Sex-age-length specific population assessment modeling of summer flounder (*Paralichthys dentatus*) in the Mid-Atlantic

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Need and Fishery Relevance

- A sex-age-length specific stock assessment model has been developed for summer flounder to account for sexual size dimorphism, whereby females grow faster, to larger sizes and to older ages than males making females more susceptible to fishing by gear type and under particular management regulations.
- Existing assessments methods use age rather than size selectivity and consequently can miss important aspects fisheries dynamics and responses to management.
- A sex-age-length based model will allow exploration of alternative management strategies (e.g. length based).

Project Goals and Objectives

- Develop 2-3 functional statistical population assessment models that use information from fishery-independent and fishery-dependent sources to estimate trends in summer flounder population dynamics using data (for example, survey CPUE, commercial and recreational landings) characterized variously by age, length and sex.

- Identify and evaluate sources of information useful to such assessments by age, length and sex for summer flounder and if such data are lacking outline a process for obtaining the needed information.

- Explore how sensitive the newly developed models are to different sources of information and assumptions needed for implementation.

- Identify and help implement a process for incorporating information from such assessments into the stock assessment review and management processes.

Age-Length-Sex Based Model

$$\mathbf{N}_{t+1} = \mathbf{P}_t \mathbf{S}_t \mathbf{N}_t + \mathbf{R}_t$$

$$
\begin{pmatrix} \begin{pmatrix} N_{1,t+1} \\ N_{2,t+1} \\ N_{3,t+1} \\ \vdots \\ N_{L,t+1} \end{pmatrix} \\ \begin{pmatrix} N_{1,t+1} \\ N_{2,t+1} \\ N_{3,t+1} \\ \vdots \\ N_{L,t+1} \end{pmatrix} \\ \begin{pmatrix} N_{1,t+1} \\ N_{2,t+1} \\ N_{3,t+1} \\ \vdots \\ N_{L,t+1} \end{pmatrix} \end{pmatrix}
=
\begin{bmatrix}
\begin{pmatrix} P_{11} & 0 & 0 & \cdots & 0 \\ P_{12} & P_{22} & 0 & \cdots & 0 \\ P_{13} & P_{23} & P_{33} & 0\cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ P_{1L} & P_{2L} & P_{3L} & \cdots & P_{LL} \end{pmatrix} & & \\
& \begin{pmatrix} P_{11} & 0 & 0 & \cdots & 0 \\ P_{12} & P_{22} & 0 & \cdots & 0 \\ P_{13} & P_{23} & P_{33} & 0\cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ P_{1L} & P_{2L} & P_{3L} & \cdots & P_{LL} \end{pmatrix} & \\
& & \begin{pmatrix} P_{11} & 0 & 0 & \cdots & 0 \\ P_{12} & P_{22} & 0 & \cdots & 0 \\ P_{13} & P_{23} & P_{33} & 0\cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ P_{1L} & P_{2L} & P_{3L} & \cdots & P_{LL} \end{pmatrix}
\end{bmatrix}
\begin{bmatrix}
\begin{pmatrix} S_1 & 0 & 0 & \cdots & 0 \\ 0 & S_2 & 0 & \cdots & 0 \\ 0 & 0 & S_3 & 0\cdots & 0 \\ \vdots & 0 & \ddots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & S_L \end{pmatrix} & & \\
& \begin{pmatrix} S_1 & 0 & 0 & \cdots & 0 \\ 0 & S_2 & 0 & \cdots & 0 \\ 0 & 0 & S_3 & 0\cdots & 0 \\ \vdots & 0 & \ddots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & S_L \end{pmatrix} & \\
& & \begin{pmatrix} S_1 & 0 & 0 & \cdots & 0 \\ 0 & S_2 & 0 & \cdots & 0 \\ 0 & 0 & S_3 & 0\cdots & 0 \\ \vdots & 0 & \ddots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & S_L \end{pmatrix}
\end{bmatrix}
\begin{pmatrix} \begin{pmatrix} N_{1,t} \\ N_{2,t} \\ N_{3,t} \\ \vdots \\ N_{L,t} \end{pmatrix} \\ \begin{pmatrix} N_{1,t} \\ N_{2,t} \\ N_{3,t} \\ \vdots \\ N_{L,t} \end{pmatrix} \\ \begin{pmatrix} N_{1,t} \\ N_{2,t} \\ N_{3,t} \\ \vdots \\ N_{L,t} \end{pmatrix} \end{pmatrix}
+
\begin{bmatrix} \begin{pmatrix} R_{1,t+1} \\ R_{2,t+1} \\ R_{3,t+1} \\ \vdots \\ R_{L,t+1} \end{pmatrix} \\ \\ \\ \end{bmatrix}
$$

- Constructed in Template Model Builder. (Next generation to ADMB.)

