INVESTIGATING MENHADEN RECRUITMENT VARIABILITY

MODELING THE RELATIONSHIP BETWEEN STRIPED BASS RECOVERY AND MENHADEN RECRUITMENT

This newsletter summarizes ongoing development of a model that describes fluctuations in the number of young menhaden within Chesapeake Bay. Using both menhaden spawning stock and striped bass predation potential, the model successfully accounts for most (~70%) of the variability seen in Chesapeake Bay menhaden recruitment. With our ongoing work suggesting that weather patterns can improve the model, this approach appears to have the potential to support ecosystem based management for the Bay's menhaden and striped bass fisheries.

THE CHALLENGE

Atlantic menhaden (*Brevoortia tyrannus*, Figure 1a) are a unique and ecologically important filter feeding fish that provides a direct trophic (food) link between plankton and top predators, such as striped bass. Furthermore, menhaden is an important fishery in Chesapeake Bay. While the latest stock assessment has shown that the coastal population of menhaden (Figure 1b) is capable of supporting current harvest levels, the number of young of the year (less than one year old) in Chesapeake Bay since 1995 has been only 10% of 1975–1985 levels (Figure 1c). Due to menhaden being an important prey for many harvested fish species, this decline has prompted a call for the development of tools to help managers use an ecosystem based approach to the Bay's fisheries.

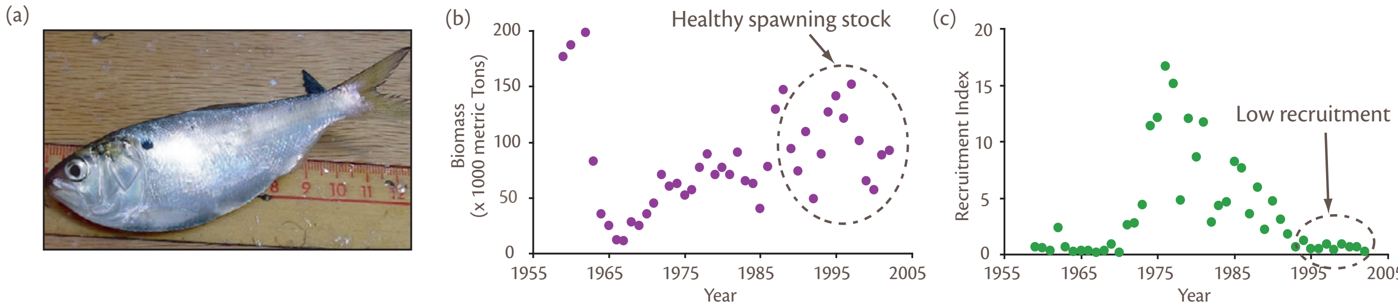


Figure 1: (a) Photo of Atlantic menhaden young of the year. (b) Menhaden spawning stock biomass along the Atlantic coast since the late 1950s. (c) Menhaden recruitment in the Maryland portion of Chesapeake Bay (MDDNR seine survey data).

