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Atlantic Herring Population Trends Linked to Egg Predation by Haddock

New Population Model Explains Historic Trends, Shows Importance of Ecological Interactions

NOAA scientists have developed a population model for Atlantic herring that links herring population trends to the size of the haddock population. The model also provides evidence that egg predation by haddock can cause alternate stable population levels in Georges Bank herring. These results have significant ecological as well as management implications.

In a study to be published online August 8, 2011 in the *Proceedings of the National Academy of Sciences* (PNAS), researchers from NOAA's Northeast Fisheries Science Center (NEFSC) looked at the role of egg predation by haddock (*Melanogrammus aeglefinus*) in the decline of the Atlantic herring (*Clupea harengus*) population off the northeast United States.

Atlantic herring spawn eggs that settle and attach to the seafloor. After two to three weeks these eggs hatch and the larvae enter the water column. Haddock feed on a variety of benthic organisms, including sand dollars, brittle stars, and polychaetes or marine worms, but also prey on herring eggs during the herring spawning season.

NEFSC researchers have been monitoring the abundance of larval herring annually since 1971. Historically, changes in larval herring abundance were thought to track changes in adult herring abundance. This study suggests that the mortality rate of herring eggs can vary substantially year to year, with most of that variability driven by haddock preying on herring eggs.

"The premise of our study is that the success of the herring spawning strategy is dependent on overwhelming egg predators, and in particular haddock," said David Richardson, a fishery biologist at the NEFSC's Narragansett, Rhode Island, Laboratory and lead author of the study. "When adult herring are abundant and haddock are at low population levels, a majority of herring eggs hatch, and enough larvae are produced to sustain the herring population at high levels. However, when the herring population is low or the haddock population reaches very high levels, a majority of the herring eggs are consumed before they can hatch into larvae."

The population model they developed, incorporating egg predation by haddock and fishing effort on herring, explains the major population trends of Georges Bank herring over the past four decades. The model predicts that when the haddock population is high, seemingly conservative levels of fishing can still trigger a severe decline in the herring population because of predation on herring eggs by haddock.

"There is a threshold herring population size that is dependent on the population size of haddock. When the herring population is pushed below this threshold population size by fishing, it will experience negative population growth until it reaches low levels and at which point it stabilizes. When this happens, reducing fishing on herring may not be sufficient to allow for a recovery of the herring population," said Richardson. Long established in theoretical studies, there has previously been limited evidence that predation-driven alternate stable population levels exist in exploited marine fish populations.

Traditional single-species fishery models assume there is only one equilibrium population size, and that this equilibrium population size is dependent on the level of fishing mortality on that population. Predictions from this type of model don't agree with the observed trends in Atlantic herring. Richardson and NEFSC co-authors Jon Hare, Michael Fogarty and Jason Link developed a new population model. They compared the predictions of this model to a compilation of 17 different fisheries-independent time-series for Atlantic herring in the region, including standard bottom trawl and acoustic survey data and food web studies that detail the percentage of herring in the diets of predator fish. This composite time-series declined from 2005 to 2008, matching the predictions of the population model.

"Our model explains how a population can experience decade-scale periods of low productivity and then rapidly switch to a period of high productivity," Richardson said. "This study also illustrates how efforts to rebuild fisheries can be undermined by not incorporating ecological interactions into fisheries models and management plans."

"The upcoming stock assessment for herring in 2012 will provide a more rigorous and integrated evaluation of the predictions from our model, particularly with respect to the recent trends in Atlantic herring population levels. On the flip-side, our model suggests some future directions for the herring assessment, including the potential for incorporating predation into the assessment model," Richardson said.

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Background:

In North Atlantic ecosystems, Atlantic herring (*Clupea harengus*) is a dominant small pelagic species, and currently supports the fourth largest fishery, by weight, in the world. During the 1960s and 1970s, many herring populations on both sides of the Atlantic were severely depleted, some by more than 98%. Overfishing was a primary force behind the collapse of these populations. However, the magnitude of the population declines, and in some instances the long delay in recovery, suggested that another mechanism was involved.

Herring have a complex life cycle, and getting to the cause of the problem was difficult since herring are planktonic as larvae, migrate as juveniles and adults, and spawn large benthic masses of eggs that are not guarded or buried. Many egg predators have been identified, but haddock (*Melanogrammus aeglefinus*) is the dominant predator.

During the 1970s herring spawning stock biomass off the northeast U.S. declined severely and remained low for a decade before recovering in the late 1980s and 1990s. While the time-series of larval herring abundance approximately follows the pattern of the spawning stock biomass, there were two notable drops in the larval abundance that did not coincide with comparable declines in the spawning stock biomass. Those declines coincided with large increases in haddock predation, which resulted from the 1975 and 2003 haddock year classes, the two largest since 1971. Larval herring abundance experienced a year-to-year decline of more than 90 percent following both of these record haddock year classes; since 2004 larval herring abundance has remained at low levels.

Other studies have discussed the importance of adult predation and climate variability on populations of herring. These elements also need to be added to the models for Georges Bank herring to develop a more complete picture of herring dynamics.

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