Model Development Approach

- Replicate ASAP type model and apply to sexes combined and separately
- Create a model with these characteristics :
  - Selectivity by length;
  - Individual growth by sex;
  - Fishing mortality by sex, age and length;
  - Survey indices by sex, age and length;
  - Landings data by sex*, age and length;
- Assemble data in proper format and build a bridging model that can suffice until complete data can be collected
- Fully document model and provide sensitivity runs for SAW/SARC review
- Recalculate Biological Reference Points

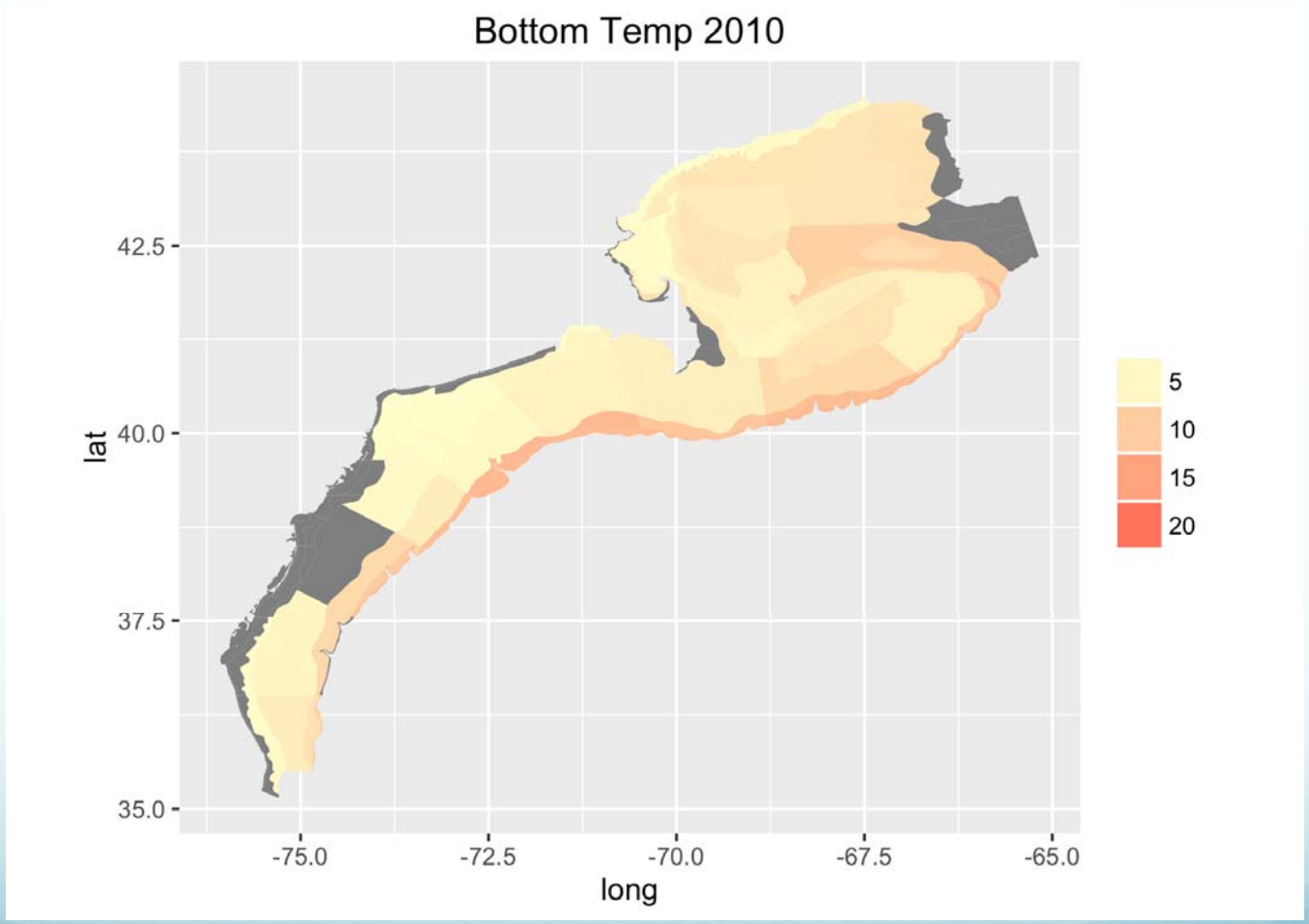
Impact

- Working with NMFS to update assessment methodology
- Motivation for collecting length-specific landings data to improve assessment and management
- Provide relevant input needed for existing Management Strategy Evaluation (MSE) procedure
- Provide the opportunity to explore alternative length-specific and therefore sex-specific management options
- Allow management to opt for greater direction of harvest to males thus increasing potential productivity of female component of the fishery

