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# Use and advice on incorporating ecosystem indicators in the stock assessment of north Atlantic swordfish

*Michael J. Schirripa*
*NOAA Fisheries*
*Southeast Fisheries Science Center, Miami, FL, USA.* Presenter contact details:
Michael.Schirripa@noaa.gov, Phone +1 305 361 4568.

## Summary

Observations of opposing trends in abundance for northern Swordfish suggested the possibility of a shift in abundance from warm, southern latitudes to cooler, more northern latitudes. Several of the observed indices of abundance changed sharply in direction in from negative to positive, while others showed an opposite change. The observed changes in the direction of the abundance indices correspond with changes in trends in the size of the Atlantic Warm Pool (AWP), the change in sign of the Atlantic Multidecadal Oscillation (AMO), and the North Atlantic Oscillation (NAO). To quantify a possible relation between the changes in abundance and the various candidate environmental indices, we fit the assessment model by allowing area specific catchabilities ($q$) to be modulated by the AMO and estimated an associated slope parameter that described the relationship between the AMO and residuals of the fit to the CPUE times series. The many of the CPUE slope parameters were significantly different from zero, and the pattern of the slope patterns suggested an east-west difference that was very similar to that of the NAO and other correlated oceanographic environmental indicators.

## Introduction

Directional differences in north Atlantic swordfish CPUE (catch-per-unit-effort) were observed from fisheries operating mostly in the northern latitudes of the northern hemisphere to those fishing more southern latitudes of the northern hemisphere. Abrupt and opposite in direction changes in the northern CPUE of Canada and Japan in 1995 were coincident in time with a drop in the southern most US CPUE. As these sets of indices are presumably indexing the abundance of a single stock, these observations suggest the possibility of a redistribution of the swordfish stock.

Poleward shifts in species distribution along the eastern seaboard of the United Sates have been documented for several other species. Swordfish are a highly mobile and migratory species and their biology and life history characteristics suggest that changes in their distribution are quite conceivable. A poleward shift suggests an imbalance in the suitability of the conditions between the area the fish are migrating from (the southern latitudes of the northern hemisphere in this case) and those in the area the fish are migrating to (the northern latitudes of the northern hemisphere). This imbalance could be the result of many things. In the case of Swordfish, movement from the south ("push") may be due unfavorable environmental conditions in the south, such as undesirable temperature, decreased oxygen, changes in salinity, or lack of prey (perhaps for similar reasons). Perhaps from another perspective, movement to the north ("pull') may be more favorable conditions in terms of temperatures, increased oxygen, and/or salinity or a poleward shift in a preferred prey item. Another possibility is that the environmental cues some portion of the Swordfish population use to start an apparent summer seasonal migration northward (assuming any exist) may have also started trending coincident with the observed CPUE patterns.

Several oceanographic indicators changed direction coincident with the change in direction of the CPUE indices of abundance. These include the Atlantic Multidecadal Oscillation (AMO), the size of the Atlantic Warm Pool (AWP) (also referred to as the Western Hemisphere Warm Pool), and the North Atlantic Oscillation (NAO). These are generally temperature based indices and as such were found to be highly correlated. While temperature is one of the most common explanatory variables used to account for changes in the distributions in fish, the true underlying driver is more likely a combination of factors, some of which could likely be correlated with temperature.

## Materials and Methods

The hypothesis that the decadal signal of the AMO could explain the residuals in the fit the CPUE indices was tested using the northern Swordfish Stock Synthesis (SS) assessment model. Rather than the usual method of aggregating and calculating CPUE by country flag, this work aggregated the CPUE data into geographic areas with flag as a covariate in the general linear model. The resulted in 14 separate, area specific, CPUE time series. For each times series a catachability coefficient (q) was estimated along with an associated environmental coefficient that allowed for annual variations in q based on changes in the AMO. This estimated parameter, along with it's standard deviation, described the slope of the regression (either positive of negative) between annual residuals and AMO. Significance of the parameter was determined by whether or not zero fell within two standard deviations of the estimated parameter value.

## Results and Discussion

Including the AMO was able to account for a large portion of the variation in the area specific CPUE residuals. Of the ten CPUE time examined within the model, seven had environmental coefficients that were significantly different than zero. Examination of the coefficients over space resulted in a pattern that looked remarkably similar to the known patterns of the AMO. When the AMO is in a positive phase (currently) the CPUE in the eastern Atlantic had mostly negative residuals. Conversely, the western Atlantic had mostly positive residuals. The addition of the AMO and the environmental covariate improved the fit the CPUE time series which should help in model convergence and increased certainty in parameter and derived quantity estimates.

There seems to be sufficient evidence to conclude the distribution of northern Swordfish has changed from what is was prior to 1996. Furthermore, this is likely due to a change in one or more environmental factors, be they related to favorable conditions, prey distribution, or both. Another plausible hypothesis is differential recruitment is responsible for the observed differences in the CPUE. Tagging data suggests very little movement of fish from one side of the Atlantic to the other. However, none of this data spans the change in the AMO in 1995. If the recruitment hypothesis is the most supported one then the assessment of north swordfish should perhaps be conducted separately for the eastern and western Atlantic. Attempting to account for this redistribution within the stock assessment model is the correct approach. It can help account for conflicting indices and provide a more precise fit the observational data. It is difficult to know if this shift is unidirectional. However, if it is in fact a function of the AMO, then we may see the trend shift again as these indices change direction. There is no way of knowing exactly what these indices will do in the future. Given To better account for environmental factors in the stock assessment of Atlantic tuna and tuna-like species, the International Commission for the Conservation of Atlantic Tuna (ICCAT) should request that CPUE data be reported with more specific areas so that CPUE time series can be estimated by geographic area rather than solely by the flag of the vessel. This would offer improvement of the assessment of the species no matter which of alternative hypotheses is the most supported.