Using Optimization Models to Evaluate Fishery Management Plans

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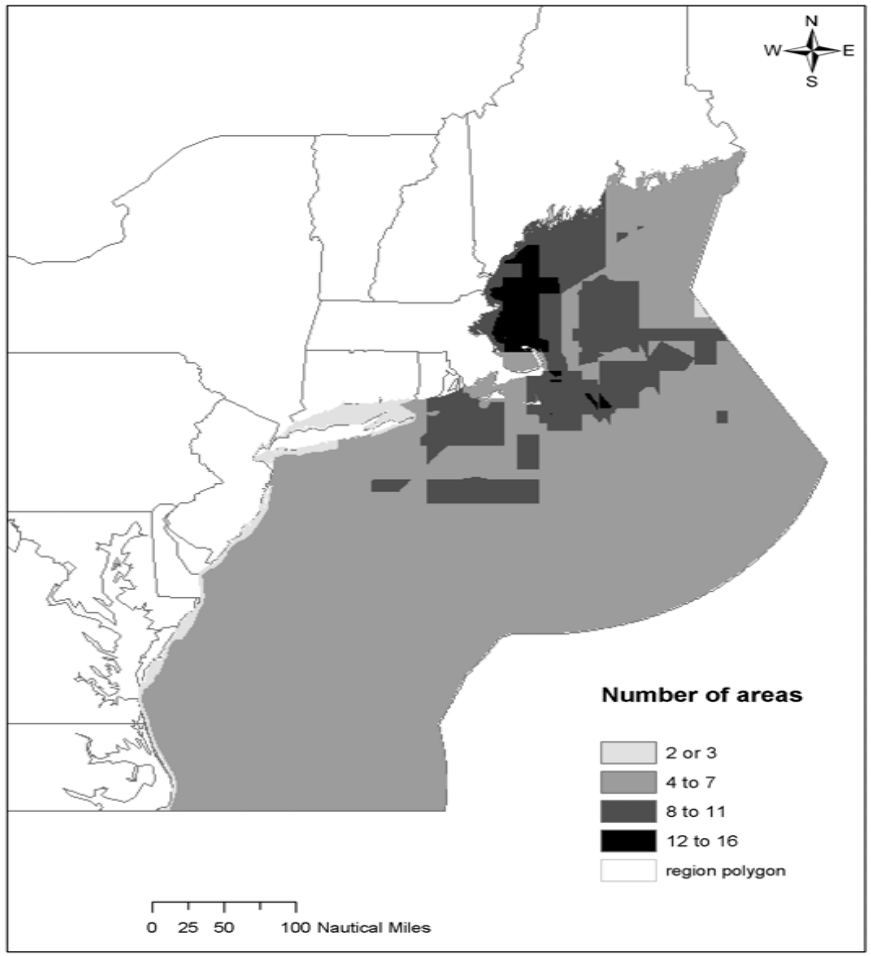
Figure 2. Raster map of overlapped management areas (1-km grid)