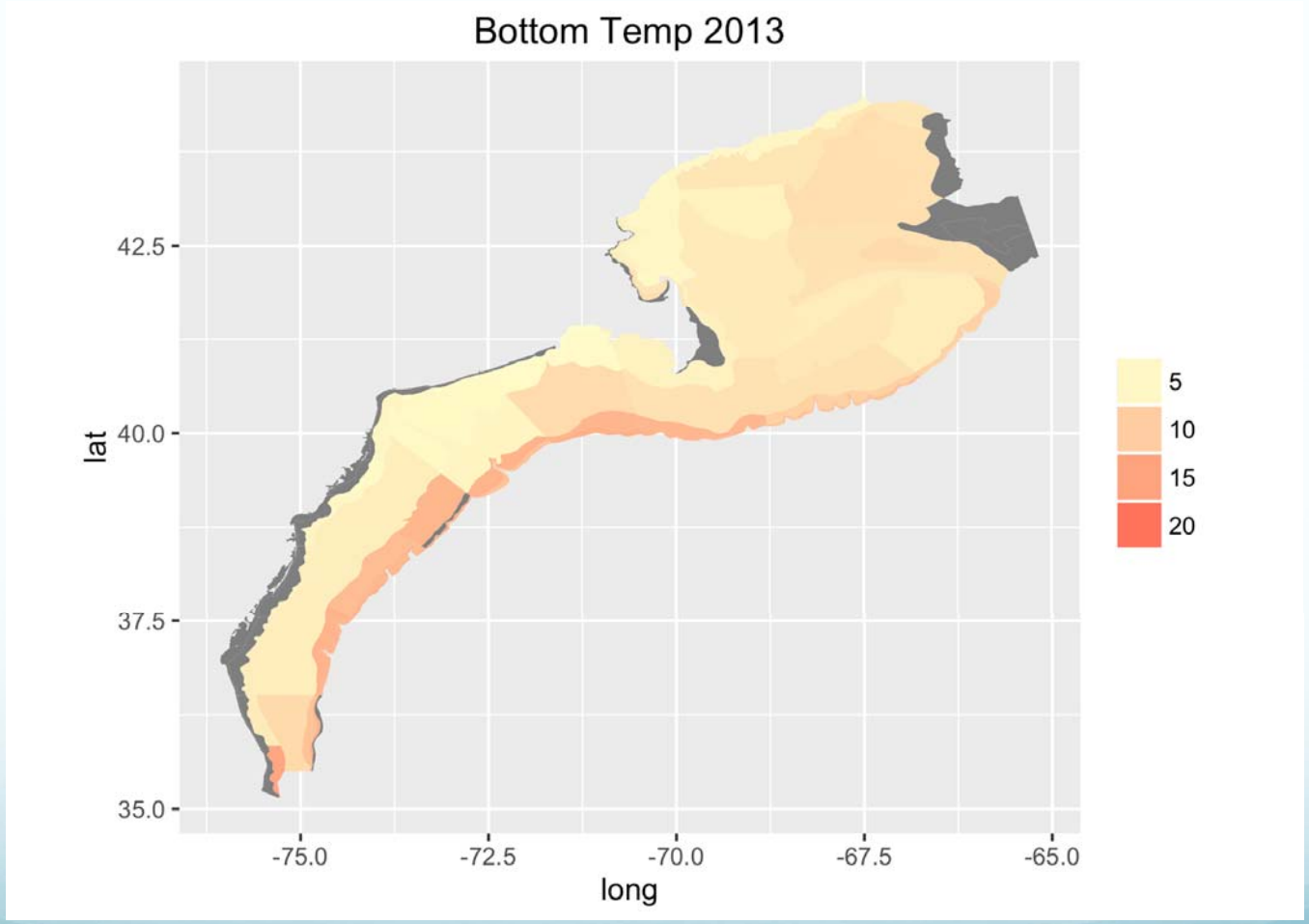
Project Duration – Budget

- Project is scheduled for completion December 2016
- Budget:
  - Matching SCeMFiS / IAB: $26,400
  - Matching SSFFF: $26,400
- Auxiliary Work
  - Conditional Autoregressive Model
    - Spatial Temporal Distribution of Summer Flounder
  - Machine Learning application to environmental drivers
  - Biological Reference Points from several models

