# Supporting Information S1: Model in BUGS language and codes to prepare data

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# model specification (BUGS)

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model {

### Define seasonal and annual patterns in detectability

for (m in 1:nyear) {

for (i in 1:n) {

logit(p[m,i]) <- lp[m,i]

lp[m,i] <- mfe[m,i]+mre[m,i]

mfe[m,i] <- a[m]\*X[i,1]+b[m]\*X[i,2]+c[m]\*X[i,3]

mre[m,i]<-sum(n.mre[m,i,1:nknots])

for (k in 1:nknots) {

n.mre[m,i,k]<-b.k[m,k]\*Z[i,k]

}

}

### Random regression coefficients corresponding to the truncated polynomial functions

for (k in 1:nknots) {

b.k[m,k] ~ dnorm(0,taub)

}

### Fixed regression coefficients corresponding to the 'plus' functions

a[m] ~ dnorm(0,0.01)

b[m] ~ dnorm(0,0.01)

c[m] ~ dnorm(0,0.01)

}

### precision for random regression coefficients corresponding to the truncated polynomial functions

taub~dgamma(1.0E-6,1.0E-6)

# Specify priors

for (k in 1:nyear) {

psi[k] ~ dunif(0, 1)

}

# Ecological submodel: Define state conditional on parameters

for (i in 1:nsite){

for (k in 1:nyear){

z[i,k] ~ dbern(psi[k])

}

}

# Observation model

for (i in 1:nobs){

muy[site[i],survey[i],year[i]] <- z[site[i],year[i]]\*p[year[i],survey[i]]

y[i] ~ dbin(muy[site[i],survey[i],year[i]], nrep[i])

}

} #End of Model

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# prepare model input (according to Crainiceanu et al., 2005)

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### degree of splines

degree <- 2

### covariate

covariate <- as.numeric(scale(min(julian dates):max(julian dates))) # “julian dates” = julian date of all days within the observation period

### covariate length

n <- length(covariate)

### location of knots

knots<-quantile(unique(covariate),seq(0,1,length=(nknots+2))[-c(1,(nknots+2))])

### fixed effects matrix

X<-NULL

for (l in 0:degree) {

X<-cbind(X,covariate^l)

}

### random coefficients matrix

Z\_K<-(abs(outer(covariate,knots,"-")))^3

OMEGA\_all<-(abs(outer(knots,knots,"-")))^3

svd.OMEGA\_all<-svd(OMEGA\_all)

sqrt.OMEGA\_all<-t(svd.OMEGA\_all$v %\*% (t(svd.OMEGA\_all$u)\*sqrt(svd.OMEGA\_all$d)))

Z<-t(solve(sqrt.OMEGA\_all,t(Z\_K)))