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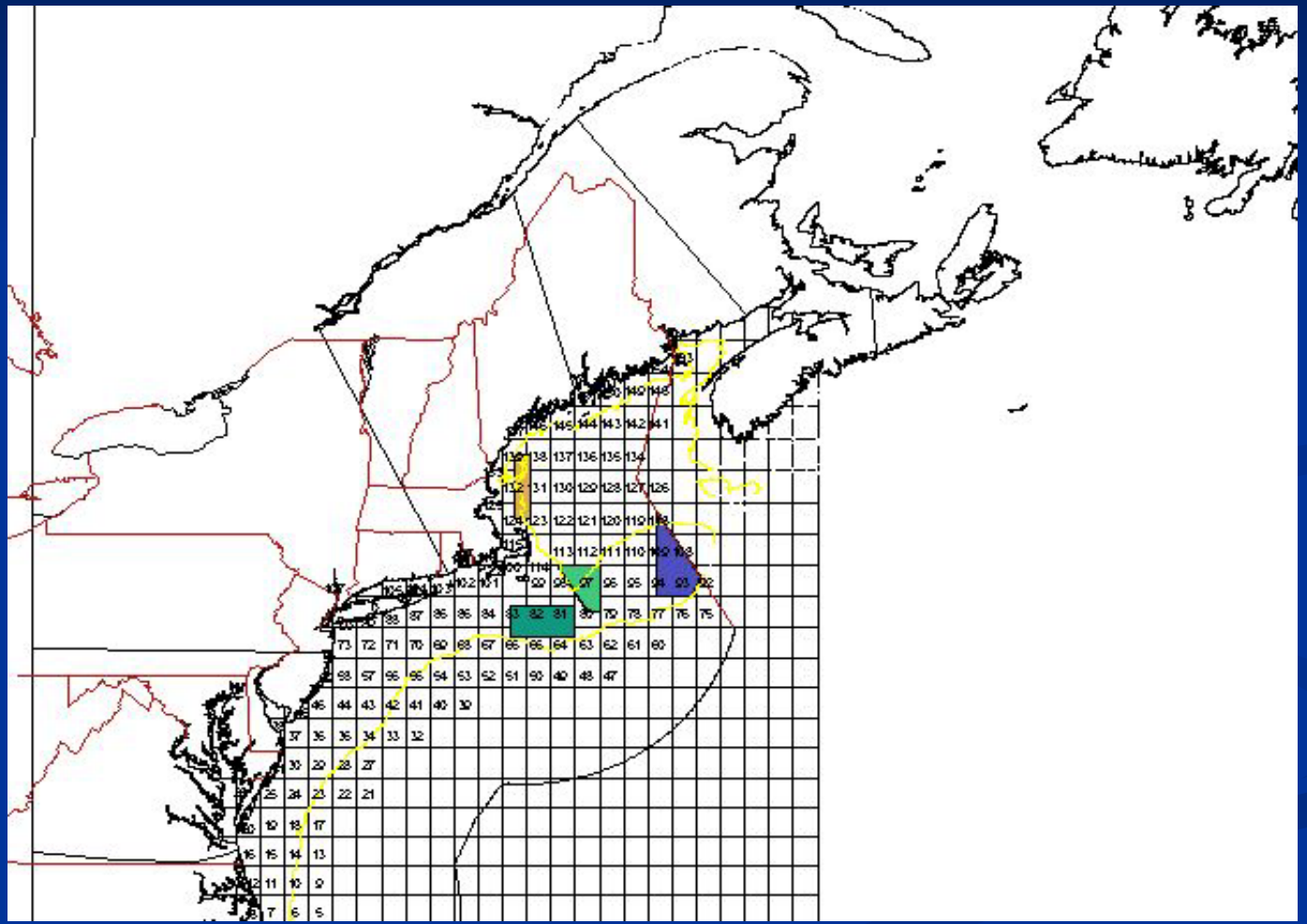
Evaluating Area Closures

- Large amount of work over last several years looking at welfare losses associated with closed areas
  - Dupont, 1993
  - Hicks 1997
  - Curtis 1999, 2000
  - Holland and Sutinen, 1999
  - Hicks, Kirkley and Strand, 2004.
- Most used Random Utility models
- In the Northeast we have tended to focus on Math Programming (Optimization) Models.

History of Optimization Models used in the Northeast Region

- Used a simple Mixed Integer Programming model for Amendment 5.
- Expanded this model to a Linear programming Model for Amendment 7.
- Developed a “two-bin” model for Amendment 7.
- Currently using a Non-Linear Math programming model for Amendment 13.

Northeast Region Grid Numbering System



$$\text{Max } Z = \sum_i \sum_j \sum_k \sum_s PC_{ks} * CPUE_{ijks} * \left(\sum_p EFF_{ijkp}\right) \quad (1)$$

s.t.

