i,t,22] <- 0
      ps[17,i,t,23] <- 0
      ps[17,i,t,24] <- 0
      ps[17,i,t,25] <- 1

      ps[18,i,t,1] <- 0
      ps[18,i,t,2] <- 0
      ps[18,i,t,3] <- 0
      ps[18,i,t,4] <- 0
      ps[18,i,t,5] <- 0
      ps[18,i,t,6] <- 0
      ps[18,i,t,7] <- 0
      ps[18,i,t,8] <- 0
      ps[18,i,t,9] <- 0
```

```
      ps[18,i,t,10] <- 0
      ps[18,i,t,11] <- 0
      ps[18,i,t,12] <- 0
      ps[18,i,t,13] <- 0
      ps[18,i,t,14] <- 0
      ps[18,i,t,15] <- 0
      ps[18,i,t,16] <- 0
      ps[18,i,t,17] <- 0
      ps[18,i,t,18] <- 0
      ps[18,i,t,19] <- 0
      ps[18,i,t,20] <- 0
      ps[18,i,t,21] <- 0
      ps[18,i,t,22] <- 0
      ps[18,i,t,23] <- 0
      ps[18,i,t,24] <- 0
      ps[18,i,t,25] <- 1

      ps[19,i,t,1] <- 0
      ps[19,i,t,2] <- 0
      ps[19,i,t,3] <- 0
      ps[19,i,t,4] <- 0
      ps[19,i,t,5] <- 0
      ps[19,i,t,6] <- 0
      ps[19,i,t,7] <- 0
      ps[19,i,t,8] <- 0
      ps[19,i,t,9] <- 0
      ps[19,i,t,10] <- 0
      ps[19,i,t,11] <- 0
      ps[19,i,t,12] <- 0
      ps[19,i,t,13] <- 0
      ps[19,i,t,14] <- 0
      ps[19,i,t,15] <- 0
      ps[19,i,t,16] <- 0
      ps[19,i,t,17] <- 0
      ps[19,i,t,18] <- 0
      ps[19,i,t,19] <- 0
      ps[19,i,t,20] <- 0
      ps[19,i,t,21] <- 0
      ps[19,i,t,22] <- 0
      ps[19,i,t,23] <- 0
      ps[19,i,t,24] <- 0
      ps[19,i,t,25] <- 1

      ps[20,i,t,1] <- 0
      ps[20,i,t,2] <- 0
      ps[20,i,t,3] <- 0
      ps[20,i,t,4] <- 0
      ps[20,i,t,5] <- 0
      ps[20,i,t,6] <- 0
      ps[20,i,t,7] <- 0
```

```
      ps[20,i,t,8] <- 0
      ps[20,i,t,9] <- 0
      ps[20,i,t,10] <- 0
      ps[20,i,t,11] <- 0
      ps[20,i,t,12] <- 0
      ps[20,i,t,13] <- 0
      ps[20,i,t,14] <- 0
      ps[20,i,t,15] <- 0
      ps[20,i,t,16] <- 0
      ps[20,i,t,17] <- 0
      ps[20,i,t,18] <- 0
      ps[20,i,t,19] <- 0
      ps[20,i,t,20] <- 0
      ps[20,i,t,21] <- 0
      ps[20,i,t,22] <- 0
      ps[20,i,t,23] <- 0
      ps[20,i,t,24] <- 0
      ps[20,i,t,25] <- 1

      ps[21,i,t,1] <- 0
      ps[21,i,t,2] <- 0
      ps[21,i,t,3] <- 0
      ps[21,i,t,4] <- 0
      ps[21,i,t,5] <- 0
      ps[21,i,t,6] <- 0
      ps[21,i,t,7] <- 0
      ps[21,i,t,8] <- 0
      ps[21,i,t,9] <- 0
      ps[21,i,t,10] <- 0
      ps[21,i,t,11] <- 0
      ps[21,i,t,12] <- 0
      ps[21,i,t,13] <- 0
      ps[21,i,t,14] <- 0
      ps[21,i,t,15] <- 0
      ps[21,i,t,16] <- 0
      ps[21,i,t,17] <- 0
      ps[21,i,t,18] <- 0
      ps[21,i,t,19] <- 0
      ps[21,i,t,20] <- 0
      ps[21,i,t,21] <- 0
      ps[21,i,t,22] <- 0
      ps[21,i,t,23] <- 0
      ps[21,i,t,24] <- 0
      ps[21,i,t,25] <- 1

      ps[22,i,t,1] <- 0
      ps[22,i,t,2] <- 0
      ps[22,i,t,3] <- 0
      ps[22,i,t,4] <- 0
      ps[22,i,t,5] <- 0
```

```
      ps[22,i,t,6] <- 0
      ps[22,i,t,7] <- 0
      ps[22,i,t,8] <- 0
      ps[22,i,t,9] <- 0
      ps[22,i,t,10] <- 0
      ps[22,i,t,11] <- 0
      ps[22,i,t,12] <- 0
      ps[22,i,t,13] <- 0
      ps[22,i,t,14] <- 0
      ps[22,i,t,15] <- 0
      ps[22,i,t,16] <- 0
      ps[22,i,t,17] <- 0
      ps[22,i,t,18] <- 0
      ps[22,i,t,19] <- 0
      ps[22,i,t,20] <- 0
      ps[22,i,t,21] <- 0
      ps[22,i,t,22] <- 0
      ps[22,i,t,23] <- 0
      ps[22,i,t,24] <- 0
      ps[22,i,t,25] <- 1

      ps[23,i,t,1] <- 0
      ps[23,i,t,2] <- 0
      ps[23,i,t,3] <- 0
      ps[23,i,t,4] <- 0
      ps[23,i,t,5] <- 0
      ps[23,i,t,6] <- 0
      ps[23,i,t,7] <- 0
      ps[23,i,t,8] <- 0
      ps[23,i,t,9] <- 0
      ps[23,i,t,10] <- 0
      ps[23,i,t,11] <- 0
      ps[23,i,t,12] <- 0
      ps[23,i,t,13] <- 0
      ps[23,i,t,14] <- 0
      ps[23,i,t,15] <- 0
      ps[23,i,t,16] <- 0
      ps[23,i,t,17] <- 0
      ps[23,i,t,18] <- 0
      ps[23,i,t,19] <- 0
      ps[23,i,t,20] <- 0
      ps[23,i,t,21] <- 0
      ps[23,i,t,22] <- 0
      ps[23,i,t,23] <- 0
      ps[23,i,t,24] <- 0
      ps[23,i,t,25] <- 1

      ps[24,i,t,1] <- 0
      ps[24,i,t,2] <- 0
      ps[24,i,t,3] <- 0
```

```
      ps[24,i,t,4] <- 0
      ps[24,i,t,5] <- 0
      ps[24,i,t,6] <- 0
      ps[24,i,t,7] <- 0
      ps[24,i,t,8] <- 0
      ps[24,i,t,9] <- 0
      ps[24,i,t,10] <- 0
      ps[24,i,t,11] <- 0
      ps[24,i,t,12] <- 0
      ps[24,i,t,13] <- 0
      ps[24,i,t,14] <- 0
      ps[24,i,t,15] <- 0
      ps[24,i,t,16] <- 0
      ps[24,i,t,17] <- 0
      ps[24,i,t,18] <- 0
      ps[24,i,t,19] <- 0
      ps[24,i,t,20] <- 0
      ps[24,i,t,21] <- 0
      ps[24,i,t,22] <- 0
      ps[24,i,t,23] <- 0
      ps[24,i,t,24] <- 0
      ps[24,i,t,25] <- 1