ECOSYSTEM BASED FISHERIES MANAGEMENT NEEDED

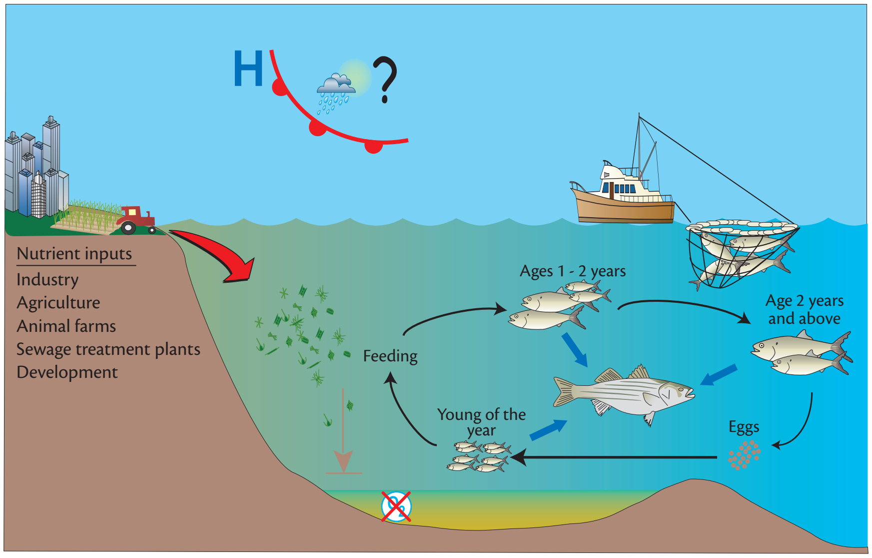


Figure 2: Conceptual diagram illustrating some of the key elements of menhaden ecosystem based fisheries management.

Ecosystem based fisheries management differs from single species management in that it acknowledges that to protect fish populations, we must account for the many interacting factors that affect a fishery. Ecosystem based fisheries management aims to consider interactions with other species, habitat and the effects of weather.

Some of the main ecological interactions affecting menhaden biomass and recruitment are availability of food (plankton), level of predation from fish such as striped bass, and habitat quality such as dissolved oxygen, nutrient inputs, and weather pattern variability (Figure 2). So far, our model addresses recruitment and striped bass predation.

ECOSYSTEM BASED MODELING APPROACH

Applying striped bass biomass to Ricker model

A Ricker model describes the theoretical relationship between resulting offspring (recruitment) and number of spawning females (spawning stock). This model is used by fisheries managers to understand how many new fish will enter the population each year and therefore, how many can safely be removed through fishing. The Ricker model has a poor relationship with actual menhaden recruitment and is of minimal use to management (Figure 3). Here we describe a model that examines the possibility that striped bass abundance (Atlantic coastwide) strongly influences Atlantic menhaden recruitment. The striped bass extended Ricker model demonstrates this possibility (Figure 3).

Despite the statistical association between striped bass biomass and menhaden recruitment, and the established predator-prey relationships, the significant association described may not be cause and effect.

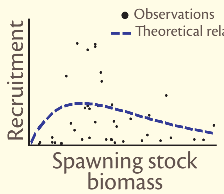
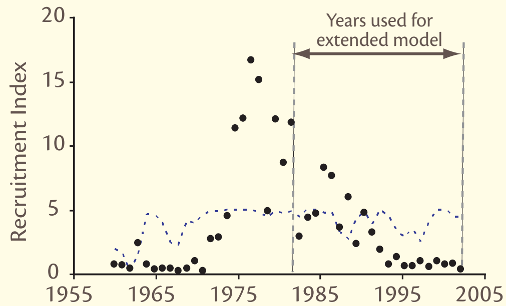
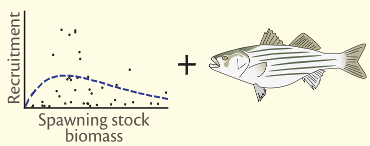
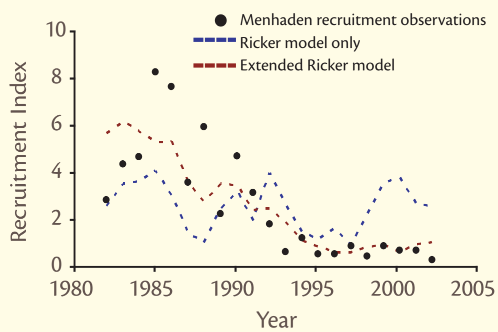
Description of the model	Model output	Interpretation of output
Ricker model only 		• Very poor at predicting menhaden recruitment • Accounts for only 18% of menhaden recruitment variation
Extended Ricker model (Ricker model + striped bass biomass) 		• Good at predicting low to medium recruitment events • Accounts for 64% of menhaden recruitment variation

Figure 3: Outputs based on the standard and the extended Ricker models.

