Apple snail population model for use in Greater Everglades restoration project assessment

Stephanie Romañach[1], Phil Darby[2], Don DeAngelis[1], Joshua Bridevaux[3], and Kevin Suir[3]

[1]USGS Southeast Ecological Science Center, [2]University of West Florida, [3]USGS National Wetlands Research Center

Abstract

The multi-species goals for conservation in peninsular Florida wetlands subject to restoration (Everglades, Upper St. Johns Marsh) include a wide range of species sensitive to both local and entire watershed conditions. The endangered snail kite (*Rostrhamus sociabilis*) is one such species, and the well being of its population is determined by the abundance of its almost sole prey, the apple snail (*Pomacea paludosa*), in impounded wetland units of the Everglades and other breeding areas in central and southern Florida. Prey-predator dynamics that exist between apple snails and snail kites are emblematic of the spectrum of ecological scales in the ecosystem. The response of both species to habitat conditions and water management regimes are viewed as performance measures for wetlands restoration in Florida. Apple snail populations respond to changes in timing and quantity of hydrologic conditions. Here we present a size-structured population model to simulate the response of apple snails to a range of water conditions that include timing, frequency, duration, and other aspects of hydrologic regimes pertinent to wetlands restoration and management in peninsular Florida. The model uses the Everglades Depth Estimation Network (EDEN) as hydrologic input and air temperature data to simulate the apple snail population at 400 x 400 m spatial resolution. Model output yields the number of individuals and eggs produced over durations of several years on a daily time step. We present results from simulated hydrologic conditions to explore impacts on apple snail populations from extreme dry and extreme wet conditions. We developed simulations by extracting dry year data from EDEN and repeating those data for three simulated years in a row, and also simulated extreme wet conditions by repeating wet year data for three simulated years in a row. The results of our model can be used to meet Greater Everglades restoration project assessment needs. Future plans are to link this model with an existing snail kite population model to see how these endangered predator populations are affected by their apple snail prey.

Apple Snail Population Model*

This is a spatially explicit model with 10,000 spatial cells (400 x 400 m each).
An independent population is simulated on daily time steps within each cell.

The model is age- and size-structured with 600 age and size cohorts.

$\boldsymbol{N} = [N_1(t), N_2(t), \ldots, N_i(t), \ldots, N_{600}(t)]$
where t is time and i is age in days.

$$\begin{bmatrix} N_1(t+1) \\ N_2(t+1) \\ N_3(t+1) \\ . \\ N_{600}(t+1) \end{bmatrix} = \begin{bmatrix} 0 & a_{21}f_2 & a_{32}f_3 & . & . & a_{600,599}f_{600} \\ a_{21} & 0 & 0 & . & . & 0 \\ 0 & 0 & 0 & . & . & 0 \\ . & . & . & . & 0 & 0 \\ 0 & 0 & 0 & 0 & a_{600,599} & a_{600,600} \end{bmatrix} \begin{bmatrix} N_1(t) \\ N_2(t) \\ N_3(t) \\ . \\ N_{600}(t) \end{bmatrix}$$

Snail reproductive rate in a given cell, f_i, depends on several factors, which are multiplicative.

f_i = (*Female Fraction*) x (*Fraction Sexually Mature*) x (*Clutch Size*) x *f(time of year)* x *f(temperature)* x *f(water depth)* x *f(lag)*

The factors are described graphically below.

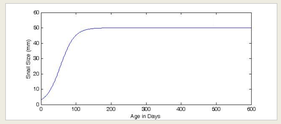


Figure 1. Snail size as a function of age.

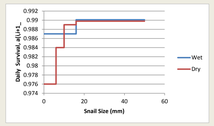


Figure 2. Snail daily survival as function of size under wet and dry conditions.

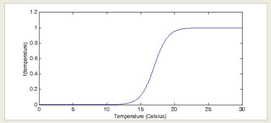


Figure 3. Temperature effect on reproduction.

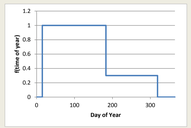


Figure 5. Effect of time of year on reproduction.

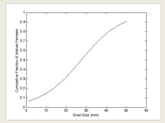


Figure 4. Cumulative fraction of mature females as a function of size.

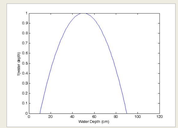


Figure 6. Effect of water depth on reproduction.