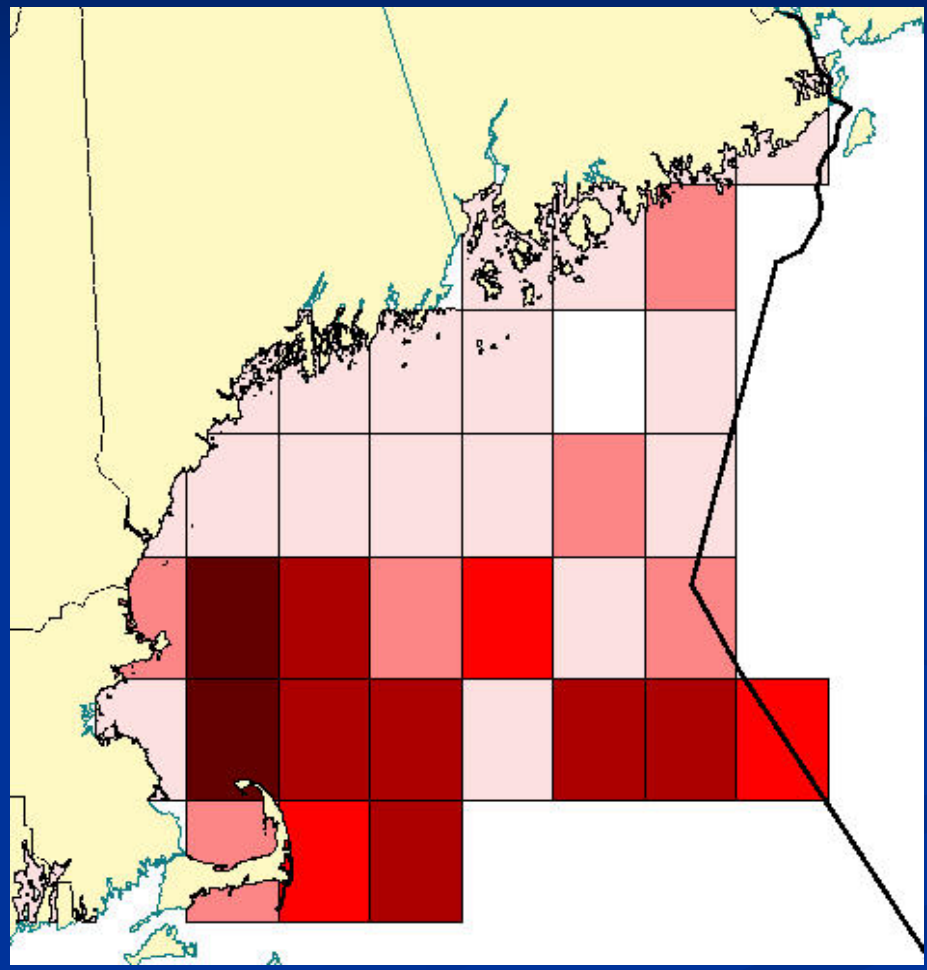
$$\sum_j \sum_k EFF_{ijkp} \le TEFF_{ip} \quad (2)$$

