$$y_{tj} \sim \begin{cases} 0, & z_t = 0 \\ 0, & z_t = 1,\ u_{tj} < 0 \\ 1, & z_t = 1,\ u_{tj} > 0 \end{cases}$$

j indexes sampling occasion
t indexes primary period

$$z_0 \sim \text{Bern}(\psi)$$
$$\psi \sim \text{Beta}(\alpha_\psi, \beta_\psi)$$

Royle and Dorazio notation

$$\underset{(t=2,\ldots,T-1)}{z_t} \sim \begin{cases} 0, & v_t \le 0,\ z_{t-1} = 0 & (1-\gamma) \\ 1, & v_t > 0,\ z_{t-1} = 0 & (\gamma) \\ 0, & q_t \le 0,\ z_{t-1} = 1 & (1-\phi) \\ 1, & q_t > 0,\ z_{t-1} = 1 & (\phi) \end{cases}$$

$v_t \to$ colonization
$\gamma = P(\text{colonization})$

$q_t \to$ persistence
$\phi = P(\text{persistence})$

$$u_{tj} \sim N(\underline{w}_{tj}'\underline{\alpha}, 1) \Rightarrow \Phi^{-1}(p_{tj}) = \underline{w}_{tj}'\underline{\alpha}$$

$$v_t \sim N(X'\underline{\beta}, 1) \Rightarrow \Phi^{-1}(\gamma) = X'\underline{\beta}$$

$$q_t \sim N(G'\underline{\theta}, 1) \Rightarrow \Phi^{-1}(\phi) = G'\underline{\theta}$$

$$\underline{\alpha} \sim N(\underline{\mu}_\alpha, \Sigma_\alpha)$$
$$\underline{\beta} \sim N(\underline{\mu}_\beta, \Sigma_\beta)$$
$$\underline{\theta} \sim N(\underline{\mu}_\theta, \Sigma_\beta)$$

Posterior Distribution:

$$[\underline{z}, z_0, \psi, \underline{u}, \underline{v}, \underline{q}, \underline{\alpha}, \underline{\beta}, \underline{\theta} \mid y] \propto \prod_{t=1}^{T} \prod_{j=1}^{J} \Big([y_{tj} \mid z_t, u_{tj}][u_{tj} \mid \underline{\alpha}]$$

$$[z_t \mid v_t, q_t][v_t \mid \underline{\beta}][q_t \mid \underline{\theta}] \Big) [z_0 \mid \psi][\underline{\alpha}][\underline{\beta}][\underline{\theta}][\psi]$$

$$[z_t \mid z_{t-1}][z_{t+1} \mid z_t] \qquad [z_0 \mid \psi, z_1]?$$

likelihood?

$$[z_0 \mid \cdot] \propto [z_1 \mid z_0][z_0 \mid \psi]$$

$$\propto \left[1_{\{z_1=0\}}^{z_0} 1_{\{q_1 \le 0\}} + 1_{\{z_1=1\}}^{z_0} 1_{\{q_1 > 0\}} + 1_{\{z_1=0\}}^{1-z_0} 1_{\{v_1 \le 0\}} + 1_{\{z_1=1\}}^{1-z_0} 1_{\{v_1 > 0\}} \right] \left(\psi^{z_0} (1-\psi)^{1-z_0} \right)$$

$$\propto \left[\psi \left(1_{\{z_1=0\}} 1_{\{q_1 \le 0\}} + 1_{\{z_1=1\}} 1_{\{q_1 > 0\}} \right) \right]^{z_0} \times$$

$$\left[(1-\psi) \left(1_{\{z_1=0\}} 1_{\{v_1 \le 0\}} + 1_{\{z_1=1\}} 1_{\{v_1 > 0\}} \right) \right]^{1-z_0}$$

$$\boxed{\begin{array}{l} q \to \phi \\ v \to \gamma \end{array}}$$

$$\propto [\underbrace{\psi \phi^{z_1} (1-\phi)^{1-z_1}}_{\boxed{A}}]^{z_0} [\underbrace{(1-\psi) \gamma^{z_1} (1-\gamma)^{1-z_1}}_{\boxed{B}}]^{1-z_0}$$

$$\propto \text{Bern}(\tilde{\psi})$$

$$\tilde{\psi} = \frac{A}{A+B}$$

$$[z_t|\cdot] \propto \prod_{j=1}^{J}\left([y_{tj}|z_t,u_{tj}]\right)[z_t|z_{t-1}][z_{t+1}|z_t]$$

$\boxed{\text{likelihood}}$

$$\propto \prod_{j=1}^{J}\left(1^{z_t}_{\{y_{tj}=0\}}1_{\{u_{tj}\le 0\}} + 1^{z_t}_{\{y_{tj}=1\}}1_{\{u_{tj}>0\}} + 1^{1-z_t}_{\{y_{tj}=0\}}\right) \times$$

$\boxed{[z_t|z_{t-1}]}$

$$\left(1^{z_{t-1}}_{\{z_t=0\}}1_{\{q_t\le 0\}} + 1^{z_{t-1}}_{\{z_t=1\}}1_{\{q_t>0\}} + 1^{1-z_{t-1}}_{\{z_t=0\}}1_{\{v_t\le 0\}} + 1^{1-z_{t-1}}_{\{z_t=1\}}1_{\{v_t>0\}}\right) \times$$

$$\left(1^{z_t}_{\{z_{t+1}=0\}}1_{\{q_{t+1}\le 0\}} + 1^{z_t}_{\{z_{t+1}=1\}}1_{\{q_{t+1}>0\}} + 1^{1-z_t}_{\{z_{t+1}=0\}}1_{\{v_{t+1}\le 0\}} + 1^{1-z_t}_{\{z_{t+1}=1\}}1_{\{v_{t+1}>0\}}\right)$$

$\boxed{[z_{t+1}|z_t]}$

Notice that:

1.) $1^{z_{t-1}}_{\{z_t=0\}}1_{\{q_t\le 0\}} \Rightarrow 1^{1-z_t}_{\{z_{t-1}\}}1_{\{q_t\le 0\}}$

2.) $1^{z_{t-1}}_{\{z_t=1\}}1_{\{q_t>0\}} \Rightarrow 1^{z_t}_{\{z_{t-1}\}}1_{\{q_t>0\}}$

3.) $1^{1-z_{t-1}}_{\{z_t=0\}}1_{\{v_t\le 0\}} \Rightarrow 1^{1-z_t}_{\{1-z_{t-1}\}}1_{\{v_t\le 0\}}$

4.) $1^{1-z_{t-1}}_{\{z_t=1\}}1_{\{v_t>0\}} \Rightarrow 1^{z_t}_{\{1-z_{t-1}\}}1_{\{v_t>0\}}$

$$\boxed{\begin{array}{l} q \to \phi \\ v \to \gamma \end{array}}$$

$$[z_t|\cdot] \propto \left[\prod_{j=1}^{J}\left(1_{\{y_{tj}=0\}}1_{\{u_{tj}\le 0\}} + 1_{\{y_{tj}=1\}}1_{\{u_{tj}>0\}}\right) + 1_{\{z_{t-1}\}}1_{\{q_t>0\}} + 1_{\{1-z_{t-1}\}}1_{\{v_t>0\}} + 1_{\{z_{t+1}=0\}}1_{\{q_{t+1}\le 0\}} + 1_{\{z_{t+1}=1\}}1_{\{q_{t+1}\ge 0\}}\right]^{z_t} +$$

$$\left[\prod_{j=1}^{J}\left(1_{\{y_{tj}=0\}}\right) + 1_{\{z_{t-1}\}}1_{\{q_t\le 0\}} + 1_{\{1-z_{t-1}\}}1_{\{v_t\le 0\}} + 1_{\{z_{t+1}=0\}}1_{\{v_{t+1}\le 0\}} + 1_{\{z_{t+1}=1\}}1_{\{v_{t+1}>0\}}\right]^{1-z_t}$$

(continued...)