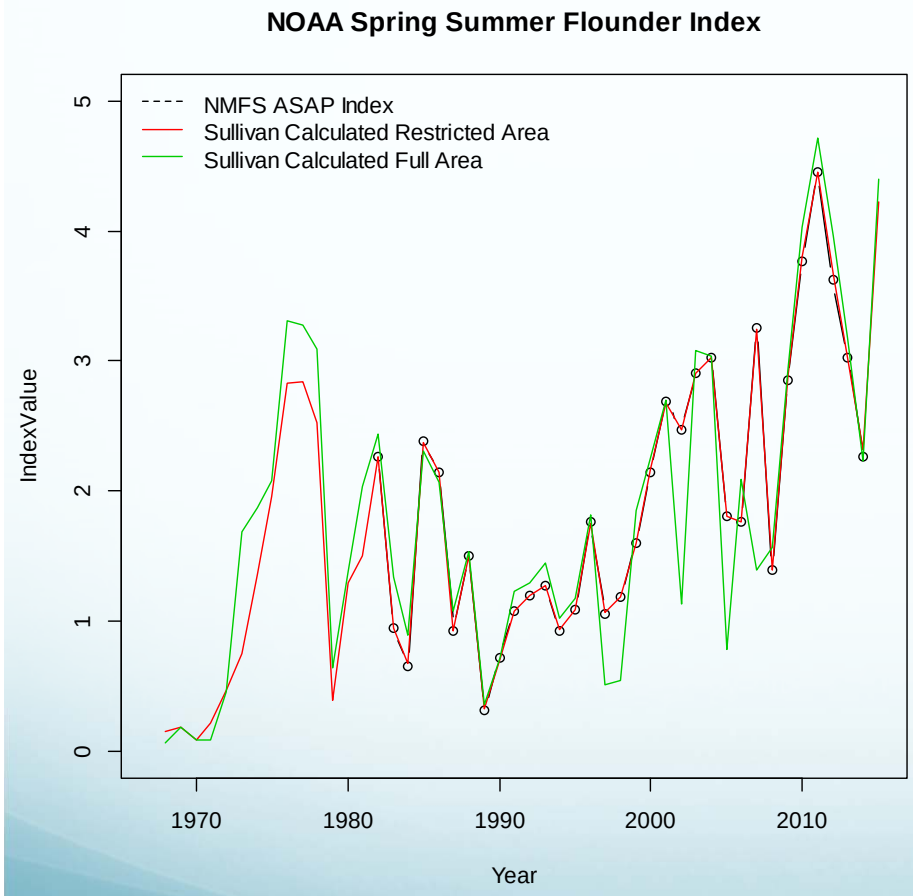
CAR Modeling / Temperature

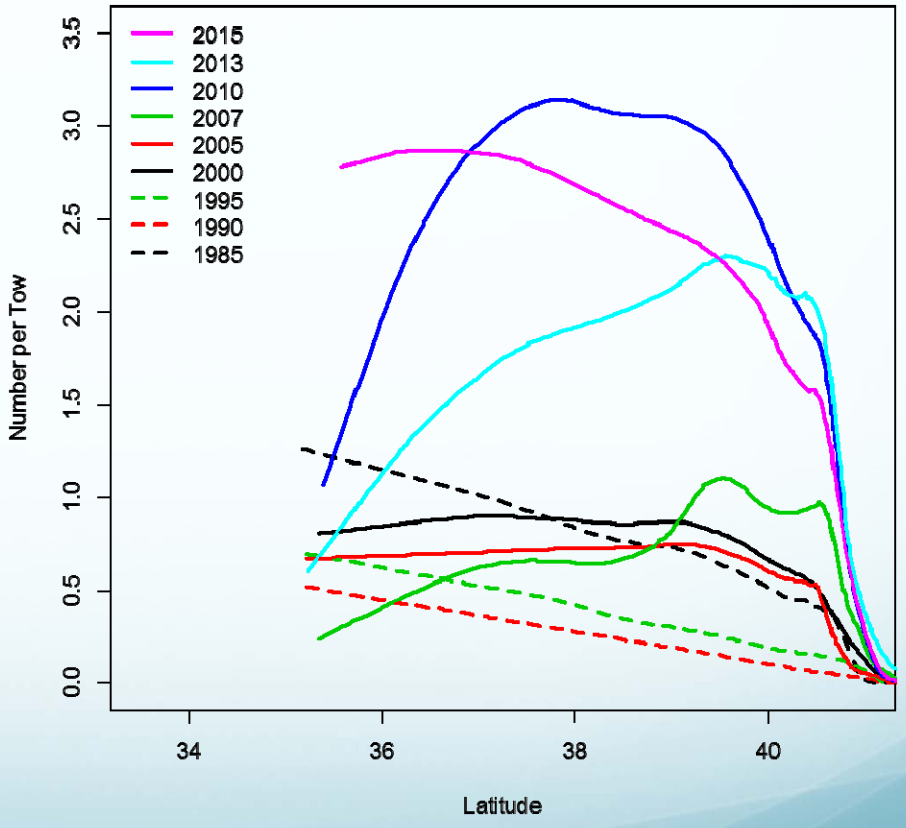


CAR Modeling / Temperature



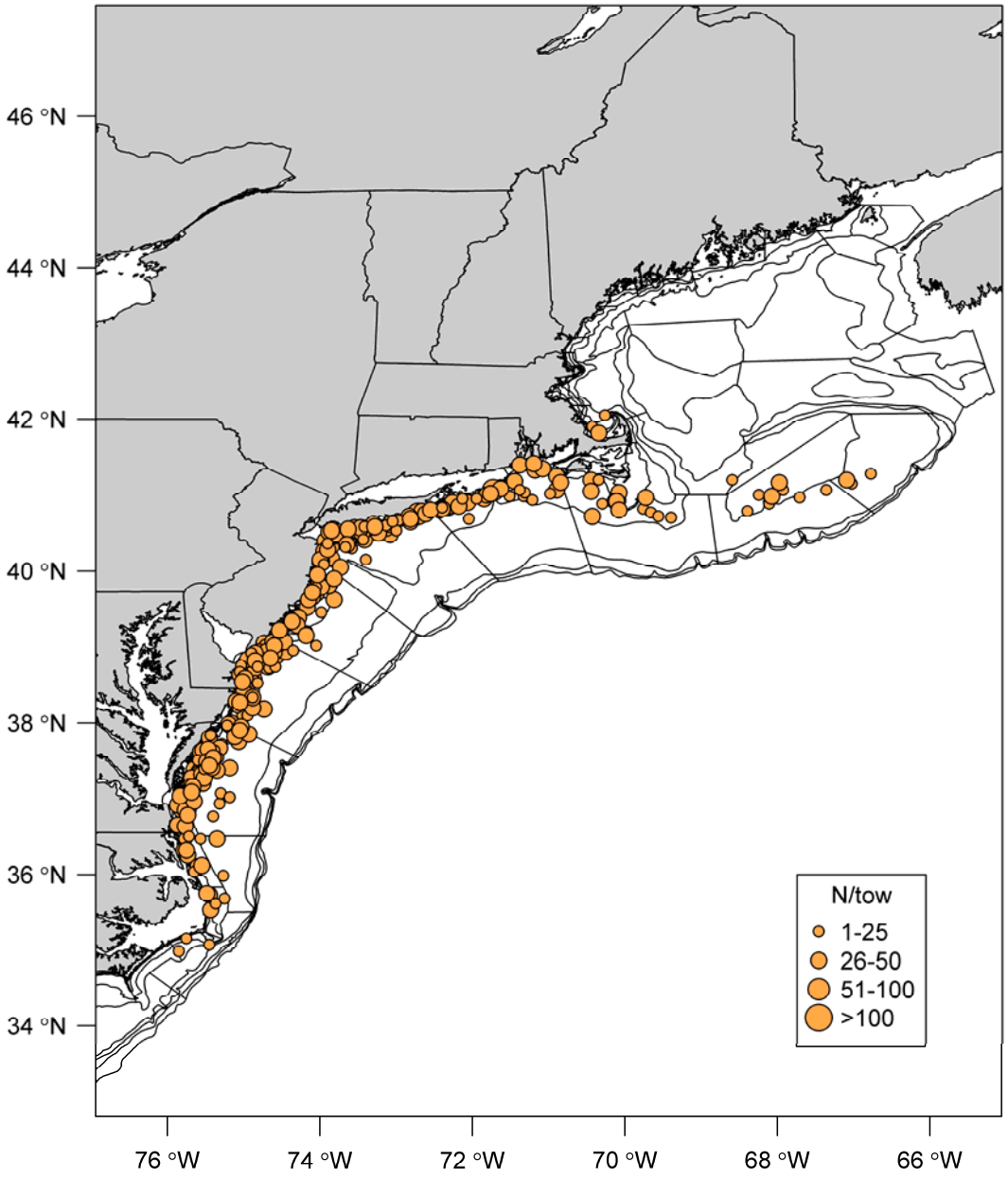