Checking model performance by hindcasting

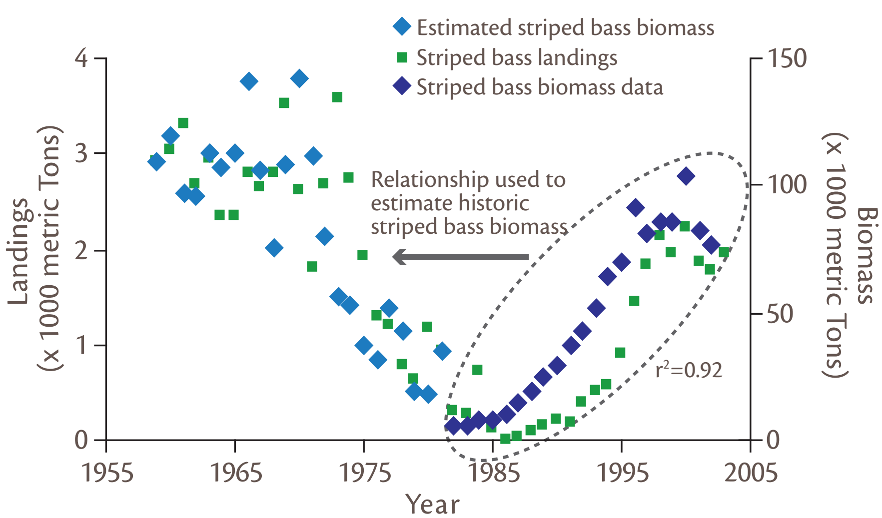


Figure 4: Estimate of striped bass biomass from 1958 to 1981. Estimate based on a significant relationship (r^2=0.92) between striped bass biomass and landings during the 1982 to 2002 period.

To test the accuracy of the striped bass extended Ricker model, a hindcasting technique was applied. Hindcasting uses historical data, that is not included in the model, to assess how well it tracks with the model output. The extended Ricker model (above) was constructed using data after 1982. Hindcasting measured how well the model simulates recruitment from 1958–1981.

Hindcasting required an estimation of historic striped bass biomass (Figure 4). This is because all available biomass data (1982–2002) was used in developing the model. Estimation of striped bass biomass, for the purpose of hindcasting only, was based on: (a) a strong (r^2=0.92) empirical relationship between coastwide age-2+ striped bass biomass and Chesapeake Bay striped bass commercial landings for the 1982–2002 period, with a 3-year delay of commercial landing applied; and (b) historic Chesapeake Bay striped bass landing data (1958–1981).

Model most reliable during low recruitment

The accuracy of the Ricker and striped bass extended Ricker models was assessed using the hindcasting technique. The extended Ricker model had good hindcast accuracy when compared to the historic menhaden recruitment data. Accuracy of the extended Ricker model hindcast was optimum in low recruitment years (1960s) and poor in high recruitment years (1970s), with the overall accuracy considered moderate (r^2 = 0.69, Figure 5).

Poor model accuracy during high recruitment events highlights that further refinement is required before it can be used for management. Ongoing research will include assessing potential non-linearity of the recruitment index and inclusion of additional data such as climate patterns (see back page).