(... continued)

$$[z_t \mid \cdot] \propto \Big[\underbrace{\prod_{j=1}^{J}\left(p_{tj}^{y_{tj}}(1-p_{tj})^{1-y_{tj}}\right)\phi^{z_{t-1}}\phi^{z_{t+1}}(1-\phi)^{1-z_{t+1}}\gamma^{1-z_{t-1}}}_{\boxed{A}}\Big]^{z_t} \times$$

$$\Big[\underbrace{(1-\phi)^{z_{t-1}}\gamma^{z_{t+1}}(1-\gamma)^{1-z_{t-1}}(1-\gamma)^{1-z_{t+1}}}_{\boxed{B}}\Big]^{1-z_t}$$

$$\propto \text{Bern}(\tilde{\psi})$$

$$\tilde{\psi} = \frac{A}{A+B}$$

$$[z_T \mid \cdot] \propto \prod_{j=1}^{J} \left([y_{Tj} \mid z_T, u_{Tj}] \right) [z_T \mid z_{T-1}]$$

$$\propto \prod_{j=1}^{J} \left(1_{\{y_{Tj}=0\}}^{z_T} 1_{\{u_{Tj} \le 0\}} + 1_{\{y_{Tj}=1\}}^{z_T} 1_{\{u_{Tj} > 0\}} + 1_{\{y_{Tj}=0\}}^{1-z_T} \right) \times$$

$$\left[\underline{1_{\{z_T=0\}}^{z_{T-1}}} 1_{\{q_T \le 0\}} + \underline{1_{\{z_T=1\}}^{z_{T-1}}} 1_{\{q_T > 0\}} + \underline{1_{\{z_T=0\}}^{1-z_{T-1}}} 1_{\{v_T \le 0\}} + \underline{1_{\{z_T=1\}}^{1-z_{T-1}}} 1_{\{v_T > 0\}} \right]$$

transform these to have exponents in terms of z_T

$$\propto \left[\prod_{j=1}^{J} \left(1_{\{y_{Tj}=0\}} 1_{\{u_{Tj} \le 0\}} + 1_{\{y_{Tj}=1\}} 1_{\{u_{Tj} > 0\}} \right) + 1_{\{z_{T-1}\}} 1_{\{q_T > 0\}} + 1_{\{1-z_{T-1}\}} 1_{\{v_T > 0\}} \right]^{z_T} \left[\prod_{j=1}^{J} 1_{\{y_{Tj}=0\}} + 1_{\{z_{T-1}\}} 1_{\{q_T \le 0\}} + 1_{\{1-z_{T-1}\}} 1_{\{v_T \le 0\}} \right]^{1-z_T}$$

$$\propto \underbrace{\left[\prod_{j=1}^{J} \left(p_{Tj}^{y_{Tj}} (1-p_{Tj})^{1-y_{Tj}} \right) \phi^{z_{T-1}} \gamma^{1-z_{T-1}} \right]^{z_T}}_{\boxed{A}} \underbrace{\left[(1-\phi)^{z_{T-1}} (1-\gamma)^{1-z_{T-1}} \right]^{1-z_T}}_{\boxed{B}}$$

(colonization)

$$[v_t|\cdot] \propto [z_t|z_{t-1}, v_t][v_t|\beta]$$

update for $z_{t-1}=0$ only

$$\propto \left(1_{\{z_{t-1}=0\}} 1_{\{v_t \le 0\}}^{1-z_t} + 1_{\{z_{t-1}=0\}} 1_{\{v_t > 0\}}^{z_t}\right) N(v_t | x'\beta, 1)$$

$$\propto \left(1_{\{v_t \le 0\}}^{1-z_t} + 1_{\{v_t > 0\}}^{z_t}\right) N(v_t | x'\beta, 1)$$

$$= \begin{cases} TN(x'\beta, 1)_{-\infty}^{0}, & z_t = 0 \\ TN(x'\beta, 1)_{0}^{\infty}, & z_t = 1 \end{cases}$$

$$[q_t|\cdot] \propto [z_t|z_{t-1}, q_t][q_t|\theta]$$

update for $z_{t-1}=1$ only

$$\propto \left(1_{\{z_{t-1}=1\}} 1_{\{q_t \le 0\}}^{1-z_t} + 1_{\{z_{t-1}=1\}} 1_{\{q_t > 0\}}^{z_t}\right) N(q_t | G'\underline{\theta}, 1)$$

$$\propto \left(1_{\{q_t \le 0\}}^{1-z_t} + 1_{\{q_t > 0\}}^{z_t}\right) N(q_t | G'\theta, 1)$$

$$= \begin{cases} TN(G'\theta, 1)_{-\infty}^{0}, & z_t = 0 \\ TN(G'\theta, 1)_{0}^{\infty}, & z_t = 1 \end{cases}$$

$$[u_{tj}|\cdot] \propto [y_{tj}|z_t, u_{tj}][u_{tj}|\underline{\alpha}]$$

update for $z_t = 1$ only

$$\propto \left(1_{\{y_{tj}=0\}}^{z_t} 1_{\{u_{tj} \le 0\}} + 1_{\{y_{tj}=1\}}^{z_t} 1_{\{u_{tj} > 0\}}\right) N(u_{tj} | W'\underline{\alpha}, 1)$$

$$= \begin{cases} TN(W'\underline{\alpha}, 1)_{-\infty}^{0}, & y_{tj} = 0 \\ TN(W'\underline{\alpha}, 1)_{0}^{\infty}, & y_{tj} = 1 \end{cases}$$

only 1 datum when # of sites = 1

$$[\psi|\cdot] \propto [z_0|\psi][\psi]$$

$$\propto \left(\psi^{z_0}(1-\psi)^{1-z_0}\right)\left(\psi^{\alpha-1}(1-\psi)^{\beta-1}\right)$$

$$\propto \psi^{z_0+\alpha-1}(1-\psi)^{(1-z_0)+(\beta-1)}$$

$$\propto \text{Beta}(z_0+\alpha, (1-z_0)+\beta)$$

1

Imperfect detection

$$y_{ijt} \sim \begin{cases} 0, & z_{it}=0 \\ 0, & u_{ijt} \le 0,\ z_{it}=1 \\ 1, & u_{ijt} > 0,\ z_{it}=1 \end{cases}$$