      ps[25,i,t,1] <- 0
      ps[25,i,t,2] <- 0
      ps[25,i,t,3] <- 0
      ps[25,i,t,4] <- 0
      ps[25,i,t,5] <- 0
      ps[25,i,t,6] <- 0
      ps[25,i,t,7] <- 0
      ps[25,i,t,8] <- 0
      ps[25,i,t,9] <- 0
      ps[25,i,t,10] <- 0
      ps[25,i,t,11] <- 0
      ps[25,i,t,12] <- 0
      ps[25,i,t,13] <- 0
      ps[25,i,t,14] <- 0
      ps[25,i,t,15] <- 0
      ps[25,i,t,16] <- 0
      ps[25,i,t,17] <- 0
      ps[25,i,t,18] <- 0
      ps[25,i,t,19] <- 0
      ps[25,i,t,20] <- 0
      ps[25,i,t,21] <- 0
      ps[25,i,t,22] <- 0
      ps[25,i,t,23] <- 0
      ps[25,i,t,24] <- 0
      ps[25,i,t,25] <- 1

      # Define observation matrix.
```

```
      # Define probabilities of O(t) given S(t)
      po[1,i,t,1] <- PdVHF[t]
      po[1,i,t,2] <- 0
      po[1,i,t,3] <- 0
      po[1,i,t,4] <- 0
      po[1,i,t,5] <- 0
      po[1,i,t,6] <- 0
      po[1,i,t,7] <- 0
      po[1,i,t,8] <- 0
      po[1,i,t,9] <- 0
      po[1,i,t,10] <- 0
      po[1,i,t,11] <- 0
      po[1,i,t,12] <- 0
      po[1,i,t,13] <- 0
      po[1,i,t,14] <- 0
      po[1,i,t,15] <- 0
      po[1,i,t,16] <- 0
      po[1,i,t,17] <- 0
      po[1,i,t,18] <- 0
      po[1,i,t,19] <- 0
      po[1,i,t,20] <- 0
      po[1,i,t,21] <- 0
      po[1,i,t,22] <- 0
      po[1,i,t,23] <- 0
      po[1,i,t,24] <- 0
      po[1,i,t,25] <- (1 - PdVHF[t])

      po[2,i,t,1] <- 0
      po[2,i,t,2] <- PdVHF[t]
      po[2,i,t,3] <- 0
      po[2,i,t,4] <- 0
      po[2,i,t,5] <- 0
      po[2,i,t,6] <- 0
      po[2,i,t,7] <- 0
      po[2,i,t,8] <- 0
      po[2,i,t,9] <- 0
      po[2,i,t,10] <- 0
      po[2,i,t,11] <- 0
      po[2,i,t,12] <- 0
      po[2,i,t,13] <- 0
      po[2,i,t,14] <- 0
      po[2,i,t,15] <- 0
      po[2,i,t,16] <- 0
      po[2,i,t,17] <- 0
      po[2,i,t,18] <- 0
      po[2,i,t,19] <- 0
      po[2,i,t,20] <- 0
      po[2,i,t,21] <- 0
      po[2,i,t,22] <- 0
      po[2,i,t,23] <- 0
```

```
      po[2,i,t,24] <- 0
      po[2,i,t,25] <- (1 - PdVHF[t])

      po[3,i,t,1] <- 0
      po[3,i,t,2] <- 0
      po[3,i,t,3] <- PdVHF[t]
      po[3,i,t,4] <- 0
      po[3,i,t,5] <- 0
      po[3,i,t,6] <- 0
      po[3,i,t,7] <- 0
      po[3,i,t,8] <- 0
      po[3,i,t,9] <- 0
      po[3,i,t,10] <- 0
      po[3,i,t,11] <- 0
      po[3,i,t,12] <- 0
      po[3,i,t,13] <- 0
      po[3,i,t,14] <- 0
      po[3,i,t,15] <- 0
      po[3,i,t,16] <- 0
      po[3,i,t,17] <- 0
      po[3,i,t,18] <- 0
      po[3,i,t,19] <- 0
      po[3,i,t,20] <- 0
      po[3,i,t,21] <- 0
      po[3,i,t,22] <- 0
      po[3,i,t,23] <- 0
      po[3,i,t,24] <- 0
      po[3,i,t,25] <- (1 - PdVHF[t])

      po[4,i,t,1] <- 0
      po[4,i,t,2] <- 0
      po[4,i,t,3] <- 0
      po[4,i,t,4] <- PdVHF[t]
      po[4,i,t,5] <- 0
      po[4,i,t,6] <- 0
      po[4,i,t,7] <- 0
      po[4,i,t,8] <- 0
      po[4,i,t,9] <- 0
      po[4,i,t,10] <- 0
      po[4,i,t,11] <- 0
      po[4,i,t,12] <- 0
      po[4,i,t,13] <- 0
      po[4,i,t,14] <- 0
      po[4,i,t,15] <- 0
      po[4,i,t,16] <- 0
      po[4,i,t,17] <- 0
      po[4,i,t,18] <- 0
      po[4,i,t,19] <- 0
      po[4,i,t,20] <- 0
      po[4,i,t,21] <- 0
```

```
      po[4,i,t,22] <- 0
      po[4,i,t,23] <- 0
      po[4,i,t,24] <- 0
      po[4,i,t,25] <- (1 - PdVHF[t])

      po[5,i,t,1] <- 0
      po[5,i,t,2] <- 0
      po[5,i,t,3] <- 0
      po[5,i,t,4] <- 0
      po[5,i,t,5] <- PdVHF[t]
      po[5,i,t,6] <- 0
      po[5,i,t,7] <- 0
      po[5,i,t,8] <- 0
      po[5,i,t,9] <- 0
      po[5,i,t,10] <- 0
      po[5,i,t,11] <- 0
      po[5,i,t,12] <- 0
      po[5,i,t,13] <- 0
      po[5,i,t,14] <- 0
      po[5,i,t,15] <- 0
      po[5,i,t,16] <- 0
      po[5,i,t,17] <- 0
      po[5,i,t,18] <- 0
      po[5,i,t,19] <- 0
      po[5,i,t,20] <- 0
      po[5,i,t,21] <- 0
      po[5,i,t,22] <- 0
      po[5,i,t,23] <- 0
      po[5,i,t,24] <- 0
      po[5,i,t,25] <- (1 - PdVHF[t])

      po[6,i,t,1] <- 0
      po[6,i,t,2] <- 0
      po[6,i,t,3] <- 0
      po[6,i,t,4] <- 0
      po[6,i,t,5] <- 0
      po[6,i,t,6] <- PdBAND[t]
      po[6,i,t,7] <- 0
      po[6,i,t,8] <- 0
      po[6,i,t,9] <- 0
      po[6,i,t,10] <- 0
      po[6,i,t,11] <- 0
      po[6,i,t,12] <- 0
      po[6,i,t,13] <- 0
      po[6,i,t,14] <- 0
      po[6,i,t,15] <- 0
      po[6,i,t,16] <- 0
      po[6,i,t,17] <- 0
      po[6,i,t,18] <- 0
      po[6,i,t,19] <- 0
```

