Trends in Northwest Atlantic Habitat Occupation: Joint Effects of Climate Variation and Harvest Removals

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Summary
The impacts of climate variability on coastal ecosystems are dependent on several factors, including assemblage structure and geographic locality. Moreover, in areas of intense harvest, removals often contribute to instability of populations and may increase the ability of climate to cause community-level reorganization. We used trawl survey data from the U.S. National Marine Fisheries Service to assess the impact of these factors on the spatial structure of four contiguous Northwest Atlantic communities. We used ordinary least squares regression (OLS) to evaluate the interspecific abundance-occupancy (A-O) relationship for each community. Yearly A-O slopes and coefficients of determination served as indices of organismal density and spatial heterogeneity, respectively. The indices were regressed on time series of average surface temperature, Gulf Stream location and regional landings data. We found the strength of trends to increase with latitude, coinciding with regional shifts in assemblage structure. There was also regionally variable evidence for the effect of each external factor on community spatial utilization. Our results highlight the complexity and variety of biological responses to disturbance, even for adjacent communities. Lastly, our research will be important for future evaluations focused on ecological impacts of extrinsic factors on communities, beyond simple depletion or translocation of populations.

Introduction
Northwest Atlantic demersal communities have traditionally supported some of the most productive fisheries in the world. Intensive harvests in these waters, especially from foreign fleets in the 1960's and 1970's, drastically reduced population sizes of several commercially valuable species (Bourne 1987). Given the importance of once-dominant species like Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and Atlantic herring (*Clupea harengus*) to overall community dynamics, this intense disturbance is believed to have fundamentally altered the composition, structure and competitive environment in Northwest Atlantic regions (Fogarty and Murawski 1998). Simultaneous with the effects of harvest, marine communities have been subjected to environmental change, namely increasing water temperatures (Nye *et al.* 2009). We used a community-level approach to identify overriding trends and drivers of spatial organization. Specifically, we evaluated interspecific A-O relationships among four Northwest Atlantic communities and assessed their relationship with harvest and climate-related variability.

Materials and Methods
We used fishery-independent trawl survey data from NOAA's Northeast Fisheries Science Center (NEFSC) to compare community trends in the Gulf of Maine (GOM), Georges Bank (GB), Southern New England (SNE) and the Mid-Atlantic Bight (MAB). Yearly abundance (A) was calculated as the number of individuals caught divided by the number of sites sampled, while occupancy (O) was the percentage of all sites sampled with at least one individual of the target species present. The arcsine transformation was

used to normalize occupancy values and abundance was transformed by its natural logarithm. Ordinary least-squares regression was used to evaluate annual A-O relationships, where yearly slopes and coefficients of determination (r^2) represented temporal indices of organismal density (OD) and spatial heterogeneity (SH), respectively. We used the Mann-Kendall trend test to determine correlations between community indices and time. Additionally, we used linear regression (supplemented by a bootstrap routine) to examine the effects of commercial landings, temperature and Gulf Stream location on community trends.

Results and Discussion

The A-O slope decreased significantly over time in the GOM (Mann-Kendall τ=-0.39, $p<0.01$) and GB (τ=-0.53, $p<0.0001$), indicating an increase in OD. However, slope trends were not significant for SNE (τ=0.15, $p=0.16$) or the MAB (τ=-0.01, $p=0.93$). The A-O r^2 displayed a decreasing trend in the GOM (τ=-0.44, $p<0.0001$) and GB (τ=-0.30, $p<0.01$), meaning that SH increased in these regions. In contrast, r^2 increased in SNE (τ=0.23, $p<0.05$), but remained unchanged in the MAB (τ=-0.19, $p=0.09$).

The A-O slope was positively associated with landings in the GOM (slope= 0.0075, $p<0.05$) and GB (slope= 0.0035, $p<0.05$), but negatively in SNE (slope= -0.00066, $p<0.05$) and not at all in the MAB. This reveals a latitudinal variation in the response of OD to commercial landings. In contrast to landings, surface temperature had a negative effect on the A-O slope in the GOM (slope= -0.0052, $p<0.01$) and GB (slope= -0.0054, $p<0.0001$), meaning that as temperature increased so did the OD of these communities. Interestingly, the position of the Gulf Stream only had a significant effect on A-O slopes in GB (slope= -0.0096, $p<0.0001$).

Landings were related to a decline in r^2 in the GOM (slope= 0.046, $p<0.05$), but were not associated with significant changes in other regions. Surface temperature, once again, appeared to mirror the effects of landings, where the relationship went from negative in the GOM (slope=-0034, $p<0.001$) to positive in SNE (slope=0.017, $p<0.05$). Therefore, with the increase of temperature, SH increased in the GOM and GB, but decreased in SNE. Lastly, the Gulf Stream location was related to deceasing r^2 in GOM (slope= -0.039, $p<0.01$) but to an increase in SNE (slope= 0.041, $p<0.01$).

Observed spatial trends and patterns of sensitivity to external factors highlight community vulnerability to drivers at multiple scales and provide evidence for the implications of environmental variation and human activity beyond simple depletion and relocation of populations. Temporal trends were associated primarily with community-specific reactions to landings and rising sea surface temperature, however it remains difficult to determine the proportion of total community change that may be attributed to one factor or the other. Whether Northwest Atlantic communities have undergone permanent transformations remains to be seen, but continued research on this system will be critical for future management and conservation efforts.

References

Bourne D.W. 1987. The fisheries. *In* Georges Bank. pp. 409-424. Ed. By R. Backus. MIT Press, Cambridge, MA.

Fogarty M.J., Murawski S.A. 1998. Large-scale disturbance and the structure of marine systems: fishery impacts of Georges Bank. Ecological Applications, 8: S6-S22.

Nye J.A., Link J.S., Hare J.A., Overholtz W.J. 2009. Changing spatial distribution of fish stocks in relation to climate and population size in the Northeast United States continental shelf. Marine Ecology Progress Series, 393: 111-129.