$z_{i0} \sim Bern(\psi)$

$\psi \sim Beta(\alpha_\psi, \beta_\psi)$

- loops)
- add false positive
- handle NA's by day + year for a whole site

detection

$$z_{it} \sim \begin{cases} 0, & v_{it} \le 0,\ z_{it-1}=0 & 1-\gamma \\ 1, & v_{it} > 0,\ z_{it-1}=0 & \gamma \\ 0, & q_{it} \le 0,\ z_{it-1}=1 & 1-\phi \\ 1, & q_{it} > 0,\ z_{it-1}=1 & \phi \end{cases}$$

$u_{ijt} \sim N(\underline{W}'_{ijt}\underline{\alpha}, I)$

$v_{it} \sim N(\underline{x}_i'\underline{\beta}_\gamma, I)$

$q_{it} \sim N(\underline{x}_i'\underline{\beta}_\phi, I)$

$\underline{\alpha} \sim N(\mu_\alpha, \Sigma_\alpha)$

$\underline{\beta}_\phi \sim N(\mu_{\beta_\phi}, \Sigma_{\beta_\phi})$

$\underline{\beta}_\gamma \sim N(\mu_{\beta_\gamma}, \Sigma_{\beta_\gamma})$

$\Phi^{-1}(p_{ijt}) = \underline{W}'_{ijt}\underline{\alpha}$

$\Phi^{-1}(\phi) = \underline{x}_i'\underline{\beta}_\phi$

$\Phi^{-1}(\gamma) = \underline{x}_i'\underline{\beta}_\gamma$

$\phi = p(\text{survival})$

$\gamma = p(\text{colonization})$

Full conditionals

$$[z, z0, \psi, \underline{v}, \underline{q}, \underline{u}, \underline{\alpha}, \underline{\beta}_\phi, \underline{\beta}_\gamma \mid y] \propto \prod_{t=1}^{T}\prod_{i=1}^{n}\prod_{j=1}^{J} 1_{\{y_{ijt}=0\}}^{1-z_{it}} + 1_{\{y_{ijt}=0\}}^{z_{it}}$$

$$\cdot\, 1_{\{u_{ijt} \le 0\}} + 1_{\{y_{ijt}=1\}}^{z_{it}} \cdot 1_{\{u_{ijt}>0\}}\Big)[u_{ijt} \mid \underline{\alpha}]\Big)\; 1_{\{z_{it}=0\}}^{1-z_{it-1}} \cdot 1_{\{v_{it} \le 0\}}$$

$$+\, 1_{\{z_{it}=1\}}^{1-z_{it-1}} \cdot 1_{\{v_{it}>0\}} + 1_{\{z_{it}=0\}}^{z_{it-1}} \cdot 1_{\{q_{it} \le 0\}} + 1_{\{z_{it}=1\}}^{z_{it-1}} \cdot 1_{\{q_{it}>0\}}\Big)$$

$$[v_{it} \mid \beta_\gamma]\,[q_{it} \mid \underline{\beta}_\phi]\,[z_{i0} \mid \psi]\,[\psi]\,[\underline{\alpha}]\,[\underline{\beta}_\gamma]\,[\underline{\beta}_\phi]$$

$$[z_{i0} \mid \cdot] \propto \prod_{i=1}^{n}\prod_{t} 1_{\{z_{i1}=0\}}^{1-z_{i0}} \cdot 1_{\{v_{i1} \le 0\}} + 1_{\{z_{i1}=1\}}^{1-z_{i0}} \cdot 1_{\{v_{i1}>0\}} + 1_{\{z_{i1}=0\}}^{z_{i0}} \cdot 1_{\{q_{i1}$$

$$+\, 1_{\{z_{i1}=1\}}^{z_{i0}} \cdot 1_{\{q_{it}>0\}}\Big)\,[z_{i0} \mid \psi]$$

$$\propto \psi^{z_{i0}}(1-\psi)^{1-z_{i0}}\Big(1_{\{z_{i1}=0\}} \cdot 1_{\{q_{i1} \le 0\}} + 1_{\{z_{i1}=1\}} \cdot 1_{\{q_{it}>0\}}\Big)^{z_{i0}}\Big(1_{\{z_{i1}=0\}} \cdot 1_{\{v_{i1} \le 0\}} + 1_{\{z_{i1}\}} \cdot 1_{\{v_{i1}\}}\Big)^{1-z_{i}}$$

$z_{i0}=1 \propto \psi\,(1-\phi)^{(1-z_{i1})}\,\phi^{z_{i1}} = A$

$\hat{\psi} = A/A+B$

$z_{i0}=0 \propto (1-\psi)\cdot(1-\gamma)^{(1-z_{i1})}\,\gamma^{z_{i1}} = B$

$$[z_{it}|\cdot] \propto \prod_{t=1}\prod_{i=1}\prod_{j=1}\Big(\mathbb{1}_{\{y_{ijt}=0\}}\mathbb{1}_{\{u_{ijt}\le 0\}}+\mathbb{1}_{\{y_{ijt}=1\}}\mathbb{1}_{\{u_{ijt}>0\}}\Big)^{z_{it}}\cdot\mathbb{1}^{1-z_{it}}_{\{y_{ijt}=0\}}\Big)\cdot$$

(2)

$$+\,\mathbb{1}^{1-z_{it-1}}_{\{z_{it}=0\}}\cdot\mathbb{1}_{\{q_{it}\le 0\}}+\mathbb{1}^{z_{it-1}}_{\{z_{it}=0\}}\cdot\mathbb{1}_{\{q_{it}>0\}}+\mathbb{1}^{z_{it}}_{\{z_{it+1}=0\}}\mathbb{1}_{\{q_{it+1}\le 0\}}$$

$$+\,\mathbb{1}^{z_{it}}_{\{z_{it+1}=1\}}\cdot\mathbb{1}_{\{q_{it+1}>0\}}+\mathbb{1}^{1-z_{it-1}}_{\{z_{it}=0\}}\cdot\mathbb{1}_{\{v_{it}\le 0\}}+\mathbb{1}^{1-z_{it-1}}_{\{z_{it}=1\}}\cdot\mathbb{1}_{\{v_{it}>0\}}$$

$$+\,\mathbb{1}^{1-z_{it}}_{\{z_{it+1}=0\}}\cdot\mathbb{1}_{\{v_{it+1}\le 0\}}+\mathbb{1}^{1-z_{it}}_{\{z_{it+1}=1\}}\cdot\mathbb{1}_{\{v_{it+1}>0\}}$$