Edge Effects





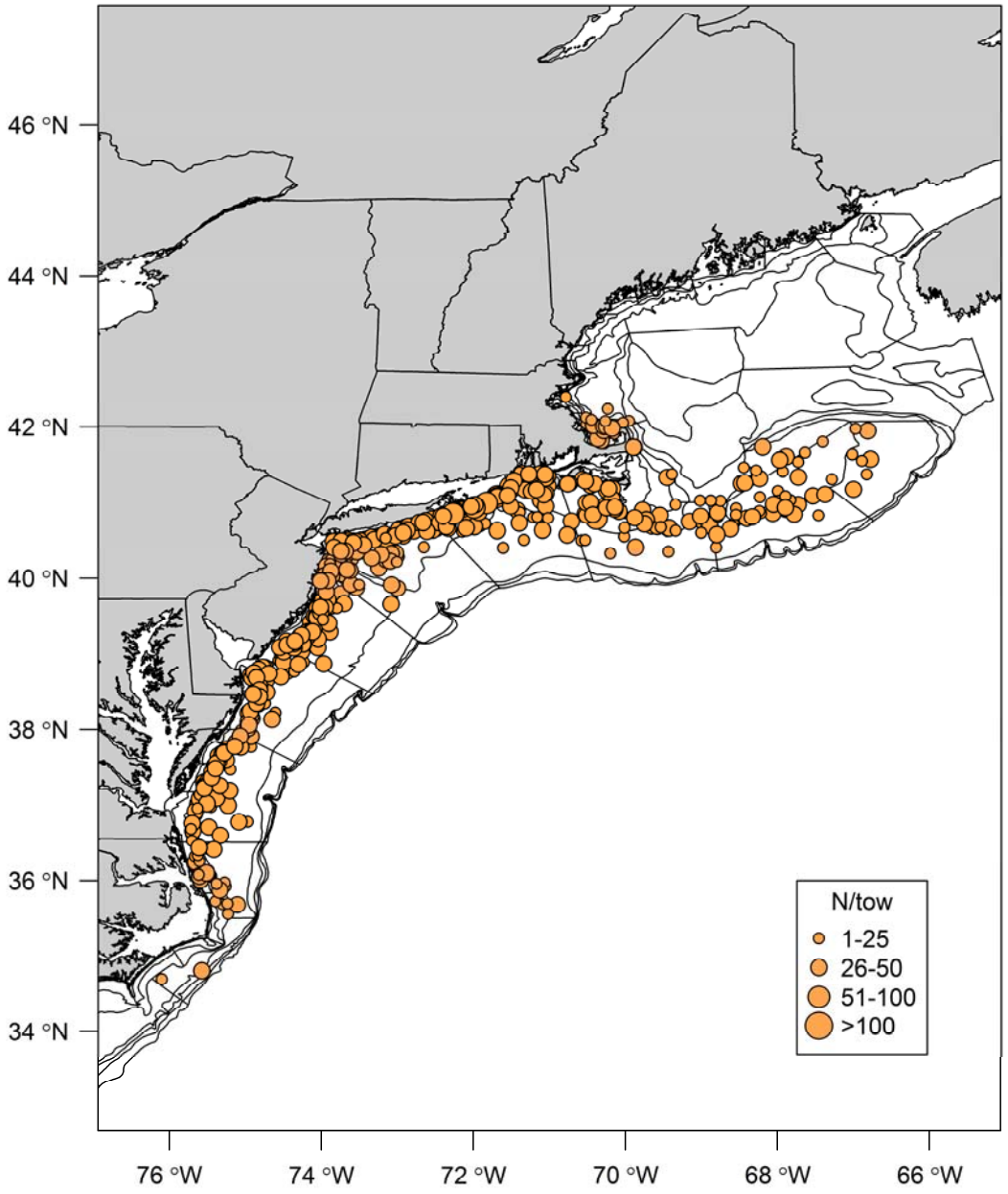
Summer Flounder NEFSC Fall Survey

1986-1990



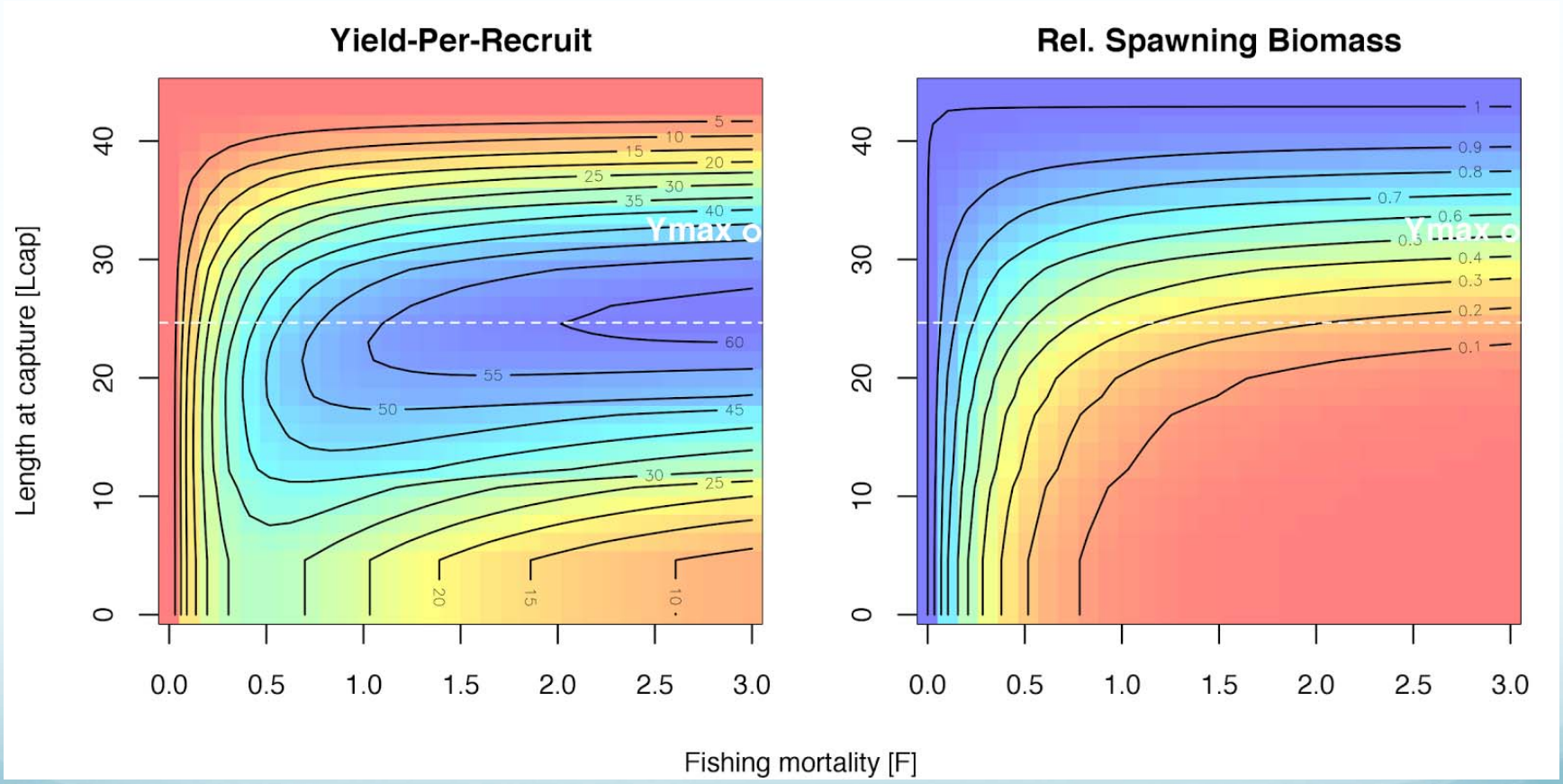