```
      po[6,i,t,20] <- 0
      po[6,i,t,21] <- 0
      po[6,i,t,22] <- 0
      po[6,i,t,23] <- 0
      po[6,i,t,24] <- 0
      po[6,i,t,25] <- (1 - PdBAND[t])

      po[7,i,t,1] <- 0
      po[7,i,t,2] <- 0
      po[7,i,t,3] <- 0
      po[7,i,t,4] <- 0
      po[7,i,t,5] <- 0
      po[7,i,t,6] <- 0
      po[7,i,t,7] <- PdVID[t]
      po[7,i,t,8] <- 0
      po[7,i,t,9] <- 0
      po[7,i,t,10] <- 0
      po[7,i,t,11] <- 0
      po[7,i,t,12] <- 0
      po[7,i,t,13] <- 0
      po[7,i,t,14] <- 0
      po[7,i,t,15] <- 0
      po[7,i,t,16] <- 0
      po[7,i,t,17] <- 0
      po[7,i,t,18] <- 0
      po[7,i,t,19] <- 0
      po[7,i,t,20] <- 0
      po[7,i,t,21] <- 0
      po[7,i,t,22] <- 0
      po[7,i,t,23] <- 0
      po[7,i,t,24] <- 0
      po[7,i,t,25] <- (1 - PdVID[t])

      po[8,i,t,1] <- 0
      po[8,i,t,2] <- 0
      po[8,i,t,3] <- 0
      po[8,i,t,4] <- 0
      po[8,i,t,5] <- 0
      po[8,i,t,6] <- 0
      po[8,i,t,7] <- 0
      po[8,i,t,8] <- PdVID[t]
      po[8,i,t,9] <- 0
      po[8,i,t,10] <- 0
      po[8,i,t,11] <- 0
      po[8,i,t,12] <- 0
      po[8,i,t,13] <- 0
      po[8,i,t,14] <- 0
      po[8,i,t,15] <- 0
      po[8,i,t,16] <- 0
      po[8,i,t,17] <- 0
```

```
      po[8,i,t,18] <- 0
      po[8,i,t,19] <- 0
      po[8,i,t,20] <- 0
      po[8,i,t,21] <- 0
      po[8,i,t,22] <- 0
      po[8,i,t,23] <- 0
      po[8,i,t,24] <- 0
      po[8,i,t,25] <- (1 - PdVID[t])

      po[9,i,t,1] <- 0
      po[9,i,t,2] <- 0
      po[9,i,t,3] <- 0
      po[9,i,t,4] <- 0
      po[9,i,t,5] <- 0
      po[9,i,t,6] <- 0
      po[9,i,t,7] <- 0
      po[9,i,t,8] <- 0
      po[9,i,t,9] <- PdBAND[t]
      po[9,i,t,10] <- 0
      po[9,i,t,11] <- 0
      po[9,i,t,12] <- 0
      po[9,i,t,13] <- 0
      po[9,i,t,14] <- 0
      po[9,i,t,15] <- 0
      po[9,i,t,16] <- 0
      po[9,i,t,17] <- 0
      po[9,i,t,18] <- 0
      po[9,i,t,19] <- 0
      po[9,i,t,20] <- 0
      po[9,i,t,21] <- 0
      po[9,i,t,22] <- 0
      po[9,i,t,23] <- 0
      po[9,i,t,24] <- 0
      po[9,i,t,25] <- (1 - PdBAND[t])

      po[10,i,t,1] <- 0
      po[10,i,t,2] <- 0
      po[10,i,t,3] <- 0
      po[10,i,t,4] <- 0
      po[10,i,t,5] <- 0
      po[10,i,t,6] <- 0
      po[10,i,t,7] <- 0
      po[10,i,t,8] <- 0
      po[10,i,t,9] <- 0
      po[10,i,t,10] <- PdBAND[t]
      po[10,i,t,11] <- 0
      po[10,i,t,12] <- 0
      po[10,i,t,13] <- 0
      po[10,i,t,14] <- 0
      po[10,i,t,15] <- 0
```

```
      po[10,i,t,16] <- 0
      po[10,i,t,17] <- 0
      po[10,i,t,18] <- 0
      po[10,i,t,19] <- 0
      po[10,i,t,20] <- 0
      po[10,i,t,21] <- 0
      po[10,i,t,22] <- 0
      po[10,i,t,23] <- 0
      po[10,i,t,24] <- 0
      po[10,i,t,25] <- (1 - PdBAND[t])

      po[11,i,t,1] <- 0
      po[11,i,t,2] <- 0
      po[11,i,t,3] <- 0
      po[11,i,t,4] <- 0
      po[11,i,t,5] <- 0
      po[11,i,t,6] <- 0
      po[11,i,t,7] <- 0
      po[11,i,t,8] <- 0
      po[11,i,t,9] <- 0
      po[11,i,t,10] <- 0
      po[11,i,t,11] <- 1
      po[11,i,t,12] <- 0
      po[11,i,t,13] <- 0
      po[11,i,t,14] <- 0
      po[11,i,t,15] <- 0
      po[11,i,t,16] <- 0
      po[11,i,t,17] <- 0
      po[11,i,t,18] <- 0
      po[11,i,t,19] <- 0
      po[11,i,t,20] <- 0
      po[11,i,t,21] <- 0
      po[11,i,t,22] <- 0
      po[11,i,t,23] <- 0
      po[11,i,t,24] <- 0
      po[11,i,t,25] <- 0

      po[12,i,t,1] <- 0
      po[12,i,t,2] <- 0
      po[12,i,t,3] <- 0
      po[12,i,t,4] <- 0
      po[12,i,t,5] <- 0
      po[12,i,t,6] <- 0
      po[12,i,t,7] <- 0
      po[12,i,t,8] <- 0
      po[12,i,t,9] <- 0
      po[12,i,t,10] <- 0
      po[12,i,t,11] <- 0
      po[12,i,t,12] <- 1
      po[12,i,t,13] <- 0
```

```
      po[12,i,t,14] <- 0
      po[12,i,t,15] <- 0
      po[12,i,t,16] <- 0
      po[12,i,t,17] <- 0
      po[12,i,t,18] <- 0
      po[12,i,t,19] <- 0
      po[12,i,t,20] <- 0
      po[12,i,t,21] <- 0
      po[12,i,t,22] <- 0
      po[12,i,t,23] <- 0
      po[12,i,t,24] <- 0
      po[12,i,t,25] <- 0

      po[13,i,t,1] <- 0
      po[13,i,t,2] <- 0
      po[13,i,t,3] <- 0
      po[13,i,t,4] <- 0
      po[13,i,t,5] <- 0
      po[13,i,t,6] <- 0
      po[13,i,t,7] <- 0
      po[13,i,t,8] <- 0
      po[13,i,t,9] <- 0
      po[13,i,t,10] <- 0
      po[13,i,t,11] <- 0
      po[13,i,t,12] <- 0
      po[13,i,t,13] <- 1
      po[13,i,t,14] <- 0
      po[13,i,t,15] <- 0
      po[13,i,t,16] <- 0
      po[13,i,t,17] <- 0
      po[13,i,t,18] <- 0
      po[13,i,t,19] <- 0
      po[13,i,t,20] <- 0
      po[13,i,t,21] <- 0
      po[13,i,t,22] <- 0
      po[13,i,t,23] <- 0
      po[13,i,t,24] <- 0
      po[13,i,t,25] <- 0

      po[14,i,t,1] <- 0
      po[14,i,t,2] <- 0
      po[14,i,t,3] <- 0
      po[14,i,t,4] <- 0
      po[14,i,t,5] <- 0
      po[14,i,t,6] <- 0
      po[14,i,t,7] <- 0
      po[14,i,t,8] <- 0
      po[14,i,t,9] <- 0
      po[14,i,t,10] <- 0
      po[14,i,t,11] <- 0
```