$$\propto\Big(\mathbb{1}_{\{y_{ijt}=0\}}\cdot\mathbb{1}_{\{u_{ijt}\le 0\}}+\mathbb{1}_{\{y_{ijt}=1\}}\cdot\mathbb{1}_{\{u_{ijt}>0\}}+\mathbb{1}_{\{z_{it+1}=0\}}\cdot\mathbb{1}_{\{q_{it+1}\le 0\}}$$

$$+\,\mathbb{1}_{\{z_{it+1}=1\}}\cdot\mathbb{1}_{\{q_{it+1}>0\}}+\mathbb{1}_{\{1-z_{it-1}\}}\cdot\mathbb{1}_{\{v_{it}>0\}}+\mathbb{1}_{\{z_{it-1}\}}\cdot\mathbb{1}_{\{q_{it}>0\}}\Big)^{z_{it}}$$

$$\Big(\mathbb{1}_{\{y_{ijt}=0\}}+\mathbb{1}_{\{z_{it+1}=0\}}\cdot\mathbb{1}_{\{v_{it+1}\le 0\}}+\mathbb{1}_{\{z_{it+1}=1\}}\cdot\mathbb{1}_{\{v_{it+1}>0\}}$$

$$+\,\mathbb{1}_{1-z_{it-1}}\cdot\mathbb{1}_{\{q_{it}\le 0\}}+\mathbb{1}_{\{1-z_{it-1}\}}\cdot\mathbb{1}_{\{v_{it}\le 0\}}\Big)^{1-z_{it}}$$

$$\propto\Big(\overset{A1}{\left(p_{ijt}^{\,y_{ijt}}(1-p_{ijt})^{1-y_{ijt}}\right)}\left((1-\phi)^{(1-z_{it+1})}\phi^{z_{it+1}}\gamma^{(1-z_{it-1})}\phi^{z_{it-1}}\right)^{z_{it}}\Big)$$

A2   A3

$$\Big((1-\gamma)^{1-z_{it+1}}(\gamma)^{z_{it+1}}(1-\phi)^{z_{it-1}}(1-\gamma)^{(1-z_{it-1})}\Big)^{1-z_{it}}$$

$$A=\left(p_{ijt}^{\,y_{ijt}}(1-p_{ijt})^{1-y_{ijt}}\right)(1-\phi)^{(1-z_{it+1})}\phi^{z_{it+1}}\gamma^{(1-z_{it-1})}\phi^{z_{it-1}}$$

OK

$$B=(1-\gamma)^{1-z_{it+1}}\gamma^{z_{it+1}}(1-\phi)^{z_{it-1}}(1-\gamma)^{(1-z_{it-1})}$$

$$\hat{\psi}=\frac{A}{A+B}\qquad [z_{it}|\cdot]\sim \mathrm{Bern}(\hat{\psi})$$

$$[z_{iT}|\cdot] \propto \prod_{t=T}\prod_{i=1}\prod_{j=1} 1_{\{y_{ijT}=1\}}\cdot 1_{\{y_{ijT}=0\}}\cdot 1_{\{u_{ijT}\le 0\}} + 1_{\{y_{ijT}=1\}}\cdot 1_{\{u_{ijT}>0\}}$$

$$1^{1-z_{iT-1}}_{\{z_{iT}=0\}}\cdot 1_{\{v_{iT}\le 0\}} + 1^{1-z_{iT-1}}_{\{z_{iT}=1\}}\cdot 1_{\{v_{iT}>0\}} + 1^{z_{iT-1}}_{\{z_{iT}=0\}}\cdot 1_{\{q_{iT}\le 0\}}$$

$$+ 1^{z_{iT-1}}_{\{z_{iT}=1\}}\cdot 1_{\{q_{iT}>0\}}\Big)$$

$$\propto \Big(1_{\{y_{ijT}=0\}} 1_{\{u_{ijT}\le 0\}} + 1_{\{y_{ijT}=1\}}\cdot 1_{\{u_{ijT}>0\}} + 1_{\{1-z_{iT-1}\}}\cdot 1_{\{v_{iT}>0\}} \cdot$$

$$1_{z_{iT-1}} 1_{\{q_{iT}>0\}}\Big)^{z_{iT}}\Big(1_{y_{ijT}=0} + 1_{\{1-z_{iT-1}\}}\cdot 1_{v_{iT}\le 0} + 1_{\{z_{iT-1}=0\}} 1_{\{q_{iT}\le 0\}}\Big)^{1-z_{iT}}$$

$$\propto \left(p_{ijT}^{\,y_{ijT}}(1-p_{ijT})^{1-y_{ijT}}\cdot \gamma^{1-z_{iT-1}}\,\phi^{z_{iT-1}}\right)^{z_{iT}}\left((1-\gamma)^{1-z_{iT-1}}(1-\phi)^{z_{iT-1}}\right)^{1-z_{iT}}$$

$$[z_{iT}|\cdot] \propto \mathrm{Bern}(\hat{\psi}) \qquad \hat{\psi} = \frac{A}{A+B} \qquad A = p_{ijT}^{\,y_{ijT}}(1-p_{ijT})^{1-y_{ijT}}\gamma^{1-z_{iT-1}}\phi^{z_{iT-1}}$$

$$B = (1-\gamma)^{1-z_{iT-1}}(1-\phi)^{z_{iT-1}} \text{ ok}$$

$$[v_{it}|\cdot] \propto \prod_{i=1}^{n} 1^{z_{it}}_{\{v_{it}>0\}}\, 1_{\{z_{it-1}=0\}} + 1^{(1-z_{it})}_{\{v_{it}\le 0\}}\, 1_{\{z_{it-1}=0\}}\; [v_{it}|\beta_\gamma]$$

$z_{it-1}=0$

$$\propto \prod_{z_{it-1}=0}^{n} 1_{\{v_{it}>0\}} + 1_{\{v_{it}\le 0\}}\; [v_{it}|\beta_\gamma]$$

$$z_{it}=0 \quad \propto TN(\underline{x}_i'\beta_\gamma, 1)_{-\infty}^{0}$$

$$z_{it}=1 \quad \propto TN(\underline{x}_i'\beta_\gamma, 1)_{0}^{\infty}$$

$$[\beta_\gamma|\cdot] = N\left((X'X+\Sigma^{-1})^{-1}X'\underline{z},\ (X'X+\Sigma^{-1})^{-1}\right)$$

$z_{i\,t-1}=0$

$$[q_{it}|\cdot] \propto \prod_{i=1}^{n} 1_{\{q_{it}\le 0\}}^{(1-z_{it})} \cdot 1_{\{z_{i,t-1}=1\}} + 1_{\{q_{it}>0\}}^{z_{it}} \cdot 1_{\{z_{i,t-1}=1\}} [q_{it}|\beta_\psi]$$ (4)

