Slow management during rapid ecosystem change
or
How rapid warming drove the collapse of Gulf of Maine cod

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Outline

• Rapid warming in the Gulf of Maine
• Warming and cod
  • recruitment
  • natural mortality
  • implications for management
• Lessons
• Synthesis
SST Trends: 2004-2013

[Graph showing SST trends over the years 1980 to 2015, with anomalies and trends indicated.]
Consequences: Cod

Spawning Stock Biomass

Data from 2014 stock assessment (Palmer, 2014)
Consequences: Cod

Data from 2014 stock assessment (Palmer, 2014)
Consequences: Cod

Age 1 Recruitment

Spawning Stock Biomass

Data from 2014 stock assessment (Palmer, 2014)
Consequences: Cod

Data from 2014 stock assessment (Palmer, 2014)
Consequences: Cod

Age 1 Recruitment

Spawning Stock Biomass

Model with SSB

Model with SSB 
&Temperature

Data from 2014 stock assessment (Palmer, 2014)
Implications of Recruitment: Temperature

- 2° increase in mean SST = 90% reduction in $B_{msy}$
- Ignoring temperature leads to unrealistic expectations for the size of the fishery
Consequences: Cod

• Mortality is also a function of temperature
Consequences: Cod

- Mortality is also a function of temperature
- Extra natural mortality means extra fishing mortality, under a fixed quota-system.
Consequences: Cod

- Mortality is also a function of temperature

- Extra natural mortality means extra fishing mortality, under a fixed quota-system.

- Setting quotas without accounting for temperature can lead to overfishing
Consequences of ignoring temperature

• Rebuilding targets are too high
• Quotas are also too high
  • *Even when the industry follows the rules, overfishing still occurs, requiring steeper cuts in the future*
• Fishermen blame the science, resist additional management
  • *cuts recommended for 2012 were spread over 2012-2013, compounding overfishing*
Lessons

• Recognize environmental change
• Include environmental effects in fisheries models
• Consider decadal trends and climate change when setting rebuilding goals
Synthesis

- **Scales**: regional, decadal
- **Decisions**: quota setting
- **Actors**: scientists, managers, industry
- **Context**: history of overfishing, good data, very rapid ecosystem change
- **Barriers**: crisis mode, poor economic state of fishery, culture of mistrust, rigid stock assessment process,