A Question of Scale: Evaluating the impact of marine protected areas off of New England on groundfish productivity

Lisa A. Kerr(1), Jake Kritzer(2), Steven X. Cadrin(3)

*(1)*Gulf of Maine Research Institute, Portland, Maine, USA; *(2)* Environmental Defense Fund, Boston, Massachusetts, USA; (3) University of Massachusetts Dartmouth, School for Marine Science & Technology, Fairhaven, Massachusetts, USA. Presenter contact details: lkerr@gmri.org, phone +1 207 228 1639

Summary

In this study, we examined the effect of MPAs in New England waters on Atlantic cod, yellowtail flounder, and haddock using before-after-control-impact (BACI) analysis of bottom trawl survey data from the Northeast Fisheries Science Center. We critically evaluated the spatial scale for assessing impacts (as individual MPAs or networks of MPAs) and how we define control areas for comparison with MPAs (habitat within the same survey strata or within a certain distance from a MPAs boundary). We identified positive effects of certain MPAs on abundance and biomass indices of specific groundfish. In some cases, the significance of the response depended on the spatial and temporal scale of the analysis. Comprehensive evaluation of the appropriate spatial and temporal scales for assessing MPA impacts is needed for robust evaluation the effectiveness of MPAs in achieving management goals.

Introduction

Marine protected areas (MPAs) have a long history of use for both conservation and fishery management purposes. A network of year-round areas closed to the harvest of groundfish in the northwest Atlantic Ocean was establishing during a period when several key groundfish species were considered collapsed and in need of rebuilding (NEFSC 1994). The closed areas include two large areas on Georges Bank (Closed Area I and II), the Nantucket Lightship (off southern New England), Western Gulf of Maine and Cashes Ledge closed areas. The original intent of individual closed areas varied, with specific closures designed to reduce fishing mortality and enhance spawning potential of haddock, yellowtail, and Atlantic cod. Currently, the management authority in the New England region is considering redesign/removal of closed areas off New England. However, there has been limited evaluation of the impact of MPAs in U.S. waters on the productivity of the groundfish stocks that they were designed to help rebuild. Additionally, there is a broad need to critically evaluate the appropriate spatial and temporal scale for characterizing MPA impacts.

Materials and Methods

A BACI (before-after-control-impact) approach was used to analyze the impact of closed areas off New England on select groundfish species (yellowtail, cod haddock). This analysis was conducted using catch (number and kg) per tow (non-zero data) from the NOAA stratified-random bottom trawl survey. Main effects included location (inside MPA, control area) and time (time periods of equal length before and after MPA implementation). Control areas where constrained to the same habitat represented within MPAs and data where drawn a certain distance (4-20 km and 20-40 km) from the MPA boundary. The interaction term was used to test significant MPA impacts. The impact of MPAs where tested individually and as a network. Due to zero-inflation and high degree of positive skewness in the positive (non-zero) catch data, general additive models for location, scale, and shape (GAMLSS) were used to fit the data. GAMLSS explicitly model the mean (location), variance (scale), and skewness parameters (shape) of the distribution. Models were fit using the R statistical programming environment (R Development Core Team 2010) and used the GAMLSSS package (Rigby and Stasinopoulos 2005).

Results

No significant responses of Atlantic cod to New England closed areas were identified when compared to control areas in close vicinity of MPA boundaries (4-20 km). However, when we compared closed areas to control areas at the broader spatial scale (20-40 km) there was a significant positive impact of Closed Area I on the probability of cod occurrence and of Closed Area II on abundance of cod per tow. A significant positive impact of the Nantucket Lightship closure on the probability of occurrence and biomass per tow of haddock was detected when compared to a control area a close distance from the MPA boundary (4-20 km). A significant positive impact of Closed Area I was detected for abundance of yellowtail per tow when compared to control areas at the 20-40 km scale. The probability of occurrence of yellowtail was also higher inside and after the closure of Closed Area II (compared to control at 20-40 km) and the Nantucket Lightship (compared to control at 4-20 km). No significant positive impacts of Closed Area I and II were identified on biomass of yellowtail per tow at the individual closure scale, however, analyzing the MPAs together as a network revealed a significant positive impact (Figure 1).

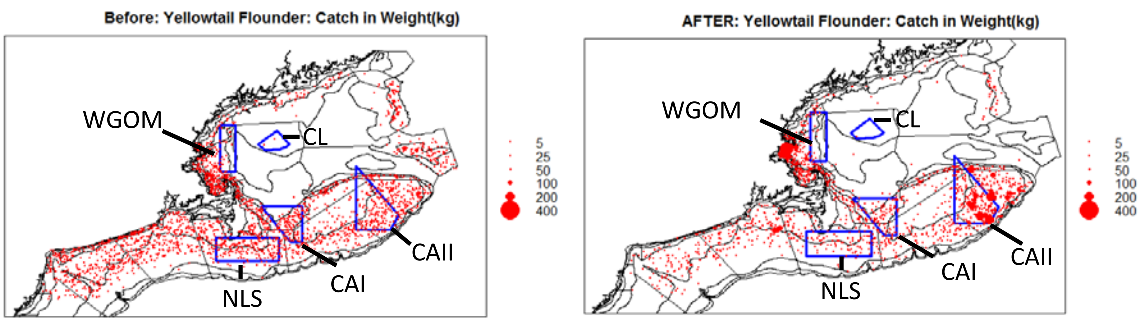

Figure 1 Map depicting the location of closed areas off of New England and the biomass (kg) of yellowtail flounder caught per tow in the trawl survey before and after the implementation of closed areas.

Discussion

Overall this analysis detected some clear positive changes in groundfish indices of abundance and biomass, reflecting the production and rebuilding of groundfish stocks associated with the implementation of closed areas. The analysis revealed that the Nantucket Lightship closure and Closed Area I and II were effective in increasing productivity of haddock, Atlantic cod and yellowtail. In some cases, the impacts were detected at the individual closure scale and depended on the definition of control areas and in other cases impacts were detected at the network scale. Additional positive indicators of increasing biomass after the implementation of closures may have some association with closed areas (i.e. positive main effects of time in the model); however, it is difficult to rule out other factors (e.g. changes in environmental conditions over time). We found that the perception of MPA effectiveness depended on the spatial and temporal scales of investigation.

References

New England Fishery Management Council (NEFMC). 1994. Amendment 5 to the Fishery Management Plan for Northeast Multispecies.

R Development Core Team. 2010. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0.

Rigby, R. A. and Stasinopoulos, D. M. 2005. Generalized additive models for location, scale, and shape (with discussion). Applied Statistics, 54: 507-554.