$z_{i,t-1}=1$

$$\propto \prod_{z_{i,t-1}=1}^{n} 1_{\{q_{it}\le 0\}}^{(1-z_{it})} + 1_{\{q_{it}>0\}}^{z_{it}} [q_{it}|\beta_\psi]$$

$$z_{it}=0 \propto TN(x_i'\beta_\psi, I)_{-\infty}^{0}$$

$$z_{it}=1 \propto TN(x_i'\beta_\psi, I)_{0}^{\infty}$$

$$[\beta_\psi|\cdot] = N((X'X+\Sigma^{-1})^{-1}X'z,\ (X'X+\Sigma^{-1})^{-1})$$

$z_{i,t-1}=1$

$$[u_{ijt}|\cdot] \propto 1_{\{y_{ijt}=0\}}^{z_{it}} \cdot 1_{\{u_{ijt}\le 0\}} + 1_{\{y_{ijt}=1\}}^{z_{it}} \cdot 1_{\{u_{ijt}>0\}} [u_{ijt}|\alpha]$$

$\boxed{y_{ijt}=0}$

$\boxed{z_{it}=1}$

$$[u_{ijt}|\cdot] \propto TN(w_{ij}'\alpha, I)_{-\infty}^{0} \quad y_{ijt}=0$$

$$\propto TN(w_{ij}'\alpha, I)_{0}^{\infty} \quad y_{ijt}=1$$

$$[\alpha|\cdot] \propto \prod_{i=1}^{n}\prod_{j=1}^{J} ((W'W+\Sigma_\alpha^{-1})^{-1}(W'u+\Sigma_\alpha^{-1}\mu_\alpha),(W'W+\Sigma_\alpha^{-1})^{-1})$$

$\boxed{y_{ijt}=0}$

$\boxed{z_{it}=1}$

$$[\psi|\cdot] \propto \psi^{\Sigma z_i} \prod_{i=1}^{n} [z_i|\psi_i][\psi_i]$$

$\boxed{z_{i0}?}$

$$\propto \psi^{\Sigma z_i}(1-\psi)^{\Sigma(1-z_i)} \cdot \psi^{\alpha-1}(1-\psi)^{\beta-1}$$

$$\propto \psi^{\Sigma z_i+\alpha-1}(1-\psi)^{\Sigma(1-z_i)+\beta-1}$$

$$\psi \sim Beta(\Sigma z_i+\alpha,\ \Sigma(1-z_i)+\beta)$$

MCMC algorithm for dynamic occupancy model from Viviana

```
probit_det_z0na_ms_msp_0908 <- function(Y,n.mcmc,n.burn,X,W){

  library(truncnorm)
  library(mvtnorm)
  library(Rlab)
  library(boot)
  library(abind)
  library(MASS)
  library(msm)
  library(MCMCpack)


  n <- dim(Y)[1]
  J <- dim(Y)[2]
  T <- dim(Y)[3]
  N <- dim(Y)[4]

  #####
  #####Save samples
  #####
  psi.save <- array(0,dim=c(n.mcmc,dim(X)[2],N))
  beta.psi.save <- array(0,dim=c(n.mcmc,dim(X)[2],N))
  sigma.beta.psi.save <- array(0,dim=c(dim(X)[2],dim(X)[2],n.mcmc))
  mu.beta.psi.save <- array(0,dim=c(n.mcmc,dim(X)[2]))

  phi.save <- array(0,dim=c(n.mcmc,dim(X)[2],N))
  beta.phi.save <- array(0,dim=c(n.mcmc,dim(X)[2],N))
  sigma.beta.phi.save <- array(0,dim=c(dim(X)[2],dim(X)[2],n.mcmc))
  mu.beta.phi.save <- array(0,dim=c(n.mcmc,dim(X)[2]))

  gamma.save <- array(0,dim=c(n.mcmc,dim(X)[2],N))
  beta.gamma.save <- array(0,dim=c(n.mcmc,dim(X)[2],N))
  sigma.beta.gamma.save <- array(0,dim=c(dim(X)[2],dim(X)[2],n.mcmc))
```

```
mu.beta.gamma.save <- array(0,dim=c(n.mcmc,dim(X)[2]))

p.save <- array(0,dim=c(n.mcmc,J,N))
alpha.save <- array(0,dim=c(n.mcmc,dim(W)[2],N))
sigma.alpha.save <- array(0,dim=c(dim(W)[2],dim(W)[2],n.mcmc))
mu.alpha.save <- array(0,dim=c(n.mcmc,dim(W)[2]))

#####
#####Set up variables for each species
#####

zi <- NULL;
Y.nz.idx <- NULL;

for(i in 1:N){
  Y.tmp <- Y[,,,i]
  Ys <- colSums(aperm(Y.tmp, c(2,1,3)),na.rm=TRUE)
  zi.tmp <- array(0,dim = c(n,T))
  zi.tmp[Ys>0] <- 1  ##zi matrix for when a species was observed at least once at a
site, per year
  Y.nz.temp <- zi.tmp==1  #index for when a species was observed at least once
  Y.nz.idx <- abind(Y.nz.idx,Y.nz.temp,along=3)
  zi <- abind(zi,zi.tmp,along=3)
}


##get priors for alpha
mu.mu.alpha <- matrix(rep(0, dim(W)[2]), ncol=1)
sigma.mu.alpha <- matrix(0, nrow=dim(W)[2], ncol=dim(W)[2])
diag(sigma.mu.alpha) <- 1.5
sigma_inv.mu.alpha <- solve(sigma.mu.alpha)

V.alpha <- diag(2)*1.5
```