```
      po[14,i,t,12] <- 0
      po[14,i,t,13] <- 0
      po[14,i,t,14] <- 1
      po[14,i,t,15] <- 0
      po[14,i,t,16] <- 0
      po[14,i,t,17] <- 0
      po[14,i,t,18] <- 0
      po[14,i,t,19] <- 0
      po[14,i,t,20] <- 0
      po[14,i,t,21] <- 0
      po[14,i,t,22] <- 0
      po[14,i,t,23] <- 0
      po[14,i,t,24] <- 0
      po[14,i,t,25] <- 0

      po[15,i,t,1] <- 0
      po[15,i,t,2] <- 0
      po[15,i,t,3] <- 0
      po[15,i,t,4] <- 0
      po[15,i,t,5] <- 0
      po[15,i,t,6] <- 0
      po[15,i,t,7] <- 0
      po[15,i,t,8] <- 0
      po[15,i,t,9] <- 0
      po[15,i,t,10] <- 0
      po[15,i,t,11] <- 0
      po[15,i,t,12] <- 0
      po[15,i,t,13] <- 0
      po[15,i,t,14] <- 0
      po[15,i,t,15] <- 1
      po[15,i,t,16] <- 0
      po[15,i,t,17] <- 0
      po[15,i,t,18] <- 0
      po[15,i,t,19] <- 0
      po[15,i,t,20] <- 0
      po[15,i,t,21] <- 0
      po[15,i,t,22] <- 0
      po[15,i,t,23] <- 0
      po[15,i,t,24] <- 0
      po[15,i,t,25] <- 0

      po[16,i,t,1] <- 0
      po[16,i,t,2] <- 0
      po[16,i,t,3] <- 0
      po[16,i,t,4] <- 0
      po[16,i,t,5] <- 0
      po[16,i,t,6] <- 0
      po[16,i,t,7] <- 0
      po[16,i,t,8] <- 0
      po[16,i,t,9] <- 0
```

```
      po[16,i,t,10] <- 0
      po[16,i,t,11] <- 0
      po[16,i,t,12] <- 0
      po[16,i,t,13] <- 0
      po[16,i,t,14] <- 0
      po[16,i,t,15] <- 0
      po[16,i,t,16] <- 1
      po[16,i,t,17] <- 0
      po[16,i,t,18] <- 0
      po[16,i,t,19] <- 0
      po[16,i,t,20] <- 0
      po[16,i,t,21] <- 0
      po[16,i,t,22] <- 0
      po[16,i,t,23] <- 0
      po[16,i,t,24] <- 0
      po[16,i,t,25] <- 0

      po[17,i,t,1] <- 0
      po[17,i,t,2] <- 0
      po[17,i,t,3] <- 0
      po[17,i,t,4] <- 0
      po[17,i,t,5] <- 0
      po[17,i,t,6] <- 0
      po[17,i,t,7] <- 0
      po[17,i,t,8] <- 0
      po[17,i,t,9] <- 0
      po[17,i,t,10] <- 0
      po[17,i,t,11] <- 0
      po[17,i,t,12] <- 0
      po[17,i,t,13] <- 0
      po[17,i,t,14] <- 0
      po[17,i,t,15] <- 0
      po[17,i,t,16] <- 0
      po[17,i,t,17] <- 1
      po[17,i,t,18] <- 0
      po[17,i,t,19] <- 0
      po[17,i,t,20] <- 0
      po[17,i,t,21] <- 0
      po[17,i,t,22] <- 0
      po[17,i,t,23] <- 0
      po[17,i,t,24] <- 0
      po[17,i,t,25] <- 0

      po[18,i,t,1] <- 0
      po[18,i,t,2] <- 0
      po[18,i,t,3] <- 0
      po[18,i,t,4] <- 0
      po[18,i,t,5] <- 0
      po[18,i,t,6] <- 0
      po[18,i,t,7] <- 0
```

```
      po[18,i,t,8] <- 0
      po[18,i,t,9] <- 0
      po[18,i,t,10] <- 0
      po[18,i,t,11] <- 0
      po[18,i,t,12] <- 0
      po[18,i,t,13] <- 0
      po[18,i,t,14] <- 0
      po[18,i,t,15] <- 0
      po[18,i,t,16] <- 0
      po[18,i,t,17] <- 0
      po[18,i,t,18] <- 1
      po[18,i,t,19] <- 0
      po[18,i,t,20] <- 0
      po[18,i,t,21] <- 0
      po[18,i,t,22] <- 0
      po[18,i,t,23] <- 0
      po[18,i,t,24] <- 0
      po[18,i,t,25] <- 0

      po[19,i,t,1] <- 0
      po[19,i,t,2] <- 0
      po[19,i,t,3] <- 0
      po[19,i,t,4] <- 0
      po[19,i,t,5] <- 0
      po[19,i,t,6] <- 0
      po[19,i,t,7] <- 0
      po[19,i,t,8] <- 0
      po[19,i,t,9] <- 0
      po[19,i,t,10] <- 0
      po[19,i,t,11] <- 0
      po[19,i,t,12] <- 0
      po[19,i,t,13] <- 0
      po[19,i,t,14] <- 0
      po[19,i,t,15] <- 0
      po[19,i,t,16] <- 0
      po[19,i,t,17] <- 0
      po[19,i,t,18] <- 0
      po[19,i,t,19] <- 1
      po[19,i,t,20] <- 0
      po[19,i,t,21] <- 0
      po[19,i,t,22] <- 0
      po[19,i,t,23] <- 0
      po[19,i,t,24] <- 0
      po[19,i,t,25] <- 0

      po[20,i,t,1] <- 0
      po[20,i,t,2] <- 0
      po[20,i,t,3] <- 0
      po[20,i,t,4] <- 0
      po[20,i,t,5] <- 0
```