Summer Flounder NEFSC Fall Survey

2011-2015

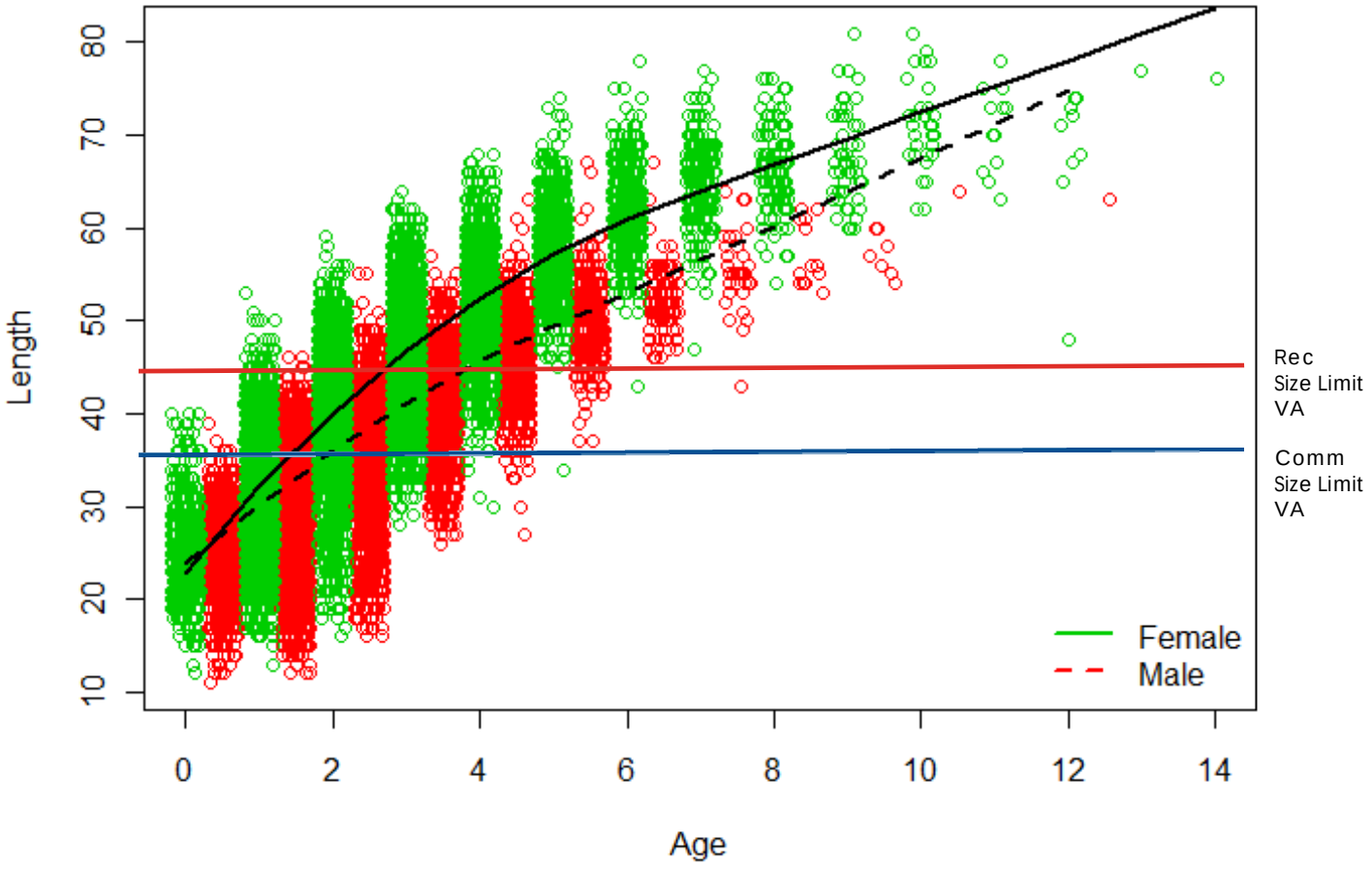


Optimal Yield and Reference Points

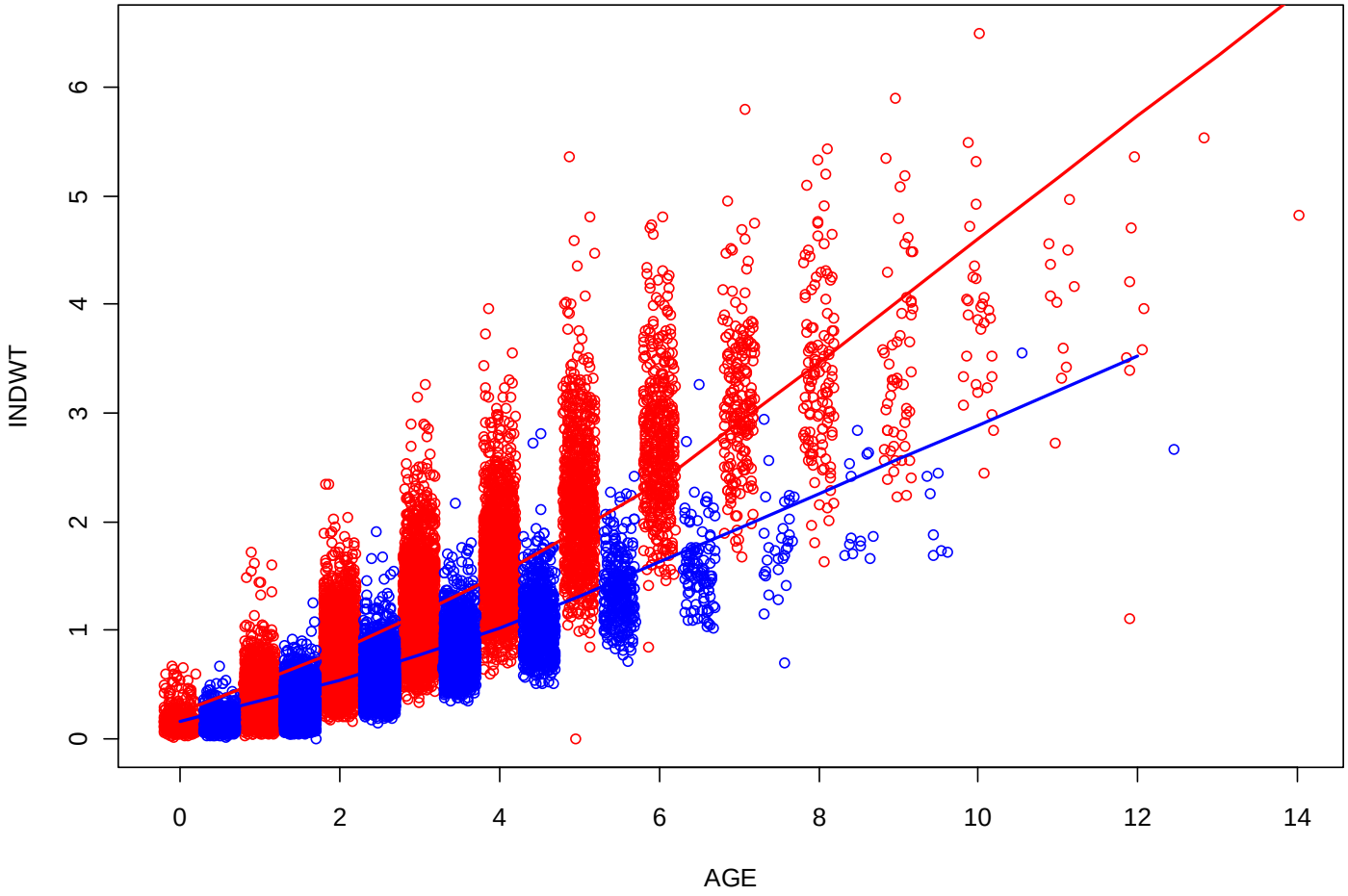
fishdynr – R-Bloggers