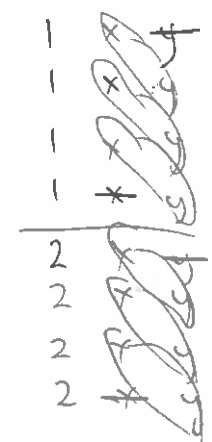
```
nu.alpha <- 100


##get priors for beta psi
mu.mu.beta.psi <- matrix(rep(0, dim(X)[2]), ncol=1)
sigma.mu.beta.psi <- matrix(0, nrow=dim(X)[2], ncol=dim(X)[2])
diag(sigma.mu.beta.psi) <- 1.5
sigma_inv.mu.beta.psi <- solve(sigma.mu.beta.psi)

V.beta.psi <- diag(2)*1.5
nu.beta.psi <- 100

##get prior mean and cov for beta Phi, it does not change with every iteration
mu.mu.beta.phi <- matrix(rep(0, dim(X)[2]), ncol=1)
sigma.mu.beta.phi <- matrix(0, nrow=dim(X)[2], ncol=dim(X)[2])
diag(sigma.mu.beta.phi) <- 1.5
sigma_inv.mu.beta.phi <- solve(sigma.mu.beta.phi)

V.beta.phi <- diag(2)*1.5
nu.beta.phi <- 100

##get prior mean and cov for beta Gamma, it does not change with every iteration
mu.mu.beta.gamma <- matrix(rep(0, dim(X)[2]), ncol=1)
sigma.mu.beta.gamma <- matrix(0, nrow=dim(X)[2], ncol=dim(X)[2])
diag(sigma.mu.beta.gamma) <- 1.5
sigma_inv.mu.beta.gamma <- solve(sigma.mu.beta.gamma)

V.beta.gamma <- diag(2)*1.5
nu.beta.gamma <- 100


##starting values for the betas for psi
```

```
x.psi <- as.matrix(cbind(c(1,1),c(1,0)))
beta.psi <- array(0,dim=c(N,dim(X)[2]))
psi <- array(0,dim=c(n,N))

##starting values for psi
for(i in 1:N){
  beta.psi[i,] <-  glm(zi[,T-2,i]  ~ X[,2],family=binomial)$coefficients
  psi[,i] <- inv.logit(X%*%beta.psi[i,])
}

##setting up the new zi matrix
zi.2 <- array(NA, dim=c(n,T+1,N))
for(i in 1:N){
  zi.2[,2:(T+1),i] <- zi[,,i]  ##add the zi
  zi.2[,1,i] <- rbern(n,mean(psi[i]))
}
Y.nz2.idx <- zi.2==1

mu.beta.psi <- apply(beta.psi,2,mean)
sigma.beta.psi <- matrix(0, nrow=dim(X)[2], ncol=dim(X)[2])
diag(sigma.beta.psi) <- apply(beta.psi,2,var)
sigma.beta.psi_inv <- solve(sigma.beta.psi)

##starting value for the alphas for detection

alphas <- array(0,dim=c(N,dim(W)[2]))
p <- array(0,dim=c(dim(W)[1],N))
p.mean <- array(0,dim=c(dim(W)[1],N))

##starting values for detection (p)

for(i in 1:N){
  Y.temp <- Y[,,i]
```

1 X
1 1
1 1
X 1
2 X
2 2
2 2
X 2

```
    alphas[i,] <- glm(c(t(Y.temp[,,T-2]))[Y.nz.idx[,T-2,i]] ~ W[Y.nz.idx[,T-2,i],2:dim(W)
[2]],family=binomial)$coefficients#get starting values for alpha
    p[,i] <- inv.logit(W%*%alphas[i,])
    p.mean[,i] <- p[,i]
  }


  mu.alpha <- apply(alphas,2,mean)
  sigma.alpha <- matrix(0, nrow=dim(W)[2], ncol=dim(W)[2])
  diag(sigma.alpha) <- apply(alphas,2,var)
  sigma.alpha_inv <- solve(sigma.alpha)

  ##starting value for the betas for persistence

  x.phi <- as.matrix(cbind(c(1,1),c(1,0)))
  x2.phi <- do.call(rbind, replicate(T, X, simplify=FALSE))
  beta.phi <- array(0,dim=c(N,dim(X)[2]))
  phi <- array(0,dim=c(n,N))

  ##starting values for persistence (Phi)

  for(i in 1:N){
    z.pers1.indx.temp <- zi[,T-2,i]==1
    beta.phi[i,] <-  glm(zi[z.pers1.indx.temp,T-1,i]~ X[z.pers1.indx.temp,
2],family=binomial)$coefficients
    phi[,i] <- inv.logit(X%*%beta.phi[i,])
  }

  mu.beta.phi <- apply(beta.phi,2,mean)
  sigma.beta.phi <- matrix(0, nrow=dim(X)[2], ncol=dim(X)[2])
  diag(sigma.beta.phi) <- apply(beta.phi,2,var)
  sigma.beta.phi_inv <- solve(sigma.beta.phi)
```

