Winter severity influences spotted seatrout mortality in a southeast US estuarine system

Timothy A. Ellis*, Jeffrey A. Buckel, Joseph E. Hightower

*Corresponding author: taellis@ncsu.edu

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Supplement 1: OpenBUGS code for multistate capture-recapture model.
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Supplement 4: Swimming speeds of telemetered spotted seatrout and bottlenose dolphins.

Supplement 1

OpenBUGS code for the multistate capture-recapture model used to estimate demographic rates of telemetered spotted seatrout; modified from Kéry and Schaub (2012).

model {

# Parameters
# Z: Instantaneous total mortality rate between t and t+1
# F: Instantaneous fishing mortality rate between t and t+1
# M: Instantaneous natural mortality rate between t and t+1
# E: Instantaneous emigration rate between t and t+1
# p: Probability of being detected in the receiver array

# States
# 1 Alive
# 2 Natural Death
# 3 Emigrated
# 4 Harvest

# Observations
# 1 Detected alive
# 2 Detected natural mortality
# 3 Detected emigrating
# 4 Not Detected

# Priors, constraints, and calculated values
for (t in 1:(Periods-1)){
    lnF[t] ~ dunif(-10,1)  # uninformative prior
    lnM[t] ~ dunif(-10,1)  # uninformative prior
    lnE[t] ~ dunif(-10,1)  # uninformative prior
    F[t] <- exp(lnF[t])
    M[t] <- exp(lnM[t])
    E[t] <- exp(lnE[t])
\[ S[t] \leftarrow \exp(-Z[t]) \]
\[ Z\_mort[t] \leftarrow F[t]+M[t] \quad \text{# total instantaneous mortality rate for fish} \]
\[ S\_mort[t] \leftarrow \exp(-Z\_mort[t]) \quad \text{# discrete survival rate for fish} \]
\[ A\_mort[t] \leftarrow 1-\exp(-Z\_mort[t]) \quad \text{# discrete mortality rate for fish} \]

\[ p[1] \leftarrow 1 \quad \text{# Model conditioned on first capture, estimate separate p for remaining periods} \]
for (t in 2:\text{Periods}){
\[ p[t] \sim \text{dunif}(0, 1) \]
}\]

\# Define state-transition and observation matrices
for (i in 1:nFish){
\# Define probabilities of State (t+1) given State (t). First index is state at time t, next is state at t+1
for (t in first[i]:\text{last}[i]-1){
\[ ps[1,i,t,1] \leftarrow S[t] \]
\[ ps[1,i,t,2] \leftarrow M[t]*\left(1-S[t]\right)/Z[t] \]
\[ ps[1,i,t,3] \leftarrow E[t]*\left(1-S[t]\right)/Z[t] \]
\[ ps[1,i,t,4] \leftarrow F[t]*\left(1-S[t]\right)/Z[t] \]
\[ ps[2,i,t,1] \leftarrow 0 \]
\[ ps[2,i,t,2] \leftarrow 1 \]
\[ ps[2,i,t,3] \leftarrow 0 \]
\[ ps[2,i,t,4] \leftarrow 0 \]
\[ ps[3,i,t,1] \leftarrow 0 \]
\[ ps[3,i,t,2] \leftarrow 0 \]
\[ ps[3,i,t,3] \leftarrow 1 \]
\[ ps[3,i,t,4] \leftarrow 0 \]
\[ ps[4,i,t,1] \leftarrow 0 \]
\[ ps[4,i,t,2] \leftarrow 0 \]
\[ ps[4,i,t,3] \leftarrow 0 \]
\[ ps[4,i,t,4] \leftarrow 1 \]
}\ #t
}

for (t in first[i]:\text{last}[i]){
\# Define probabilities of Observed (t) given State (t). First index is state, last index is observed
\[ po[1,i,t,1] \leftarrow p[t] \quad \text{# State=alive, detected alive} \]
\[ po[1,i,t,2] \leftarrow 0 \quad \text{# State=alive, natural death} \]
\[ po[1,i,t,3] \leftarrow 0 \quad \text{# State=alive, emigrated} \]
\[ po[1,i,t,4] \leftarrow 1-p[t] \quad \text{# State=alive, not detected} \]
\[ po[2,i,t,1] \leftarrow 0 \quad \text{# State=natural mortality, detected alive} \]
\[ po[2,i,t,2] \leftarrow 1 \quad \text{# State=natural mortality, detected natural mortality} \]
\[ po[2,i,t,3] \leftarrow 0 \quad \text{# State=natural mortality, detected emigration} \]
\[ po[2,i,t,4] \leftarrow 0 \quad \text{# State=natural mortality, not detected} \]
\[ po[3,i,t,1] \leftarrow 0 \quad \text{# State=emigrated, detected alive} \]
\[ po[3,i,t,2] \leftarrow 0 \quad \text{# State=emigrated, detected natural mortality} \]
\[ po[3,i,t,3] \leftarrow 1 \quad \text{# State=emigrated, detected emigration} \]
\[ po[3,i,t,4] \leftarrow 0 \quad \text{# State=emigrated, not detected} \]
\[ po[4,i,t,1] \leftarrow 0 \quad \text{# State=harvested, detected alive} \]
\[ po[4,i,t,2] \leftarrow 0 \quad \text{# State=harvested, detected natural mortality} \]
\[ po[4,i,t,3] \leftarrow 0 \quad \text{# State=harvested, detected emigration} \]
\[ po[4,i,t,4] \leftarrow 1 \quad \text{# State=harvested, not detected} \]
}\ #t
}\ #i
# Likelihood
for (i in 1:nFish){
    for (t in 1:first[i]-1) {Alive[i,t]<-0}
    z[i,first[i]] <- 1  # Individuals have known status (alive) at first occasion in study
    Alive[i, first[i]] <- 1
    for (t in (first[i]+1):last[i]){
        z[i,t] ~ dcat(ps[z[i,t-1], i, t-1,])  # State process: draw State (t) given State (t-1)
        Alive[i,t] <- step(-z[i,t]+2)  # Should be 1 for z=1, 0 for z=2 or 3
    }
    for (t in last[i]+1:Periods){Alive[i,t]<- 0}
    for (t in first[i]:last[i]){
        y[i,t] ~ dcat(po[z[i,t], i, t,])  # Observation process: draw Observed (t) given State (t)
    }
    for (t in 1:Periods){FishAtRisk[t] <- sum(Alive[,t])}
}