```
      po[20,i,t,6] <- 0
      po[20,i,t,7] <- 0
      po[20,i,t,8] <- 0
      po[20,i,t,9] <- 0
      po[20,i,t,10] <- 0
      po[20,i,t,11] <- 0
      po[20,i,t,12] <- 0
      po[20,i,t,13] <- 0
      po[20,i,t,14] <- 0
      po[20,i,t,15] <- 0
      po[20,i,t,16] <- 0
      po[20,i,t,17] <- 0
      po[20,i,t,18] <- 0
      po[20,i,t,19] <- 0
      po[20,i,t,20] <- 1
      po[20,i,t,21] <- 0
      po[20,i,t,22] <- 0
      po[20,i,t,23] <- 0
      po[20,i,t,24] <- 0
      po[20,i,t,25] <- 0

      po[21,i,t,1] <- 0
      po[21,i,t,2] <- 0
      po[21,i,t,3] <- 0
      po[21,i,t,4] <- 0
      po[21,i,t,5] <- 0
      po[21,i,t,6] <- 0
      po[21,i,t,7] <- 0
      po[21,i,t,8] <- 0
      po[21,i,t,9] <- 0
      po[21,i,t,10] <- 0
      po[21,i,t,11] <- 0
      po[21,i,t,12] <- 0
      po[21,i,t,13] <- 0
      po[21,i,t,14] <- 0
      po[21,i,t,15] <- 0
      po[21,i,t,16] <- 0
      po[21,i,t,17] <- 0
      po[21,i,t,18] <- 0
      po[21,i,t,19] <- 0
      po[21,i,t,20] <- 0
      po[21,i,t,21] <- 1
      po[21,i,t,22] <- 0
      po[21,i,t,23] <- 0
      po[21,i,t,24] <- 0
      po[21,i,t,25] <- 0

      po[22,i,t,1] <- 0
      po[22,i,t,2] <- 0
      po[22,i,t,3] <- 0
```

```
      po[22,i,t,4] <- 0
      po[22,i,t,5] <- 0
      po[22,i,t,6] <- 0
      po[22,i,t,7] <- 0
      po[22,i,t,8] <- 0
      po[22,i,t,9] <- 0
      po[22,i,t,10] <- 0
      po[22,i,t,11] <- 0
      po[22,i,t,12] <- 0
      po[22,i,t,13] <- 0
      po[22,i,t,14] <- 0
      po[22,i,t,15] <- 0
      po[22,i,t,16] <- 0
      po[22,i,t,17] <- 0
      po[22,i,t,18] <- 0
      po[22,i,t,19] <- 0
      po[22,i,t,20] <- 0
      po[22,i,t,21] <- 0
      po[22,i,t,22] <- 1
      po[22,i,t,23] <- 0
      po[22,i,t,24] <- 0
      po[22,i,t,25] <- 0

      po[23,i,t,1] <- 0
      po[23,i,t,2] <- 0
      po[23,i,t,3] <- 0
      po[23,i,t,4] <- 0
      po[23,i,t,5] <- 0
      po[23,i,t,6] <- 0
      po[23,i,t,7] <- 0
      po[23,i,t,8] <- 0
      po[23,i,t,9] <- 0
      po[23,i,t,10] <- 0
      po[23,i,t,11] <- 0
      po[23,i,t,12] <- 0
      po[23,i,t,13] <- 0
      po[23,i,t,14] <- 0
      po[23,i,t,15] <- 0
      po[23,i,t,16] <- 0
      po[23,i,t,17] <- 0
      po[23,i,t,18] <- 0
      po[23,i,t,19] <- 0
      po[23,i,t,20] <- 0
      po[23,i,t,21] <- 0
      po[23,i,t,22] <- 0
      po[23,i,t,23] <- 1
      po[23,i,t,24] <- 0
      po[23,i,t,25] <- 0

      po[24,i,t,1] <- 0
```

```
      po[24,i,t,2] <- 0
      po[24,i,t,3] <- 0
      po[24,i,t,4] <- 0
      po[24,i,t,5] <- 0
      po[24,i,t,6] <- 0
      po[24,i,t,7] <- 0
      po[24,i,t,8] <- 0
      po[24,i,t,9] <- 0
      po[24,i,t,10] <- 0
      po[24,i,t,11] <- 0
      po[24,i,t,12] <- 0
      po[24,i,t,13] <- 0
      po[24,i,t,14] <- 0
      po[24,i,t,15] <- 0
      po[24,i,t,16] <- 0
      po[24,i,t,17] <- 0
      po[24,i,t,18] <- 0
      po[24,i,t,19] <- 0
      po[24,i,t,20] <- 0
      po[24,i,t,21] <- 0
      po[24,i,t,22] <- 0
      po[24,i,t,23] <- 0
      po[24,i,t,24] <- 1
      po[24,i,t,25] <- 0

      po[25,i,t,1] <- 0
      po[25,i,t,2] <- 0
      po[25,i,t,3] <- 0
      po[25,i,t,4] <- 0
      po[25,i,t,5] <- 0
      po[25,i,t,6] <- 0
      po[25,i,t,7] <- 0
      po[25,i,t,8] <- 0
      po[25,i,t,9] <- 0
      po[25,i,t,10] <- 0
      po[25,i,t,11] <- 0
      po[25,i,t,12] <- 0
      po[25,i,t,13] <- 0
      po[25,i,t,14] <- 0
      po[25,i,t,15] <- 0
      po[25,i,t,16] <- 0
      po[25,i,t,17] <- 0
      po[25,i,t,18] <- 0
      po[25,i,t,19] <- 0
      po[25,i,t,20] <- 0
      po[25,i,t,21] <- 0
      po[25,i,t,22] <- 0
      po[25,i,t,23] <- 0
      po[25,i,t,24] <- 0
      po[25,i,t,25] <- 1
```

```
    }#t
  }#i

  # Likelihoods
  for (i in 1:n.ind){
    # Define latent state at first capture
    z[i,f[i]] <- y[i,f[i]]
    for (t in (f[i]+1):n.occasions){
      # State process: draw S(t) given S(t-1)
      z[i,t] ~ dcat(ps[z[i,t-1], i, t-1,])
      # Observation process: draw O(t) given S(t)
      y[i,t] ~ dcat(po[z[i,t], i, t-1,])
    }#t
  }#i

  # Derived Parameters
  Sfymu <- ilogit(lmu1)
  Ssymu <- ilogit(lmu2)
  Safymu <- ilogit(lmu3)
  var.yr1 <- 1/(TaufyYr^2)
  var.yr3 <- 1/(TauafyYr^2)
  Pfyemmu <- ilogit(lmu.emig1)
  psiFY.Coll <- psiFY[1] + psiFY[2] + psiFY[3] + psiFY[4]
  psiAFY.Coll <- psiAFY[1] + psiAFY[2] + psiAFY[3] + psiAFY[4]
  psiFY.Anthro <- psiFY.Coll+psiFY[5]+psiFY[6]+psiFY[9]+psiFY[11]
  psiFY.Nat <- 1 - psiFY.Anthro
  psiAFY.Anthro <- psiAFY.Coll+psiAFY[5]+psiAFY[6]+psiAFY[9]+psiAFY[11]
  psiAFY.Nat <- 1 - psiAFY.Anthro
}
"
```

Run the model

Results

Model output

The table of model outputs as formatted by jagsUI is printed below.

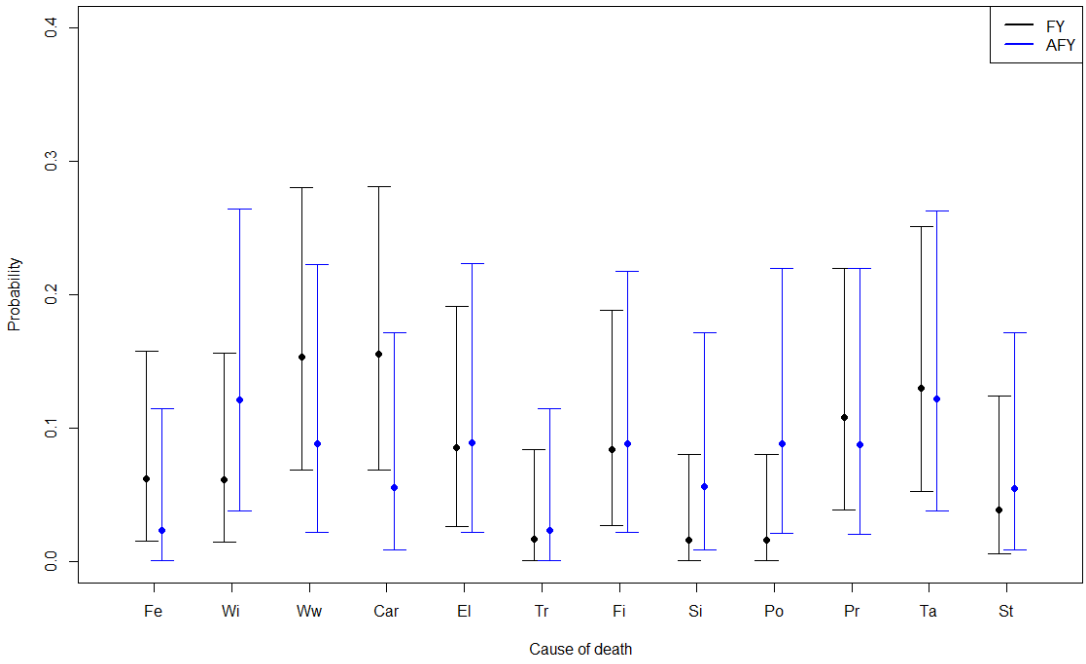
```
COD.summary <- read.csv('COD.summary.csv')
## Print the model output.
COD.sum <- COD.summary[,c(1:4,6,8:10)]
stat.names <- c('Parameter', 'Mean', 'SD', 'Q2.5', 'Q50', 'Q97.5', 'Rhat', 'N
eff')
colnames(COD.sum) <- stat.names
print(COD.sum, row.names = FALSE, digits = 2)