	Z	Persistence
0	0	-
1	1	~~0~~
2	1	1
3	0	-



```
#Starting value for the betas for colonization

x2.gamma <- do.call(rbind, replicate(T, X, simplify=FALSE))
x.gamma <- as.matrix(cbind(c(1,1),c(1,0)))
beta.gamma <- array(0,dim=c(N,dim(X)[2]))
gamma <- array(0,dim=c(n,N))

##starting values for colonization (Gamma)

for(i in 1:N){
  z.col0.indx.temp <- zi[,2,i]==0 ##how many sites were empty
  beta.gamma[i,] <-  glm(zi[z.col0.indx.temp,3,i] ~ X[z.col0.indx.temp,
2],family=binomial)$coefficients
  gamma[,i] <- inv.logit(X%*%beta.gamma[i,])
}

mu.beta.gamma <- apply(beta.gamma,2,mean)
sigma.beta.gamma <- matrix(0, nrow=dim(X)[2], ncol=dim(X)[2])
diag(sigma.beta.gamma) <- apply(beta.gamma,2,var)
sigma.beta.gamma_inv <- solve(sigma.beta.gamma)

for(k in 1:n.mcmc){
  if(k %% 100 == 0) cat(k, " "); flush.console()

  ####
  ####  Sample mu.alpha
  ####

  temp.alpha.var <- solve(N*sigma.alpha_inv + sigma_inv.mu.alpha)
  temp.alpha.mean <- temp.alpha.var%*%(sigma.alpha_inv%*%apply(alphas,2,sum))

  mu.alpha <- matrix(rmvnorm(1, temp.alpha.mean, temp.alpha.var,method="chol"), ncol=1)
```

```
####
####  sigma.alpha
####

mu.alphas <- matrix(mu.alpha,N,dim(W)[2],byrow = TRUE)
alpha.mu.diff <- alphas - mu.alphas
V.alpha.temp <- crossprod(alpha.mu.diff)
sigma.alpha_inv <- rwish((N + nu.alpha),solve(V.alpha.temp+V.alpha*nu.alpha))

####
####  Sample mu.beta.psi
####

temp.beta.psi.var <- solve(N*sigma.beta.psi_inv + sigma_inv.mu.beta.psi)
temp.beta.psi.mean <- temp.beta.psi.var%*%(sigma.beta.psi_inv%*%apply(beta.psi,
2,sum))

mu.beta.psi <- matrix(rmvnorm(1, temp.beta.psi.mean,
temp.beta.psi.var,method="chol"), ncol=1)

####
####  sigma.beta.psi
####

mu.beta.psis <- matrix(mu.beta.psi,N,2,byrow = TRUE)
beta.psi.mu.diff <- beta.psi - mu.beta.psis
V.psi.temp <- crossprod(beta.psi - mu.beta.psis)
sigma.beta.psi_inv <- rwish((N + nu.beta.psi),solve(V.psi.temp
+V.beta.psi*nu.beta.psi))

####
####  Sample mu.beta.phi
####
```

```
    temp.beta.phi.var <- solve(N*sigma.beta.phi_inv + sigma_inv.mu.beta.phi)
    temp.beta.phi.mean <- temp.beta.phi.var%*%(sigma.beta.phi_inv%*%apply(beta.phi,
2,sum))

    mu.beta.phi <- matrix(rmvnorm(1, temp.beta.phi.mean,
temp.beta.phi.var,method="chol"), ncol=1)

    ####
    ####  sigma.beta.phi
    ####

    mu.beta.phis <- matrix(mu.beta.phi,N,2,byrow = TRUE)
    beta.phi.mu.diff <- beta.phi - mu.beta.phis
    V.phi.temp <- crossprod(beta.phi - mu.beta.phis)
    sigma.beta.phi_inv <- rwish((N + nu.beta.phi),solve(V.phi.temp
+V.beta.phi*nu.beta.phi))

    ####
    ####  Sample mu.beta.gamma
    ####

    temp.beta.gamma.var <- solve(N*sigma.beta.gamma_inv + sigma_inv.mu.beta.gamma)
    temp.beta.gamma.mean <- temp.beta.gamma.var%*%(sigma.beta.gamma_inv%*
%apply(beta.gamma,2,sum))

    mu.beta.gamma <- matrix(rmvnorm(1, temp.beta.gamma.mean,
temp.beta.gamma.var,method="chol"), ncol=1)

    ####
    ####  sigma.beta.gamma
    ####
```

```
    mu.beta.gammas <- matrix(mu.beta.gamma,N,2,byrow = TRUE)
    beta.gamma.mu.diff <- beta.gamma - mu.beta.gammas
    V.gamma.temp <- crossprod(beta.gamma - mu.beta.gammas)
    sigma.beta.gamma_inv <- rwish((N + nu.beta.gamma),solve(V.gamma.temp
+V.beta.gamma*nu.beta.gamma))


    for(j in 1:N) {
#       cat(j, " ")
      ####
      ####  Sample Zi0
      ####

      if(sum(is.na(zi.2[,,j]))>1){
          zi.2[,2:(T+1),i] <- zi[,,j]
          zi.2[,1,j] <- rbern(n,mean(psi[i]))
      }

      z0.tmp.numer <- (phi[,j]^zi.2[,2,j])*((1-phi[,j])^(1-zi.2[,2,j]))

      z0.temp.denom <- (gamma[,j]^zi.2[,2,j])*((1-gamma[,j])^(1-zi.2[,2,j]))

      z0.psi.tmp=z0.tmp.numer/(z0.tmp.numer+z0.temp.denom)

      zi.2[,1,j] <- rbern(dim(zi.2)[1],z0.psi.tmp)


      ####
      ####  Sample Zi2 to T-1
      ####

      ##get rid of loop if possible
        for(t in 2:T){## from 2 to five in zi.2, but from year 1 to 4 in real data
```

```
          tmp.numer <- prod(dbinom(Y[,,t-1,j],1,t(matrix(p,J,n))),na.rm=TRUE)*((1-
phi[,j])^(1-zi.2[,t-1,j]))*
            (phi[,j]^zi.2[,t+1,j])*(gamma[,j]^(1-zi.2[,t-1,j]))*(phi[,j]^zi.2[,t-1,j])
          temp.denom <- ((1-gamma[,j])^(1-zi.2[,t+1,j]))*(gamma[,j]^zi.2[,t+1,j])*((1-
phi[,j])^(1-zi.2[,t-1,j]))*((1-gamma[,j])^(1-zi.2[,t-1,j]))
          psi.tmp=tmp.numer/(tmp.numer+temp.denom)
          zi.2[!Y.nz2.idx[,t,j],t,j]=rbern(sum(!Y.nz2.idx[,t,j]),psi.tmp[!
Y.nz2.idx[,t,j]])
        }


      ####
      ####  Sample ZiT
      ####

      tmp.numer <- prod(dbinom(Y[ ,,T,j],1,t(matrix(p,J,n))),na.rm=TRUE)*(gamma[,j]^(1-
zi.2[,T,j]))*(phi[,j]^zi.2[,T,j])
      temp.denom <- ((1-gamma[,j])^(1-zi.2[,T,j]))*((1-phi[,j])^(zi.2[,T,j]))
      psi.tmp=tmp.numer/(tmp.numer+temp.denom)
      zi.2[!Y.nz2.idx[,T+1,j],T+1,j]=rbern(sum(!Y.nz2.idx[,T+1,j]),psi.tmp[!Y.nz2.idx[,T
+1,j]])

      ####
      ####  Sample u
      ####

      u.all <- NULL;
      W.all <- NULL;
      for(t in 1:T){
      z.year.1.idx <- c(t(matrix(zi[,t,j],n,J)==1))##fills in occupied sites with 1 in a
vector same length as Y

      Y.zi1 <- c(t(Y[,,t,j]))[z.year.1.idx]##creates a vector for the occupied sites only
```

```
    Y.zi1.idx <- Y.zi1==1 & !is.na(Y.zi1)##index of when yij==1 for the occupied sites
    Y.zi0.idx <- Y.zi1==0 & !is.na(Y.zi1)##index of when yij==0 for the occupied sites

    u.mean <- as.vector(W[z.year.1.idx,] %*% alphas[j,])##get mu for u to sample from
the truncated normal
    u <- rep(NA, dim(W[z.year.1.idx,])[1])
    u[Y.zi1.idx] <- rtruncnorm(sum(Y.zi1.idx), a=0,b=Inf,mean=u.mean[Y.zi1.idx],
sd=1)##sample from a left truncated normal
    u[Y.zi0.idx] <- rtruncnorm(sum(Y.zi0.idx), a=-Inf,b=0,mean=u.mean[Y.zi0.idx],
sd=1)##sample from a right truncated normal
    u.all <- c(u.all,u)
    W.all <- rbind(W.all,W[z.year.1.idx,])
    }


    ####
    ####  Sample alpha.p
    ####

    V.alpha <- solve(sigma.alpha_inv + t(W.all) %*% W.all)
    u.na.red <- u.all[!is.na(u.all)]
    u.na.idx <- !is.na(u.all)
    W.na.1 <- t(W.all)
    W.na.red <- W.na.1[,u.na.idx]
    sigma.alpha <- solve(sigma.alpha_inv)
    alpha.mean <- V.alpha %*% (sigma.alpha%*%mu.alpha + (W.na.red %*% u.na.red))
    alphas[j,] <- matrix(rmvnorm(1, alpha.mean, V.alpha), ncol=1)


  ####
  ####  Sample m
  ####
```

```
    m.mean.1t <- as.vector(X %*% beta.psi[j,])##get mu for m to sample from the truncated
normal

    ##indicator for all cases where zit==1

    zi.m1.idx <- zi.2[,1,j] == 1

    m = rep(NA, length(m.mean.1t))

    ##sample from a left TN, when mit > 0
    m[zi.m1.idx] <- rtruncnorm(sum(zi.m1.idx), a=0,b=Inf,mean=m.mean.1t[zi.m1.idx], sd=1)

    ##sample from a right TN, when mit =< 0
    m[!zi.m1.idx] <- rtruncnorm(sum(!zi.m1.idx), a=-Inf,b=0,mean=m.mean.1t[!zi.m1.idx],
sd=1)

    ####
    ####  Sample Beta.psi
    ####

    m.beta <- solve(sigma.beta.psi_inv + (t(X) %*% X))
    sigma.beta.psi<- solve(sigma.beta.psi_inv)
    beta.psi.mean <- m.beta %*% (sigma.beta.psi%*%mu.beta.psi + (t(X) %*% m))
    beta.psi[j,] <- matrix(rmvnorm(1, beta.psi.mean, m.beta), ncol=1)##sample from a
multivariate normal

    ####
    ####  Sample q
    ####


    q.mean.1t <- as.vector(X %*% beta.phi[j,])##get mu for q to sample from the truncated
```

```
normal
    q.mean.all <- rep(q.mean.1t,T) ##repeat this for all the sites and years

    ##indicator for all cases where zit-1==1, and where zit=0 or =1

    zi.q1 <- c(zi.2[,1:T,j]) ## create a vector from z0 to T-1
    zi.q2 <- c(zi.2[,2:(T+1),j])
    zi.q10.idx <- zi.q1 == 1 & zi.q2 == 0
    zi.q11.idx <- zi.q1 == 1 & zi.q2 == 1
    zi.q1.idx <- zi.q1 == 1

    q = rep(NA, length(q.mean.all))

    ##sample from a left TN, wnen zit = 1,vit > 0, zit-1=1
    q[zi.q11.idx] <- rtruncnorm(sum(zi.q11.idx), a=0,b=Inf,mean=q.mean.all[zi.q11.idx],
sd=1)

    ##sample from a right TN, when zit = 0, vit =< 0, zit-1=1
    q[zi.q10.idx] <- rtruncnorm(sum(zi.q10.idx), a=-Inf,b=0,mean=q.mean.all[zi.q10.idx],
sd=1)

      ####
      ####  Sample Beta.phi
      ####

      q.beta <- solve(sigma.beta.phi_inv + (t(x2.phi[zi.q1.idx,]) %*%
x2.phi[zi.q1.idx,]))
      x2.phi.red <- x2.phi[zi.q1.idx,] ##take the elongated X cov matrix for phi, and
index those sites where zit-1=1
      q.red <- q[zi.q1.idx] ##take only those values for when zit-1=1
      sigma.beta.phi<- solve(sigma.beta.phi_inv)
      beta.phi.mean <- q.beta %*% (sigma.beta.phi%*%mu.beta.phi + (t(x2.phi.red) %*%
q.red))
```

```
      beta.phi[j,] <- matrix(rmvnorm(1, beta.phi.mean, q.beta), ncol=1)##sample from a
multivariate normal

      ####
      ####  Sample v
      ####

      v.mean.1t <- as.vector(X %*% beta.gamma[j,])##get mu for v to sample from the
truncated normal
      v.mean.all <- rep(v.mean.1t,T)

      ##indicator for all cases where zit-1==0

      zi.v1 <- c(zi.2[,1:T,j])
      zi.v2 <- c(zi.2[,2:(T+1),j])
      zi.v00.idx <- zi.v1 == 0 & zi.v2 == 0
      zi.v01.idx <- zi.v1 == 0 & zi.v2 == 1
      zi.v0.idx <- zi.v1 == 0

      v = rep(NA, length(v.mean.all))

      ##sample from a left TN, wnen zit = 1,vit > 0, zit-1=0
      v[zi.v01.idx] <- rtruncnorm(sum(zi.v01.idx), a=0,b=Inf,mean=v.mean.all[zi.v01.idx],
sd=1)##sample from a left TN, wnen zit = 1, zit-1=0, vit-1=0

      ##sample from a right TN, when zit = 0, vit =< 0, zit-1=0
      v[zi.v00.idx] <- rtruncnorm(sum(zi.v00.idx), a=-
Inf,b=0,mean=v.mean.all[zi.v00.idx], sd=1)##sample from a right TN, when zit = 0,
zit-1=0, vit-1=0

        ####
        ####  Sample Beta.gamma
        ####
```