$$EFF_{ijkp} = 0,\ j \in \text{closed},\ k \in \text{closed} \quad (3)$$

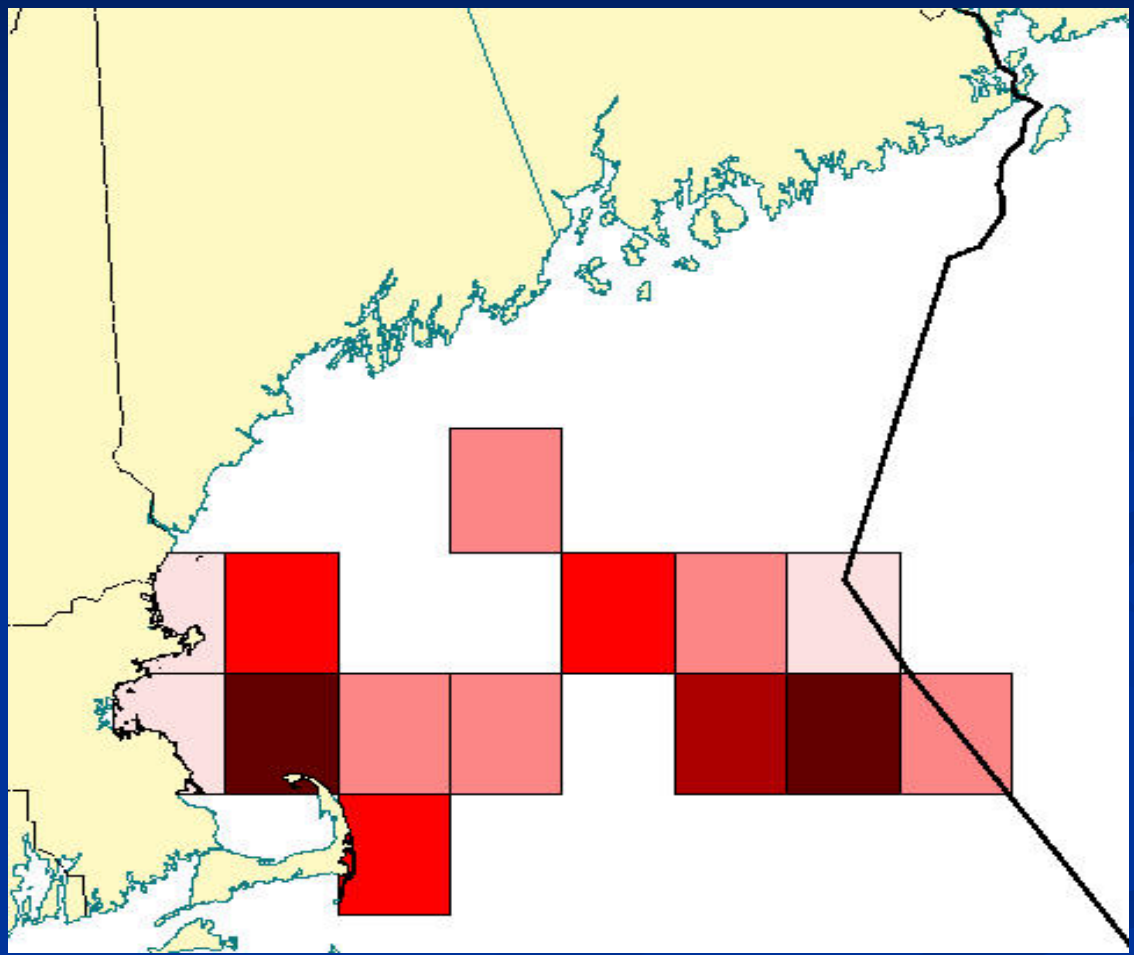
$$EFF_{ijkp} \le 3 * DABASE_{ijkp},\ j \in \text{open},\ k \in \text{open} \quad (4)$$