Also: *Female fraction* = 0.5; *Clutch size* = 30 eggs; *f(lag)* specifies that after a female has laid a clutch, it cannot lay eggs again for at least 7 days

Egg survival. The egg clusters are laid about 18 cm above the water level. Rule 1: If they are not submerged, they will hatch within 20 days, with the assumption that 5% of the original number of eggs laid hatch each day. Rule 2: If the eggs are submerged for longer than 14 days, they only 5% of the remaining unhatched eggs survive to hatching.

*Based on empirical data collected primarily by Turner et al. (F.I.T), Hanning (1979 MS Thesis, F.S.U), and Darby et al. (U.W.F.)

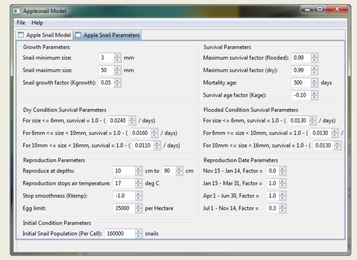
Model Details

Inputs

- Can accept water depths from:
  - Everglades Depth Estimation Network (EDEN), 1992-2011
  - South Florida Water Management Model (2x2 mile or downscaled to 500 x 500 m), 1965 - 2000
  - Regional Simulation Model (over 27,000 variable mesh cells), 1965 - 2000
- Air temperatures from DBHYDRO (SFWMD) interpolated across hydro input domain

Outputs

- Apple snail population numbers on a daily time step
- Snail egg numbers on a daily time step



Graphical User Interface for model

Model runs

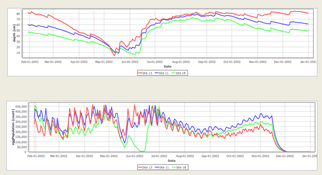
Adult-sized apple snail densities seen each spring reflect the hydrologic conditions associated with recruitment from the previous year (including egg cluster production, hatching, and growth of hatchlings to adult size). In our model simulation, the primary influences on recruitment are seasonal water depth and temperature, especially during peak apple snail egg laying season (April - June). Egg flooding (if water levels rise fast enough) may also influence egg survival. Below we show adult-snail densities on simulated year April 1, 1994 (right side map output), and also (a) egg cluster production (simulated model output); (b) water depth; and (c) temperatures for January-June 1993. The 2002 graphics represent three study sites for which empirical data are available for comparison. Red graph lines correspond to site 13 on the map, blue to site 11, and green to site 18.

Visualizations made using EverVIEW
Available free at jem.gov

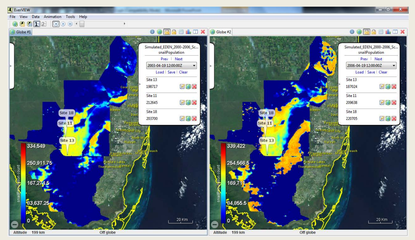
See poster #184

We simulated relatively wet conditions by repeating three EDEN wet years in a row to examine how snail populations following high water events compared to snail populations following generally lower depths (as represented by conditions in 2002) in the Everglades. Map output below (center) shows adult snail population size on April 19th 2003 (left map panel, c) following egg cluster production associated with hydrologic conditions prevailing in 2002. The map below (center, right panel d) shows adult snail population size after three consecutive years of relatively wet conditions, as simulated in the model. Lower egg cluster production in Site 13 in the relatively wet years (compared to site 18, with lower water depths) is consistent with empirical data indicating that relatively high water may suppress egg cluster production. Conversely, relatively wet years resulted in higher snail populations (panel d) in some wetland areas (e.g., 3B and portions of Everglades National Park) that were likely too dry to support robust egg cluster production as compared to 2002 (panel c).

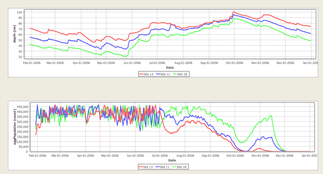
Water depth (a) and egg production (b), in 2002, one year preceding the 2003 adult snail population output (c).



c) d)



Adult snail population output (d), water depth (e) and egg production (f) in the third year of three consecutive relatively wet years.



Future

- Sensitivity analyses will be conducted to assess which parameters in the model appear to have the greatest influence on model outputs
- Model will be validated by comparing model output of snail count and egg cluster count to empirical data, most of which were collected in WCA3A from 2002-2007
- Model is being used as an Ecological Planning Tool as part of the Central Everglades Planning Process (CEPP)
- Linking apple snail model with demographic snail kite model