

Hierarchical Models Accounting for Detection

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N-mixture Model

Simulate data and look at summary

```
library(unmarked)

## Warning: package 'unmarked' was built under R version 3.3.2
## Loading required package: reshape
## Loading required package: lattice
## Loading required package: parallel
## Loading required package: Rcpp
## Warning: package 'Rcpp' was built under R version 3.3.2

# Simulate data
set.seed(35)
nSites <- 100
nVisits <- 3
x <- rnorm(nSites)           # a covariate
beta0 <- 0
beta1 <- 1
lambda <- exp(beta0 + beta1*x) # expected counts at each site
N <- rpois(nSites, lambda)    # latent abundance
y <- matrix(NA, nSites, nVisits)
p <- c(0.3, 0.6, 0.8)        # detection prob for each visit
for(j in 1:nVisits) {
  y[,j] <- rbinom(nSites, N, p[j])
}

# Organize data
visitMat <- matrix(as.character(1:nVisits), nSites, nVisits, byrow=TRUE)

umf <- unmarkedFramePCount(y=y, siteCovs=data.frame(x=x),
  obsCovs=list(visit=visitMat))
summary(umf)

## unmarkedFrame Object
##
## 100 sites
## Maximum number of observations per site: 3
## Mean number of observations per site: 3
## Sites with at least one detection: 73
##
## Tabulation of y observations:
##      0      1      2      3      4      5      6      7      8     13     17     29 <NA>
## 126    85    43    27     9     1     1     2     3     1     1     1     0
##
```

```
## Site-level covariates:
##      x
## Min.   :-2.0468
## 1st Qu.: -0.5044
## Median : 0.1656
## Mean    : 0.1916
## 3rd Qu.: 0.7925
## Max.    : 3.3378
##
## Observation-level covariates:
## visit
## 1:100
## 2:100
## 3:100
```

Fit a model

```
# Fit a model
fm1 <- pcount(~visit-1 ~ x, umf, K=50)
fm1

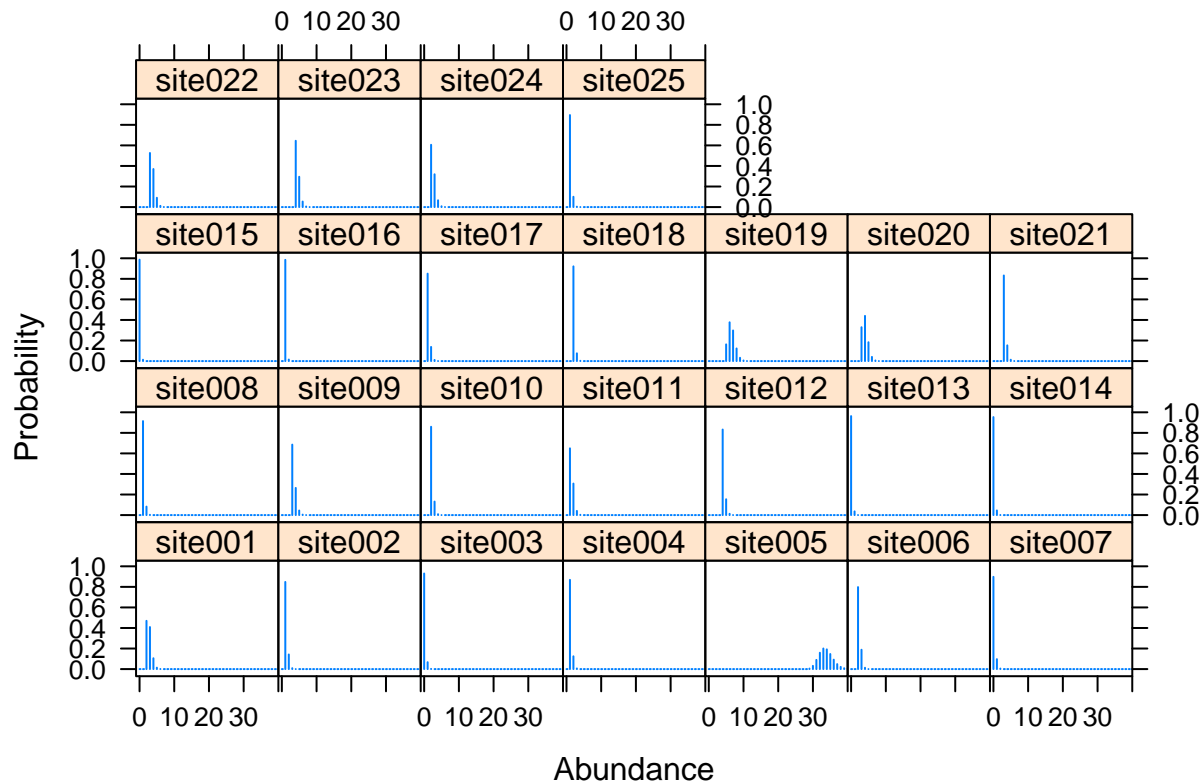
##
## Call:
## pcount(formula = ~visit - 1 ~ x, data = umf, K = 50)
##
## Abundance:
##      Estimate      SE      z  P(>|z|)
## (Intercept)  0.222 0.1112  2.0 4.57e-02
## x            0.895 0.0604 14.8 9.66e-50
##
## Detection:
##      Estimate      SE      z  P(>|z|)
## visit1  -0.617 0.164 -3.76 1.71e-04
## visit2   0.339 0.193  1.76 7.85e-02
## visit3   1.258 0.306  4.11 3.92e-05
##
## AIC: 660.5915

plogis(coef(fm1, type="det")) # Should be close to p

## p(visit1) p(visit2) p(visit3)
## 0.3504258 0.5840434 0.7787245
```