##      Parameter  Mean    SD    Q2.5   Q50 Q97.5 Rhat  Neff
##          Sfymu 0.193 0.056 0.09834 0.188 0.317    1 15000
```

```
##          Ssymu 0.676 0.081 0.51898 0.676 0.836    1  1557
##         Safymu 0.749 0.027 0.69677 0.749 0.802    1 10135
##         Sfy[1] 0.217 0.111 0.05440 0.199 0.501    1  7390
##         Sfy[2] 0.235 0.087 0.10178 0.222 0.445    1  2300
##         Sfy[3] 0.152 0.066 0.04307 0.145 0.296    1 12886
##         Sfy[4] 0.172 0.055 0.07860 0.168 0.293    1  7959
##         Sfy[5] 0.156 0.076 0.03580 0.148 0.330    1 15000
##         Sfy[6] 0.270 0.100 0.12591 0.252 0.509    1  1173
##         Sfy[7] 0.160 0.078 0.03655 0.153 0.341    1 15000
##         Sfy[8] 0.193 0.085 0.06833 0.180 0.402    1  7547
##         Sfy[9] 0.251 0.119 0.08355 0.226 0.551    1  2325
##        Sfy[10] 0.293 0.108 0.13336 0.274 0.547    1  1873
##        Sfy[11] 0.160 0.078 0.03725 0.152 0.338    1  9036
##         Ssy[1] 0.678 0.149 0.35046 0.682 0.941    1 15000
##         Ssy[2] 0.703 0.135 0.42331 0.704 0.947    1  1154
##         Ssy[3] 0.632 0.112 0.39620 0.637 0.839    1 10892
##         Ssy[4] 0.598 0.113 0.35543 0.605 0.804    1  3731
##         Ssy[5] 0.512 0.139 0.22620 0.523 0.749    1  6159
##         Ssy[6] 0.756 0.110 0.53870 0.760 0.949    1   862
##         Ssy[7] 0.533 0.107 0.31565 0.538 0.723    1  3276
##         Ssy[8] 0.748 0.121 0.50889 0.750 0.960    1  1673
##         Ssy[9] 0.614 0.134 0.31485 0.625 0.850    1 15000
##        Ssy[10] 0.749 0.122 0.50624 0.751 0.959    1   787
##        Ssy[11] 0.739 0.109 0.51867 0.741 0.935    1   643
##        Safy[1] 0.754 0.046 0.66119 0.753 0.852    1  6890
##        Safy[2] 0.730 0.048 0.61312 0.737 0.807    1  3452
##        Safy[3] 0.751 0.040 0.66913 0.751 0.834    1  6263
##        Safy[4] 0.755 0.038 0.67822 0.754 0.835    1 15000
##        Safy[5] 0.759 0.038 0.68622 0.757 0.842    1  4495
##        Safy[6] 0.759 0.039 0.68687 0.756 0.843    1  2507
##        Safy[7] 0.727 0.042 0.62832 0.733 0.794    1 15000
##        Safy[8] 0.730 0.039 0.63874 0.734 0.795    1  3036
##        Safy[9] 0.745 0.037 0.66729 0.746 0.814    1 15000
##       Safy[10] 0.751 0.037 0.67457 0.751 0.826    1 15000
##       Safy[11] 0.764 0.042 0.68984 0.761 0.858    1  2268
##        PdVHFmu 0.979 0.015 0.94191 0.982 0.997    1 15000
##        PdVIDmu 0.924 0.016 0.88970 0.925 0.953    1 15000
##       PdBANDmu 0.102 0.046 0.03606 0.094 0.216    1 15000
##          rVHmu 0.336 0.066 0.22050 0.331 0.476    1 15000
##         rBnfymu 0.043 0.021 0.01229 0.040 0.094    1  3508
##        rBnafymu 0.215 0.036 0.14825 0.214 0.292    1 15000
##        Pfyem[1] 0.838 0.135 0.47550 0.861 0.999    1 15000
##        Pfyem[2] 0.661 0.184 0.23355 0.705 0.906    1  1475
##        Pfyem[3] 0.860 0.111 0.58902 0.876 0.999    1  4165
##        Pfyem[4] 0.849 0.088 0.64485 0.860 0.982    1  7651
##        Pfyem[5] 0.712 0.222 0.08247 0.785 0.959    1  4457
##        Pfyem[6] 0.818 0.095 0.58276 0.833 0.960    1 15000
##        Pfyem[7] 0.851 0.122 0.54023 0.871 0.999    1 15000
##        Pfyem[8] 0.884 0.090 0.68062 0.896 0.999    1  4002
##        Pfyem[9] 0.758 0.167 0.29605 0.803 0.965    1 15000
```