$$EFF_{ijkp} \ge 0 \quad (5)$$

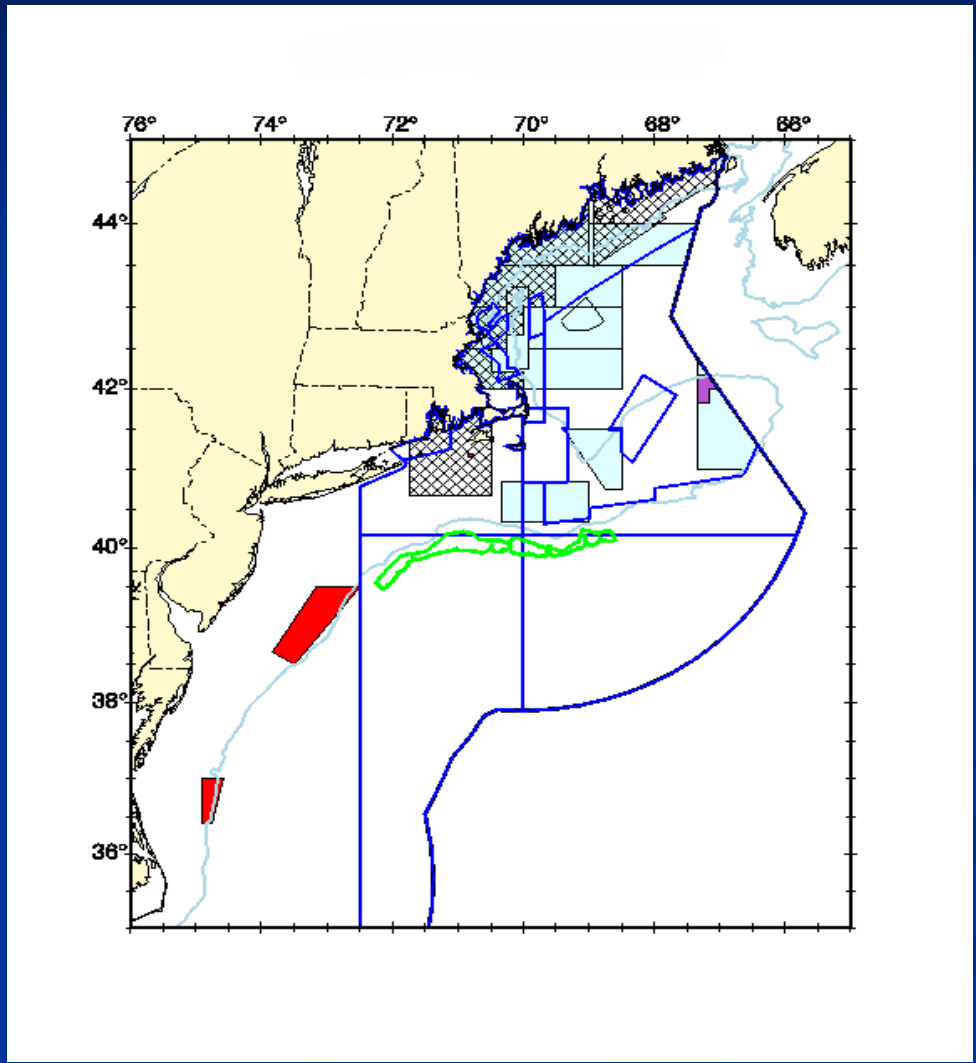
Distribution of Cod Catch by All Gear Types During March



Distribution of Cod Catch by Gillnet Vessels in March

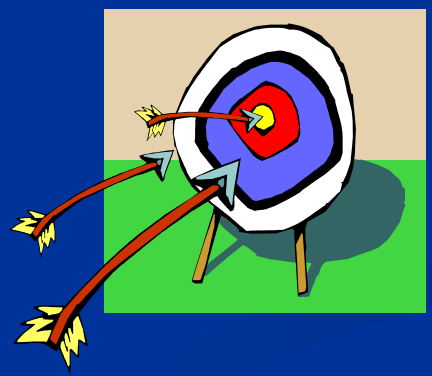


Pre-Amendment 13 Area Closures in the Northeast Region



Amendment 13 Objectives

- Rebuild Spawning Stock Biomass and end overfishing on groundfish stocks.
- Species - Cod, Haddock, Winter Flounder, American Plaice, Witch flounder, Windowpane flounder, Yellowtail flounder, Pollock, Red Hake and White Hake.
- Stock Areas - Georges Bank, Gulf of Maine, Southern New England, Cape Cod, Mid-Atlantic



Mortality Reductions Needed for Rebuilding Selected Stocks under Amendment 13.

		Stock Areas		
Species	Stock	Assumed F	F rebuild	Needed Reduction in F
Cod	GB	0.45	0.18	-60%
	GOM	0.36	0.22	-38.89
Haddock	GB	0.2	0.25	+25%
Yellowtail Flounder	GB	0.14	0.23	+64.29
	SNE/MA	0.74	0.18	-75.68
	CC/GOM	0.95	.09	-90.53
American Plaice		0.26	0.15	-42.31
Witch Flounder	No Formal rebuilding program required			
Winter Flounder	GB	No Formal Rebuilding Program required		
	GOM	No Formal Rebuilding Program required		
	SNE/MA	0.45	0.25	-44.44%

Measures Considered during Development of Amendment 13

- Further Area Closures, both seasonal and year round
- Trip Limits
- Days at Sea Reductions
- Gear restrictions, minimum fish sizes

Alternative 1

Effort Reduction	Area Closures	Seasonal Closures	Trip Limits
55%	Status-Quo Year Round	March -121,122,123 April 121-125, 129-133 May 124-125, 129-133, 136-140 June 132-133, 139-140, 141-147, 152 October 124,125 November 124,125	•GOM Cod -800 lb/day, 4,000 lb/trip. •GB Cod – 2,000 lb/day, 20,000 lb/trip •CC/GOM yellowtail – March1-May 31 250 lb. possession limit. June1-Feb. 28, 750 lb/day, 3,000 pounds per trip