Empirical Bayes estimation of random effects

```
fm1re <- ranef(fm1)
plot(fm1re, subset=site %in% 1:25, xlim=c(-1,40))
```



```
sum(bup(fmire))           # Estimated population size
```

```
## [1] 231.1472
```

```
sum(N)                   # Actual population size
```

```
## [1] 229
```

Try with real data

Mallard counts

```
data(mallard)
mallardUMF <- unmarkedFramePCount(mallard.y, siteCovs = mallard.site,
obsCovs = mallard.obs)
(fm.mallard <- pcount(~ ivel+ date + I(date^2) ~ length + elev + forest, mallardUMF, K=30))
```

```
## Warning: 4 sites have been discarded because of missing data.
```

```
##
```

```
## Call:
```

```
## pcount(formula = ~ivel + date + I(date^2) ~ length + elev + forest,
##       data = mallardUMF, K = 30)
```

```
##
```

```
## Abundance:
```

```
##           Estimate      SE      z  P(>|z|)
## (Intercept)  -1.989 0.245 -8.14 4.10e-16
## length      -0.413 0.134 -3.07 2.14e-03
## elev        -1.507 0.247 -6.11 1.01e-09
## forest      -0.707 0.162 -4.37 1.22e-05
```

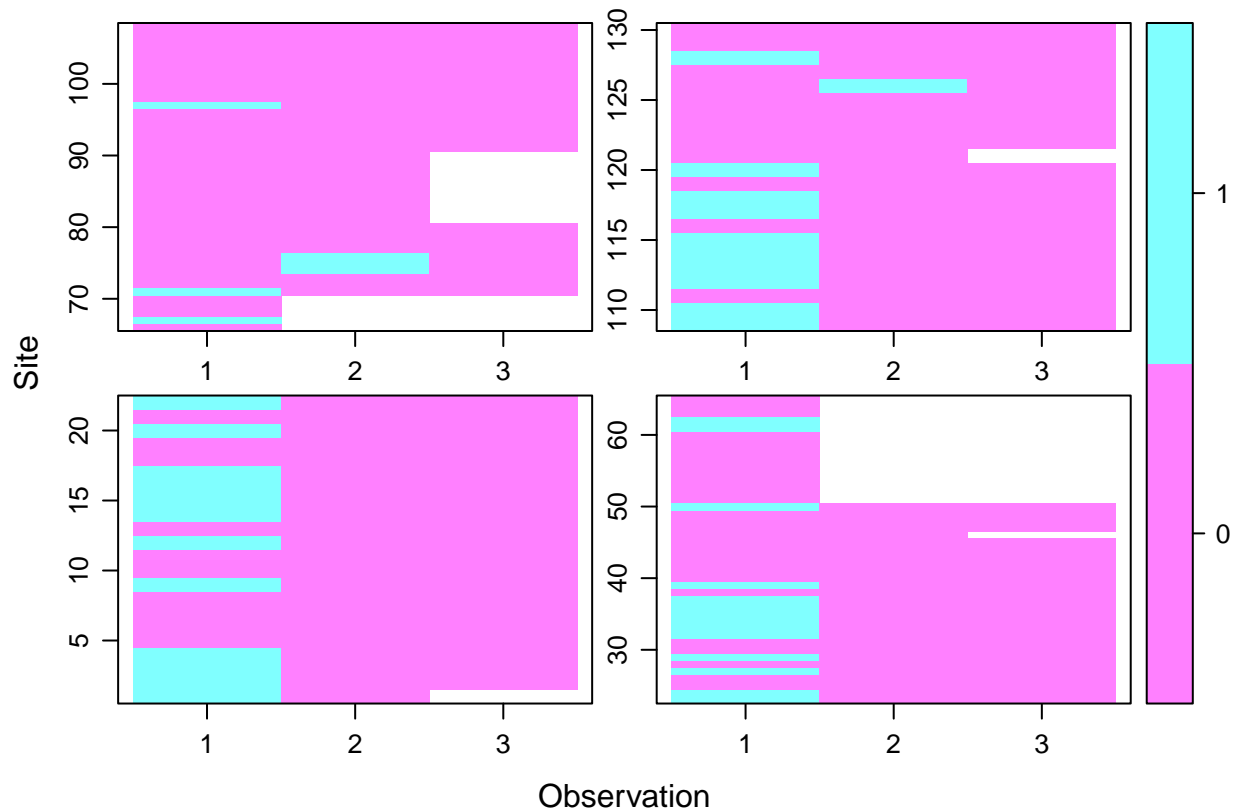
```
##
## Detection:
##      Estimate      SE      z P(>|z|)
## (Intercept)  0.25516 0.2240  1.139 0.2546
## ivel         0.29778 0.1773  1.680 0.0930
## date        -0.36894 0.1521 -2.425 0.0153
## I(date^2)     0.00908 0.0886  0.103 0.9183
##
## AIC: 511.2066
(fm.mallard.nb <- pcount(~ date + I(date^2) ~ length + elev, mixture = "NB", mallardUMF, K=30))

## Warning: 4 sites have been discarded because of missing data.
##
## Call:
## pcount(formula = ~date + I(date^2) ~ length + elev, data = mallardUMF,
##       K = 30, mixture = "NB")
##
## Abundance:
##      Estimate      SE      z P(>|z|)
## (Intercept)  -1.760 0.304 -5.78 7.31e-09
## length       -0.383 0.208 -1.84 6.59e-02
## elev         -1.637 0.322 -5.08 3.72e-07
##
## Detection:
##      Estimate      SE      z P(>|z|)
## (Intercept) -0.09070 0.2879 -0.3150 0.7528
## date        -0.29341 0.1413 -2.0770 0.0378
## I(date^2)   -0.00561 0.0756 -0.0742 0.9408
##
## Dispersion:
##      Estimate      SE      z P(>|z|)
##      -0.983 0.328 -2.99 0.00277
##
## AIC: 484.6365
```