Reference
**Supplement 2**

OpenBUGS code for the daily survival model that used logistic regression to predict the daily natural mortality rate of telemetered spotted seatrout as a function of mean daily water temperature; modified from McCarthy (2007). The known fates (alive, natural mortality, fishing mortality) were assumed to follow a multinomial distribution (see Friedl et al. 2013).

```r
model {

  # Parameters
  # TelM: Instantaneous daily natural mortality rate
  # TelF: Instantaneous daily fishing mortality rate
  # WTemp: Mean daily water temperature (degrees Celsius)
  # b[1]: intercept for logistic function
  # b[2]: slope for logistic function

  # Priors
  b[1] ~ dnorm(0, 1.0E-6)  # uninformative prior
  b[2] ~ dnorm(0, 1.0E-6)  # uninformative prior
  for (i in 1:493) {
    lnTelF[i] ~ dunif(-10,1)  # uninformative prior
    TelF[i] <- exp(lnTelF[i])
  }

  # Model Structure and Likelihood
  for (i in 1:493) {
    AtRisk[i] <- sum(X[i,1:3])  # total number of fish at risk
    TelM[i] <- 1 / (1 + exp(-(b[1]+b[2]*WTemp[i])))
    S[i] <- exp(-TelF[i]-TelM[i])  # daily survival
    p[i, 1] <- S[i]
    p[i, 2] <- TelM[i]*(1-S[i])/(TelF[i]+TelM[i])
    p[i, 3] <- 1-sum(p[i, 1:2])  # Probability of not being seen again (=harvested)
    X[i,1:3] ~ dmulti(p[i,1:3], AtRisk[i])  # X matrix known fates are 1 = alive, 2 = natural mortality, and 3 = fishing mortality
  }

  # Calculated values
  for (i in 2:28) {
    M_temp[i] <- 1 / (1 + exp(-(b[1]+b[2]*i)))  # predicted daily natural mortality
  }
}

References

```
**Figure S1.** Relocation histories for 37 telemetered spotted seatrout released in 2 adjacent tributaries of the Pungo River, North Carolina, USA, from December 2009 to March 2010. Each row characterizes the daily automated and manual detections and assumed fates for a tagged individual, including a 7-d censorship period following postsurgical release. Fates are coded as natural mortality determined from stationary transmitter (NM1), natural mortality determined from removal of transmitter during cold temperatures (NM2), unconfirmed fishing mortality (UF), immigration (I), and emigration (E).
Figure S2. Relocation histories for 10 telemetered spotted seatrout released in 2 adjacent tributaries of the Pungo River, North Carolina, USA, from November to December 2010. Each row characterizes the daily automated and manual detections and assumed fates for a tagged individual, including a 7-d censorship period following postsurgical release. Fates are coded as surgery-related mortality (SM), natural mortality determined from stationary transmitter (NM1), natural mortality determined from removal of transmitter during cold temperatures (NM2), immigration (I), and emigration (E).
Figure S3. Relocation histories for 26 telemetered spotted seatrout released in 2 adjacent tributaries of the Pungo River and for 45 telemetered spotted seatrout released in 2 adjacent tributaries of the Neuse River, North Carolina, USA, from November 2011 to May 2012. Each row characterizes the daily automated and manual detections and assumed fates for a tagged individual, including a 7-d censorship period following postsurgical release. Fates are coded as natural mortality due to possible predation event (NMP), unconfirmed fishing mortality (UF), confirmed fishing mortality (F), immigration (I), and emigration (E).
Figure S4. Estimated speeds of telemetered spotted seatrout emigrating from study sites in the Pungo River and Neuse River estuaries, North Carolina, USA, compared to estimates reported by Bacheler et al. (2009) from the Neuse River estuary for bottlenose dolphins.

Reference