Other Management Measures (non-modeled)

- Net Caps on Both Day and Trip Gillnet Vessels
- Gear restrictions based on area fished for Trawl Vessels
- Limits on total hooks for vessels based on area fished
- Minimum Size Limits by Species

Estimating Mortality Changes Under Each Management Option

- Desirable features:
  - A focus on 30 minute square blocks, and monthly time periods.
  - Estimate changes in mortality by species and stock area
  - The ability to incorporate days at sea changes, trip limit changes and area closures simultaneously.
  - A focus on the individual vessel level, and revenue changes.

Positive Math Programming

- Originally Published in AJAE (1995)
- Idea is to use a model which is calibrated to observed conditions in a base year, to examine policy changes.
- Models are widely used in Agriculture, particularly by the USDA.
- We use three stages – the first uses a linear program to obtain dual values based on observed activity in a base year. The second stage uses the dual values along with average values to obtain yield function parameters. In the Third Stage, the yield parameters are used with base year data to construct the model.

Math Programming Model

$$\text{Max } TR_a = \sum_i \sum_j \sum_s P_{js} * (\beta_{ijs} - \delta ijs * E_{ij}) * E_{ij} \quad (1)$$

s.t.

$$E_i \leq 30 \quad (2)$$

$$\sum_i \sum_j E_{ij} \leq EFF \quad (3)$$

$$E_{ij} \geq 0 \quad (4)$$

Data

- Logbook data from the years 1998-2001 were used to determine landings, days at sea and CPUE per block
- Vessel trip data were aggregated to a monthly level in each block
- Price data were based on dealer records for the years 1998-2001.
- Prices were deflated to 1998 levels using the GDP implicit price deflator

Data (Continued)

- 156 blocks, 12 months, 10 species.
- 1,872 distinct choices per vessel.
- Lack of Cost Data on an individual vessel level precluded using a profit maximizing framework.
- Revenue maximizing model may be better choice given the lay systems used for crew payments.
- A formal price model could not be incorporated because the models developed are on an annual, not monthly basis.

Procedure

- Run Model with the status-quo management options
- Run model again with the proposed new management options
- Compare landings under proposed management options and status quo to determine change in exploitation.
- Changes in revenue and distributional impacts were also provided.
- Model results should be interpreted as an ordinal ranking of alternatives. Information from the model helps managers choose alternative.

Change in Exploitation Rates under Alternative 1

			Stock Areas				
		GOM	GB	SNE	CAPE	Mid-Atlantic	Other
Cod		-45.5	-43.4				
Haddock		-47.7	-44.2				
Winter Flounder		-50.6	-36.3	-58.3			
Yellowtail Flounder			-38.9		-60.3	-72.7	
Windowpane Flounder		-31.6					
American Plaice							-52.9
Witch Flounder							-50.6
Pollock							-42.3
Redfish							-49.3
White Hake							-47.7

Limitations

- Model only allows vessel effort to shift into areas or times where the vessel has previously fished. Mortality reductions and revenue losses may be overestimated.
- Non-linear programming model assumes "perfect" planning and foresight. Will maximize revenue for every vessel in the model.
- Did not integrate non-groundfish activity in model, due to model size.
- Latent effort could not be incorporated into model.
- Provides an ordinal ranking of alternatives, not precise point estimates of impacts.

Future Direction

- Management has become very complex. Need a decision support system.
- Need models which build in uncertainty.
- Positive Math Programming can provide underlying equations for a stochastic model.
- Monte Carlo Methods may provide necessary tools.
- Decision Support System combined with GIS applications may be beneficial.
- Other Ideas???

Epilogue

- Amendment 13 was a large undertaking and incorporated several new options
- Allowable fishing days were divided into A days, B days and C days, with each having different management implications
- Days at Sea Transfers and Leases were also allowed
- Special Access Programs (SAP's) were put in place to allow vessels to fish in areas and for species that were not being overfished