```
##      Pfyem[10] 0.844 0.091 0.62984 0.857 0.980    1 15000
##      Pfyem[11] 0.852 0.123 0.54337 0.873 0.999    1 15000
##       Pemafymu 0.023 0.011 0.00749 0.022 0.049    1 13671
##       Pimafymu 0.117 0.049 0.04338 0.109 0.233    1 15000
##        Pfailmu 0.134 0.035 0.07465 0.132 0.210    1  3729
##          Sfysig 0.675 0.354 0.06895 0.649 1.455    1   416
##          Ssysig 5.013 2.850 0.24258 5.052 9.734    1 15000
##         Safysig 0.192 0.150 0.00860 0.160 0.555    1  1013
##          Semsig 1.242 1.284 0.03366 0.897 4.834    1  1909
##       psiFY[1] 0.068 0.037 0.01485 0.062 0.158    1  5991
##       psiFY[2] 0.068 0.037 0.01430 0.061 0.156    1  4380
##       psiFY[3] 0.159 0.055 0.06872 0.153 0.280    1  8089
##       psiFY[4] 0.160 0.055 0.06824 0.155 0.281    1 15000
##       psiFY[5] 0.091 0.043 0.02629 0.085 0.191    1 15000
##       psiFY[6] 0.023 0.022 0.00055 0.016 0.084    1  9935
##       psiFY[7] 0.090 0.042 0.02655 0.084 0.188    1 15000
##       psiFY[8] 0.023 0.022 0.00059 0.016 0.080    1  5165
##       psiFY[9] 0.022 0.022 0.00058 0.016 0.080    1 15000
##      psiFY[10] 0.114 0.047 0.03858 0.108 0.220    1 15000
##      psiFY[11] 0.136 0.051 0.05254 0.130 0.251    1 15000
##      psiFY[12] 0.046 0.031 0.00560 0.039 0.124    1  7522
##      psiAFY[1] 0.032 0.031 0.00083 0.023 0.114    1 11193
##      psiAFY[2] 0.129 0.059 0.03789 0.121 0.265    1  7610
##      psiAFY[3] 0.097 0.053 0.02153 0.088 0.223    1 15000
##      psiAFY[4] 0.064 0.043 0.00835 0.055 0.171    1 15000
##      psiAFY[5] 0.097 0.053 0.02170 0.089 0.223    1  5953
##      psiAFY[6] 0.032 0.031 0.00081 0.023 0.115    1  9066
##      psiAFY[7] 0.097 0.052 0.02157 0.088 0.217    1 10688
##      psiAFY[8] 0.065 0.044 0.00823 0.056 0.172    1  7160
##      psiAFY[9] 0.097 0.052 0.02089 0.088 0.220    1 11207
##     psiAFY[10] 0.096 0.052 0.02028 0.088 0.220    1  7354
##     psiAFY[11] 0.129 0.059 0.03749 0.122 0.263    1 14233
##     psiAFY[12] 0.064 0.044 0.00830 0.054 0.172    1  6179
##     psiFY.Coll 0.455 0.075 0.31241 0.454 0.601    1 15000
##    psiAFY.Coll 0.323 0.083 0.17517 0.319 0.496    1 15000
##   psiFY.Anthro 0.727 0.066 0.58831 0.731 0.847    1 15000
##      psiFY.Nat 0.273 0.066 0.15296 0.269 0.412    1 15000
##  psiAFY.Anthro 0.678 0.083 0.50722 0.682 0.828    1  7212
##     psiAFY.Nat 0.322 0.083 0.17160 0.318 0.493    1  7212
```

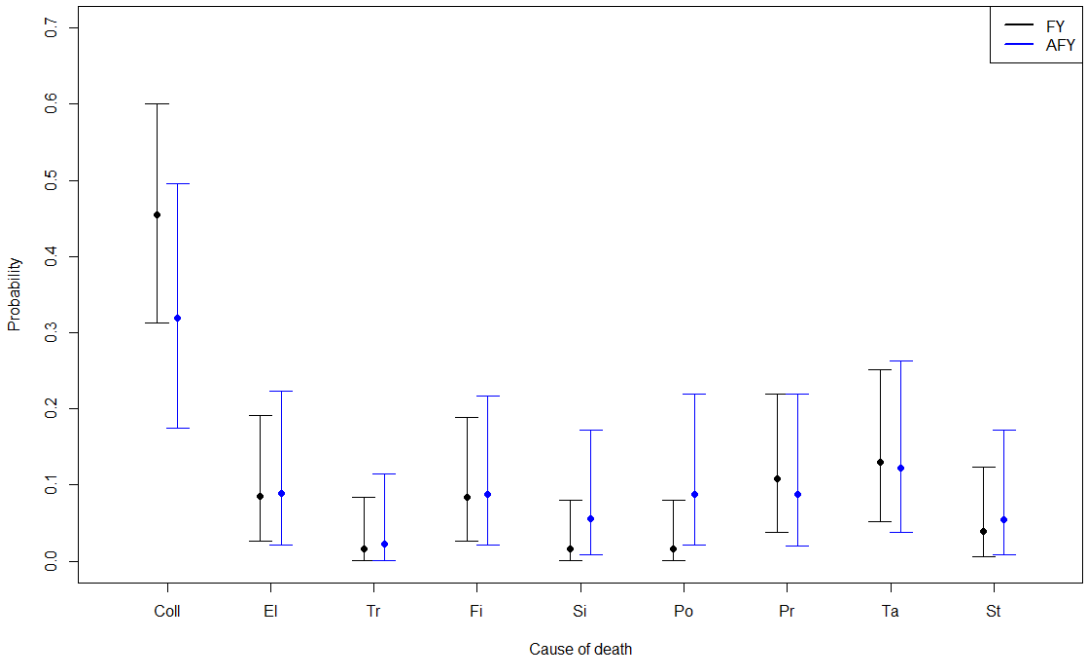
Probability of causes of mortality and 95% credible intervals

The figure below depicts probabilities for each cause of death and their 95% credible intervals. The axis tick labels are Fe = collision with fence, Wi = collision with an electric distribution wire, Ww = collision with a window, Car = collision with a vehicle, El = electrocuted, Tr = trapped in an building or structure, Fi = intraspecific fight, Si = disease, Po = poisoned, Pr = predation, Ta = take (e.g., shot, captured and killed), St = starvation.



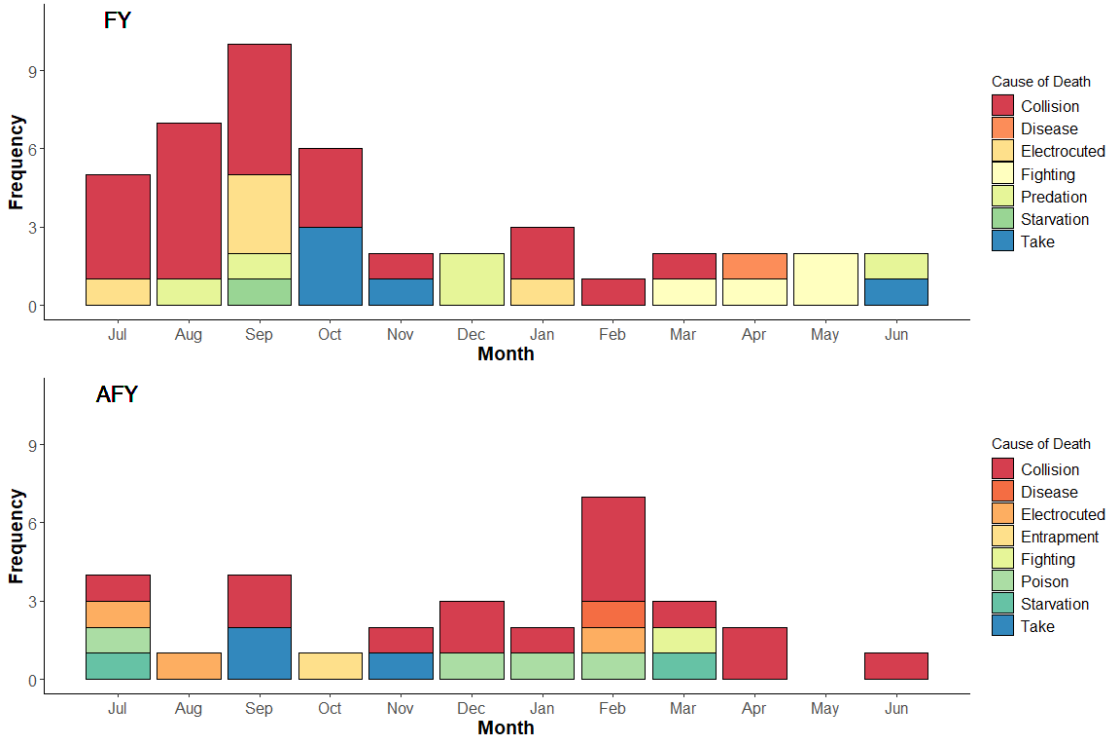
Probability of causes of mortality (collisions pooled) and 95% credible intervals

The figure below is the same as the preceding figure, but with collisions pooled. The axis tick labels are as described above, except Coll = all types of collisions.



Frequency of deaths by month

The two figures below show the frequency of female Cooper's hawk deaths by month. Note, I adjusted death date of female RED U/E to be June 1 rather than May 26.



Number of deaths by cause

In this section we use the posterior distribution of population size in 2020 from a 2-sex integrated population model (Millsap et al. 2023) to estimate the numerical imapact of different causes of mortality on the study population.