Occupancy Data

Data from NAAMP for *Pseudacris feriarum* (pfer) and *Pseudacris crucifer* (pcru) in 2001 (chorus frogs)

```
data(frogs)
pferUMF <- unmarkedFrameOccu(pfer.bin)
plot(pferUMF, panels=4)
```



```
# add some fake covariates for illustration
siteCovs(pferUMF) <- data.frame(sitevar1 = rnorm(numSites(pferUMF)))

# observation covariates are in site-major, observation-minor order
obsCovs(pferUMF) <- data.frame(obsvar1 = rnorm(numSites(pferUMF) * obsNum(pferUMF)))

(fm <- occu(~ obsvar1 ~ 1, pferUMF))
```

```
##
## Call:
## occu(formula = ~obsvar1 ~ 1, data = pferUMF)
##
## Occupancy:
## Estimate SE      z P(>|z|)
##      8.03 21 0.381    0.703
##
## Detection:
##      Estimate      SE      z P(>|z|)
## (Intercept) -1.935 0.166 -11.68 1.57e-31
## obsvar1      0.229 0.156   1.47 1.41e-01
##
## AIC: 261.1599
```

Look at confidence intervals

```
confint(fm, type='det', method = 'normal')
```

```
##              0.025      0.975
## p(Int)      -2.26005341 -1.6106548
## p(obsvar1) -0.07613163  0.5334236
```

```

confint(fm, type='det', method = 'profile')

## Profiling parameter 1 of 2 ... done.
## Profiling parameter 2 of 2 ... done.

##           0.025      0.975
## p(Int)      -2.2746905 -1.5653245
## p(obsvar1) -0.0755488  0.5363642

# estimate detection effect at obsvars=0.5
(lc <- linearComb(fm['det'],c(1,0.5)))

## Linear combination(s) of Detection estimate(s)
##
## Estimate      SE (Intercept) obsvar1
##      -1.82 0.173           1      0.5

# transform this to probability (0 to 1) scale and get confidence limits
(btlc <- backTransform(lc))

## Backtransformed linear combination(s) of Detection estimate(s)
##
## Estimate      SE LinComb (Intercept) obsvar1
##      0.139 0.0207      -1.82           1      0.5
##
## Transformation: logistic

confint(btlc, level = 0.9)

##           0.05      0.95
## 0.1085939 0.1769897

# Empirical Bayes estimates of proportion of sites occupied
re <- ranef(fm)
sum(bup(re, stat="mode"))

## [1] 130

```