J indexes site

```
        V.beta <- solve(sigma.beta.gamma_inv + (t(x2.phi[zi.v0.idx,]) %*%
x2.phi[zi.v0.idx,]))
        x2.gamma.red <- x2.phi[zi.v0.idx,] ##take the elongated X cov matrix for gamma,
and index those sites where zit-1=0
        v.red <- v[zi.v0.idx] ##take only those values for when zit-1=0
        sigma.beta.gamma <- solve(sigma.beta.gamma_inv)
        beta.gamma.mean <- V.beta %*% (sigma.beta.gamma%*%mu.beta.gamma +
(t(x2.gamma.red) %*% v.red)) ##a n by cov X matrix * V that's n dims
        beta.gamma[j,] <- matrix(rmvnorm(1, beta.gamma.mean, V.beta), ncol=1)##sample
from a multivariate normal


      ####
      ####  Sample psi, p, Phi and Gamma
      ####

      p[,j] <- as.vector(pnorm(W%*%alphas[j,]))

      psi[,j] <- as.vector(pnorm(X %*% beta.psi[j,]))

      phi[,j] <- as.vector(pnorm(X %*% beta.phi[j,]))

      gamma[,j] <- as.vector(pnorm(X %*% beta.gamma[j,]))


      ####
      ####  Save samples
      ####

      psi.save[k,,j] <- unique(psi[,j])
      beta.psi.save[k,,j]  <- t(beta.psi[j,])
```

```
      phi.save[k,,j] <- unique(phi[,j])
      beta.phi.save[k,,j]<- t(beta.phi[j,])
      gamma.save[k,,j] <- unique(gamma[,j])
      beta.gamma.save[k,,j]<- t(beta.gamma[j,])
      p.save[k,,j] <- p[1:J,j]
      alpha.save[k,,j] <- t(alphas[j,])
    }

    sigma.beta.psi.save[,,k] <- sigma.beta.psi
    mu.beta.psi.save[k,] <- t(mu.beta.psi)
    sigma.beta.phi.save[,,k] <- sigma.beta.phi
    mu.beta.phi.save[k,] <- t(mu.beta.phi)
    sigma.beta.gamma.save[,,k] <- sigma.beta.gamma
    mu.beta.gamma.save[k,] <- t(mu.beta.gamma)
    sigma.alpha.save[,,k] <- sigma.alpha
    mu.alpha.save[k,] <- t(mu.alpha)
  }

list(psi.save=psi.save,beta.psi.save=beta.psi.save,phi.save=phi.save,beta.phi.save=beta.p
hi.save,gamma.save=gamma.save,beta.gamma.save=beta.gamma.save,p.save=p.save,alpha.save=al
pha.save,sigma.beta.psi.save=sigma.beta.psi.save,mu.beta.psi.save=mu.beta.psi.save,sigma.
beta.phi.save=sigma.beta.phi.save,mu.beta.phi.save=mu.beta.phi.save,sigma.beta.gamma.save
=sigma.beta.gamma.save,mu.beta.gamma.save=mu.beta.gamma.save,sigma.alpha.save=sigma.alpha
.save,mu.alpha.save=mu.alpha.save,Y=Y,X=X,W=W)

}
```