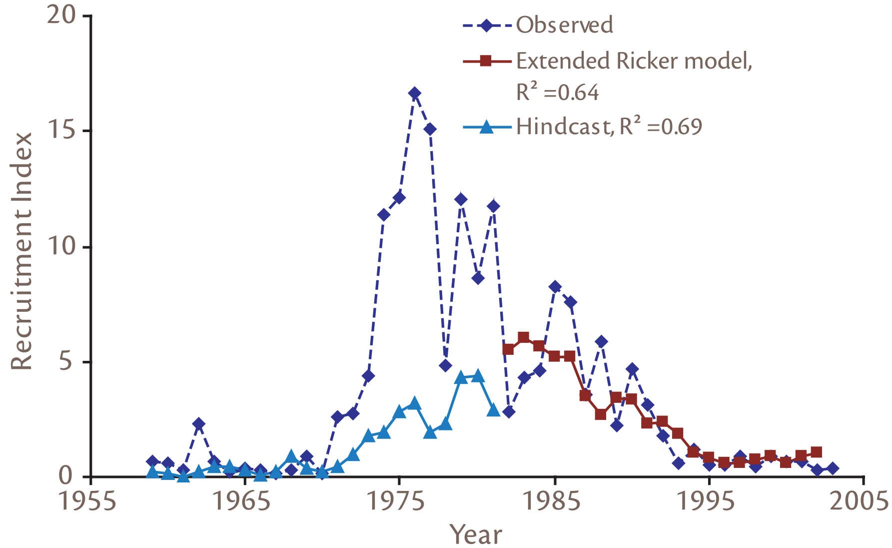


Figure 5: Hindcast of menhaden recruitment in Chesapeake Bay based on the striped bass biomass model compared to the observed data.

APPLICATION TO MENHADEN MANAGEMENT

The extended Ricker model, by accounting for the relationship between the numbers of spawners and the potential effects of striped bass predation sets the foundation for a more comprehensive tool to aid management of menhaden in Chesapeake Bay. For example the model could inform managers when menhaden stock deviates from expected patterns and how the deviations relate to important forcing factors. In addition, this modeling strategy can be adapted for other fish species. Therefore, results from this research could greatly assist in the development of an ecosystem based fisheries management plan in Chesapeake Bay (Figure 6).

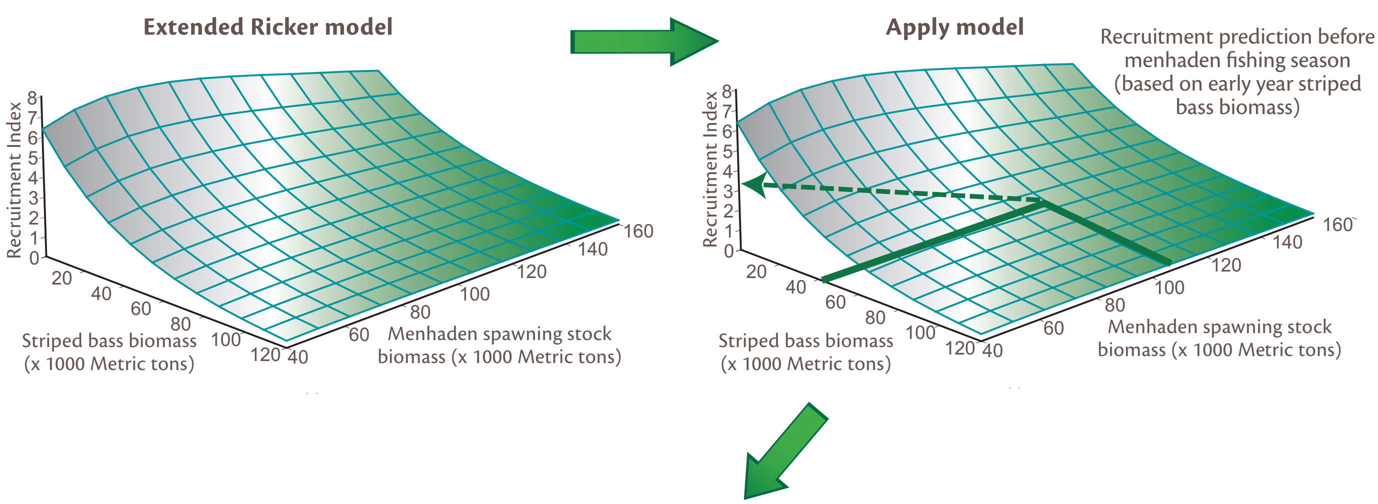
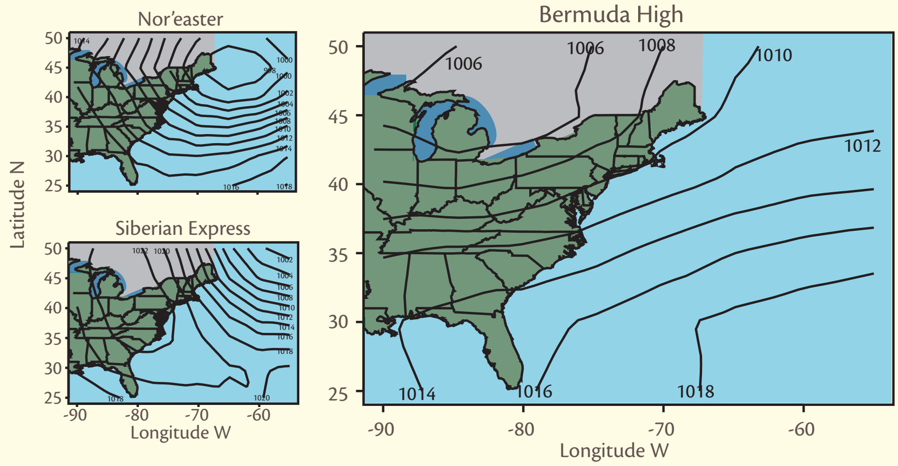


