**Population Viability Analysis (PVA)** – to predict the probability of the population persisting into the future or the probability of falling below some threshold (quasi-extinction)

Many methods

- Highly complex - Model each life stage/age (e.g. Atlantic salmon; Legault 2005)

- Simple – extrapolate current trends (e.g. diffusion approximation; Dennis et al. 1991)

- …and everything in between

## Improved diffusion approximation methods

(Holmes 2001; Holmes 2004; Holmes and Fagan 2002; and McClure et al. 2003)

Running sum method – allows better estimates of the population growth rate (μ) by accounting for life history and year class effects

$$R_t = \sum_{j=1}^{\tau} S_{t+j-1}$$

$$\hat{\mu} = mean\ \ ln\ \ R_{t+1}/R_t$$

$$\sigma^2{}_{\hat{\mu}} = slope\ of\ var\ \ ln\ \ \frac{R_{t+\tau}}{R_t} \quad vs.\tau$$

$$\tau = 1, 2, 3, 4, 5, \ldots n$$

$R_t = running\ sum\ in\ year\ t$

$S_t = adult\ returns\ in\ year\ t$

$\hat{\mu} = mean\ growth\ rate$

$\sigma^2{}_{\hat{\mu}} = variance$

$\tau = time\ lag$

## Probability of extinction [P(E)]

$$P\ E = \pi\Phi\ \frac{-ln\ TS_0/TS_e\ +\ \hat{\mu}\ t_e}{\hat{\sigma}\ \overline{t_e}}$$

$$+exp\ \frac{2ln\ TS_0/TS_e\ \ \hat{\mu}}{\hat{\sigma}^2}$$

$$\times\ \Phi\ \frac{-ln\ TS_0/TS_e\ -\ \hat{\mu}\ t_e}{\hat{\sigma}\ \overline{t_e}}$$

$$\pi = \begin{cases} 1, & \hat{\mu} \leq 0 \\ exp\ -2\mu\ ln\ TS_0/TS_e\ /\hat{\sigma}^2\ , & \hat{\mu} > 0 \end{cases}$$

$TS_0 = initial\ number\ of\ returns$

$TS_e = extinction\ treshold$

$t_e = time\ to\ extinction$

$\Phi = standard\ normal\ cdf$

## Bootstrapped 90% CI on P(E)

Distribution used to calculate P(E): $\hat{\mu} + \sqrt{\hat{\sigma}^2 / \ n - 5} \times t_{df}$

$n = number\ of\ years\ used\ in\ the\ calulation\ of\ \hat{\mu}$

$t_{df} = t\ distributed\ random\ variable\ with\ df\ degrees\ of\ freedom$

$\hat{\sigma}^2 = chi\ square\ distributed\ with\ df\ degrees\ of\ freedom\ \times \hat{\sigma}^2/df$

$df \approx 0.33 + 0.212n - 0.387T$

## Probability of 90% decline

$$P\ \frac{TS_{t_e}}{TS_0} < \frac{10}{1}\ = 1 - \Phi\ \frac{ln\ 10/1\ + \hat{\mu} t_e}{\hat{\sigma}\ \ \overline{t_e}}$$

$TS_0 = initial\ number\ of\ returns$

$TS_e = extinction\ treshold$

$t_e = time\ to\ extinction$

$\Phi = standard\ normal\ cdf$

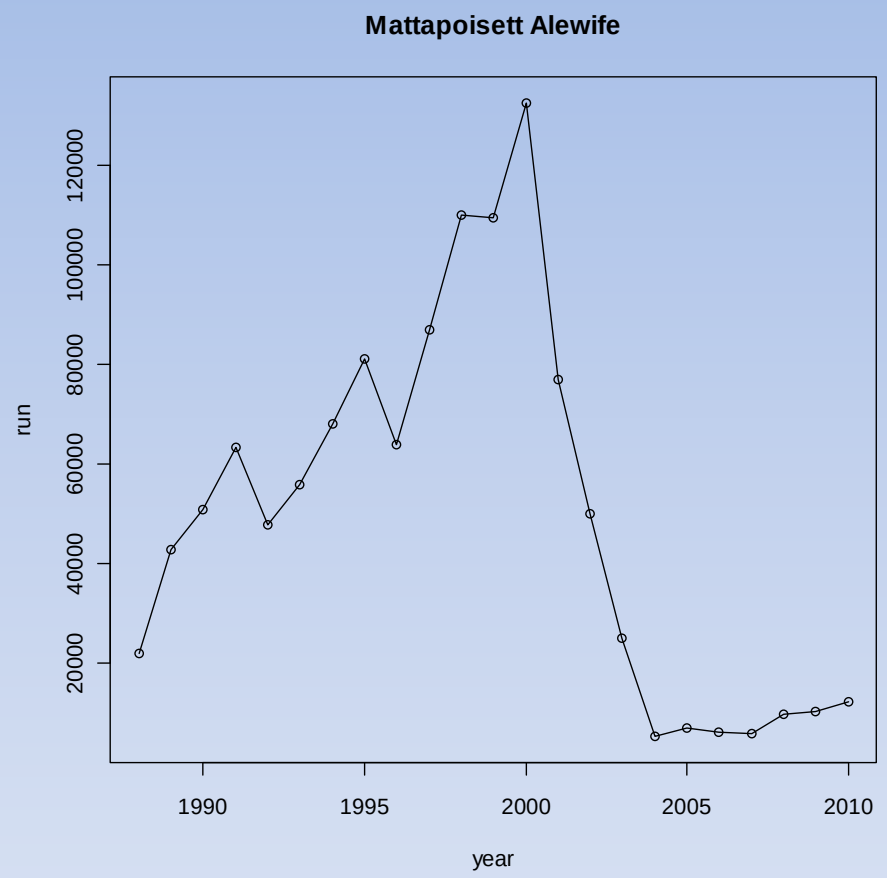
# Application to River Herring

Use time series of run counts where available

≈20 time series with ≥ 10 years of data

Most time series are in the New England area

# Issue: Which years to include?




$$\hat{\mu} = 0.032 \text{ including } 1988 - 2010$$

$$\hat{\mu} = -0.242 \text{ including } 2000 - 2010$$