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The Use of Generalized Additive Models to Examine Relationships between Environmental Variables and Commercial Catch Rates

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Generalized Additive Models (GAMs) have become an accepted method for assessing non-linear effects of factors on catch rates of commercial species. Catch data reported by the University of Massachusetts School for Marine Science and Technology study fleet from 2006 to 2009 were standardized to catch per unit effort (CPUE) for Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and windowpane flounder (*Scophthalmus aquosus*). The study fleet is a fishermen self-sampling project that reports catch by disposition along with environmental variables at the haul level. GAMs were applied to determine how fluctuations in CPUE were influenced by environmental conditions. The response variable was CPUE (kg/hr) by disposition (i.e. kept or discarded) for Atlantic cod and haddock and total CPUE for windowpane flounder. Explanatory variables included year, season, time of day, latitude, longitude, depth, and bottom temperature. Models were built with stepwise forward selection based on the Akaike information criterion value (AIC), deviance explained, and generalized cross-validation (GCV). Successive models were tested for significant differences with a *Chi*-square test. Results indicated that spatial variables described the majority of the explained deviance. Other variables were significant, but the contribution to the explained deviance was small. A disadvantage of having a large number of explanatory variables is that an optimal model may have many variables with significant effects. A possible artifact of including many explanatory variables is that they may be correlated, effecting model fit. While GAMs can characterize spatial and temporal patterns in catch rates, selection of explanatory variables has implications for the results. If identifying trends in catch rates or shifts in species abundance are an intended outcome, then certain variables like depth and water temperature may need to be included. Despite these technical challenges, GAMs appear to be a robust method for identifying factors associated with catch rates.

Generalized full model

Log (CPUE + 1) = s(latitude) + s(longitude) + s(mean temperature (C))+ s(mean depth (m)) + s(time-of-day) + year + season

- Latitude and Longitude smoothing parameters were automatically selected by R
- Mean temperature, mean depth and time-of-day had soothing parameters set with a cubic regression spline and 3 degrees of freedom
- Year and season were categorical variables
- The package mgcv in R was used for the analysis

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Windowpane Flounder Total CPUE			
Model	Variables	Deviance Explained	Δ GCV
1	Mean Depth & Longitude	24	0
2	+ Latitude	27	0.06
3	+ Season	31	0.09
4	+ Year	32	0.02
5	+ Mean Temperature	33	0.03

- The only explanatory variable that was not significant in individual models was time-of-day.
- Latitude and longitude were in the top four variables for all models and usually the first two.
- There were only small changes in the GCV score as more variables were added.

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Atlantic Cod Kept CPUE			
Model	Variables	Deviance Explained	Δ GCV
1	Latitude & Longitude	30	0
2	+ Mean Depth	43	0.32
3	+ Season	44	0.02
4	+ Mean Temperature	45	0.02
5	+ Year	46	0.01

Atlantic Cod Discarded CPUE			
Model	Variables	Deviance Explained	Δ GCV
1	Latitude & Longitude	19	0
2	+ Mean Temperature	22	0.05
3	+ Year	23	0.01
4	+ Season	23	0.01
5	+ Mean Depth	23	0.01

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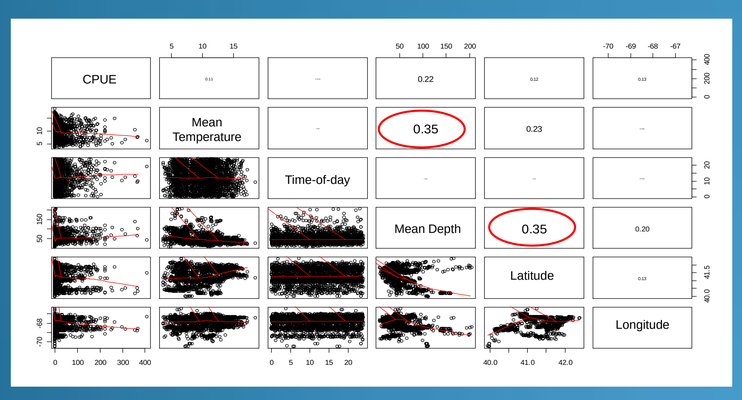
Haddock Kept CPUE			
Model	Variables	Deviance Explained	Δ GCV
1	Mean Depth & Mean Temperature	16	0
2	+ Longitude	27	0.25
3	+ Latitude	35	0.19
4	+ Season	40	0.11
5	+ Year	40	0

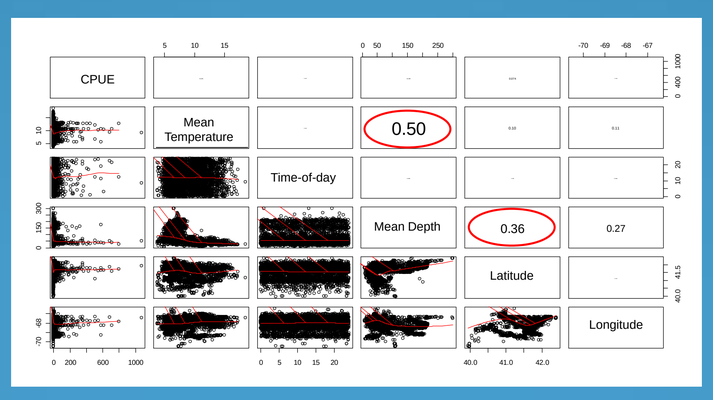
Haddock Discarded CPUE			
Model	Variables	Deviance Explained	Δ GCV
1	Latitude & Longitude	18	0
2	+ Year	26	0.15
3	+ Mean Temperature	29	0.06
4	+ Mean Depth	33	0.07
5	+ Season	33	0
6	+ Time	34	0.03

Pair plots of the response variable and all explanatory variables, including a lowess smooth on the data on the bottom and Spearman correlation coefficient on the top, show that certain explanatory variables are correlated for all response variables.

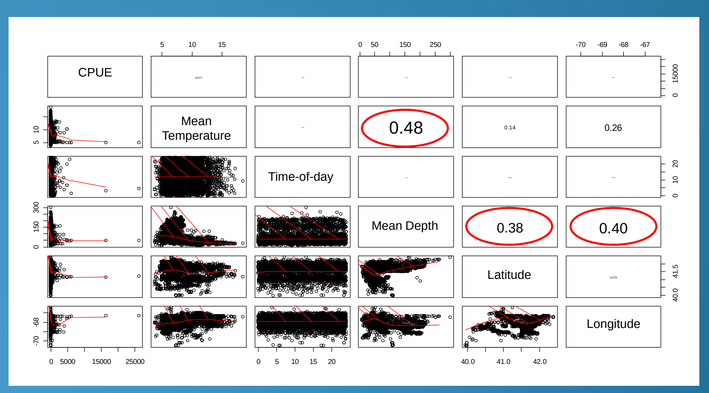
- Mean temperature and mean depth
- Mean depth and latitude
- Mean depth and longitude – to a lesser extent



Windowpane Flounder Total CPUE



Atlantic Cod Discarded CPUE



Haddock Kept CPUE

Should latitude and longitude be removed as explanatory variables?

- The study area where the study fleet collects data is relatively small.
- What is the best way to approach to exploring the effects of correlated explanatory variables (e.g., mean temperature and mean depth)?
- The effects of other explanatory variables may be more pronounced.