```
# Number of deaths by cause, 2019 cohort.
# First-year birds.
COD.samples <- read.csv('COD.samples.csv')
psiFY <- select(as.data.frame(COD.samples),starts_with("psiFY"))
CODbyTypeY <- data.frame(NULL)
causes <- c("Total N", "Total alive", "Total dead", "Fence", "Wire",
            "Window", "Vehicle", "Electrocution", "Trapped",
            "Fight", "Disease", "Poisoned", "Predated",
            "Take", "Starved")

for(i in 1:12){
  temp <- sample(Nfy.dead, dim(COD.samples)[1]) * psiFY[,i]
  temp2 <- as.numeric(quantile(temp, probs = c(0.025, 0.5, 0.975)))
  temp3 <- mean(temp)
  temp4 <- sd(temp)
  temp5 <- list("mean" = temp3, "sd" = temp4, "Q2.5" = temp2[1],
```

```
                "Q50" = temp2[2], "Q97.5" = temp2[3])
  CODbyTypeY <- rbind(CODbyTypeY, temp5)
}
FYtotal <- c(mean(Nfy), sd(Nfy),
             as.numeric(quantile(Nfy, 0.025)),
             as.numeric(quantile(Nfy, 0.5)),
             as.numeric(quantile(Nfy, 0.975)))
FYalive <- c(mean(Nfy.alive), sd(Nfy.alive),
             as.numeric(quantile(Nfy.alive, 0.025)),
             as.numeric(quantile(Nfy.alive, 0.5)),
             as.numeric(quantile(Nfy.alive, 0.975)))
FYdead <- c(mean(Nfy.dead), sd(Nfy.dead),
             as.numeric(quantile(Nfy.dead, 0.025)),
             as.numeric(quantile(Nfy.dead, 0.5)),
             as.numeric(quantile(Nfy.dead, 0.975)))

CODbyTypeFY <- rbind(FYtotal, FYalive, FYdead, CODbyTypeY)
row.names(CODbyTypeFY) <- causes

write.csv(CODbyTypeFY, "CODbyTypeFYT.csv")
print(CODbyTypeFY)
```

```
##                    mean        sd         Q2.5        Q50      Q97.5
## Total N       130.760089 16.313649 101.00000000 130.000000 165.000000
## Total alive    27.055921  7.397354  14.23847244  26.466306  43.399380
## Total dead    103.704168 14.498069  77.09498862 103.068799 133.566160
## Fence           7.074174  4.038666   1.46631977   6.319074  16.986091
## Wire            7.006413  4.022182   1.41691364   6.276469  16.679599
## Window         16.522819  6.177617   6.75288683  15.732450  30.772100
## Vehicle        16.601064  6.260202   6.65464951  15.794600  30.764834
## Electrocution   9.490098  4.707907   2.60319763   8.707927  20.768482
## Trapped         2.384819  2.372102   0.05717619   1.650689   8.708898
## Fight           9.380254  4.642176   2.65554727   8.606650  20.369346
## Disease         2.369473  2.329239   0.06089561   1.653338   8.604101
## Poisoned        2.291115  2.291985   0.05859228   1.608498   8.428441
## Predated       11.818114  5.228125   3.84710537  11.048381  23.955342
## Take           14.141752  5.734610   5.13248385  13.382046  27.232832
## Starved         4.721427  3.317660   0.57306875   3.983827  13.154412
```

```
# Older birds.
psiAFY <- select(as.data.frame(COD.samples),starts_with("psiAFY"))
CODbyType.AFY <- data.frame(NULL)
for(i in 1:12){
  temp <- sample(Nafy.dead, dim(COD.samples)[1]) * psiAFY[,i]
  temp2 <- as.numeric(quantile(temp, probs = c(0.025, 0.5, 0.975)))
  temp3 <- mean(temp)
  temp4 <- sd(temp)
  temp5 <- list("mean" = temp3, "sd" = temp4, "Q2.5" = temp2[1],
                "Q50" = temp2[2], "Q97.5" = temp2[3])
  CODbyType.AFY <- rbind(CODbyType.AFY, temp5)
```

```
}
AFYtotal <- c(mean(Nafy), sd(Nafy),
              as.numeric(quantile(Nafy, 0.025)),
              as.numeric(quantile(Nafy, 0.5)),
              as.numeric(quantile(Nafy, 0.975)))
AFYalive <- c(mean(Nafy.alive), sd(Nafy.alive),
              as.numeric(quantile(Nafy.alive, 0.025)),
              as.numeric(quantile(Nafy.alive, 0.5)),
              as.numeric(quantile(Nafy.alive, 0.975)))
AFYdead <- c(mean(Nafy.dead), sd(Nafy.dead),
              as.numeric(quantile(Nafy.dead, 0.025)),
              as.numeric(quantile(Nafy.dead, 0.5)),
              as.numeric(quantile(Nafy.dead, 0.975)))

CODbyType.AFY <- rbind(AFYtotal, AFYalive, AFYdead, CODbyType.AFY)
row.names(CODbyType.AFY) <- causes
write.csv(CODbyType.AFY, "CODbyType.AFYT.csv")
print(CODbyType.AFY, digits = 2)
```

```
##                mean   sd   Q2.5  Q50 Q97.5
## Total N       85.2 1.68 83.000 85.0  89.0
## Total alive   63.5 2.90 58.102 63.3  69.6
## Total dead    21.8 2.49 16.903 21.7  26.7
## Fence          0.7 0.69  0.018  0.5   2.5
## Wire           2.8 1.34  0.798  2.6   5.9
## Window         2.1 1.17  0.460  1.9   4.9
## Vehicle        1.4 0.96  0.179  1.2   3.8
## Electrocution  2.1 1.18  0.455  1.9   4.9
## Trapped        0.7 0.69  0.018  0.5   2.5
## Fight          2.1 1.17  0.454  1.9   4.9
## Disease        1.4 0.97  0.175  1.2   3.8
## Poisoned       2.1 1.18  0.445  1.9   4.9
## Predated       2.1 1.17  0.431  1.9   4.9
## Take           2.8 1.32  0.797  2.6   5.9
## Starved        1.4 0.97  0.173  1.2   3.8
```

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