Figure 6: Incorporation of model into menhaden fisheries management.

ONGOING RESEARCH TO REFINE MODEL

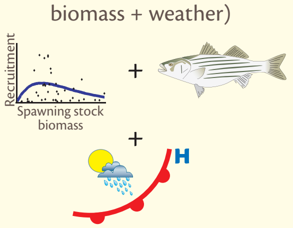
Menhaden are vulnerable to climate variability due to their complicated life cycle (Figure 2, page 1). However, the relative influences of climate variability and striped bass predation have not been quantified. Several weather patterns were investigated for correlation with menhaden recruitment (Figure 7, step 1). The Bermuda High weather pattern had the highest correlation with recruitment and was incorporated into the model. A Ricker model that incorporates both striped bass biomass and the Bermuda High weather pattern was found to have a strong relationship at all recruitment levels (Figure 7, step 2). However, accuracy of model fit and associated hindcast was inconsistent when the weather pattern was included in the model, either alone or when combined with striped bass biomass (data not shown). Due to this inconsistency, and because previous studies have shown a strong relationship between weather patterns and menhaden recruitment in the Bay, it is the aim of this project to investigate the discrepancies when weather patterns are included.

Step 1: Test several weather patterns for correlation with menhaden recruitment.



Step 2: Incorporate Bermuda High weather pattern into extended Ricker model to produce an ecosystem based model.

Ecosystem based model (Ricker model + striped bass biomass + weather)



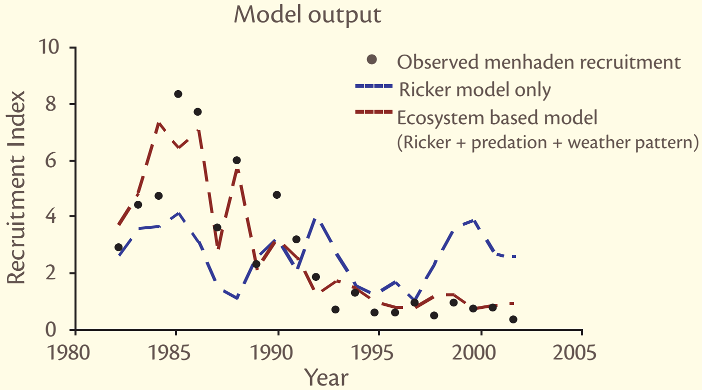


Figure 7: Examples of weather patterns investigated for correlations with menhaden recruitment and how the model responded when the Bermuda High weather pattern was included.

Model development: *Xinsheng Zhang and Bob Wood*

Newsletter production: *Caroline Wicks, Ben Longstaff, Xinsheng Zhang and Bob Wood*

Further information: *www.eco-check.org*

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