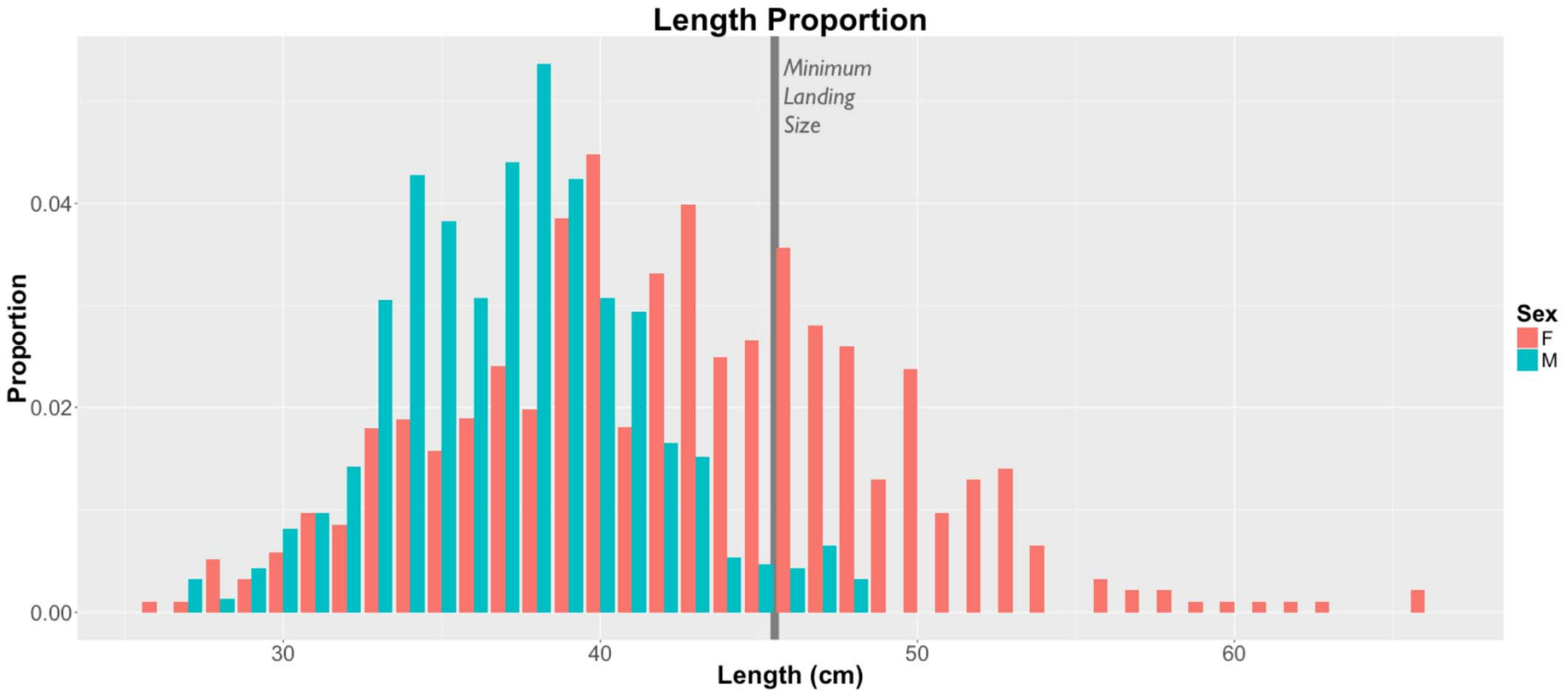


LENGTH AT AGE



WEIGHT RELATIVE TO AGE





Previous studies, led by Rutgers University's Haskin Shellfish Research Laboratory, demonstrated that summer flounder (*Paralichthys dentatus*) landings in the recreational fishery have been composed primarily of females (95%). Daphne Munroe and Jason Morson.