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MS & Aggregate Production Model: Simulator

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Summary of Ecosystem Considerations

- Ecosystem approaches to Gulf of Maine/Georges Bank fisheries (TOR 3):
- a.) Determine the production potential of the fishery based on food chain processes and estimate the aggregate yield from the ecosystem;
- b.) Comment on aggregate single stock yield projections in relation to overall ecosystem production, identifying potential inconsistencies between the two approaches.

Production Model Structure

Recall a Schaefer Production Model:

$$\frac{dB}{dt} = rB(1 - \frac{B}{k}) - qEB$$

Just add in a few terms for competition & predation and a do a few dumb algebra tricks:

$$\frac{dN_i}{dt} = r_i N_i (1 - \frac{N_i}{K_G} - \frac{\sum_1^g \beta_{ig} N_g}{K_G} - \frac{\sum_1^G \beta_{iG} N_G}{(K_\sigma - K_G)} - \sum_1^p \alpha_{ip} N_p) - H_i N_i$$

Aggregate/MS Production Model Structure

$$\frac{dN_i}{dt} = r_i N_i \left(1 - \frac{N_i}{K_G} - \frac{\sum_1^g \beta_{ig} N_g}{K_G} - \frac{\sum_1^G \beta_{iG} N_G}{(K_\sigma - K_G)}\right) - N_i \sum_1^p \alpha_{ip} N_p - H_i N_i$$

N = biomass
r = growth rate
H = harvest rate

β = competition coefficient
α = predation coefficient
K = carrying capacity

i = species
p = predator (on species i)
g = guild member
G = guild

Model Parameterization & Inputs

- Set species, assign to guilds/groups
- Determine system and guild carrying capacities, based off of B_{MSY}'s
  - System = 8 Million mt
  - Groundfish = 2.85 M mt
  - Pelagics = 2.59 M mt
  - Elasmobranchs = 2.31 M mt
  - From Overholtz et al.

Model Parameterization & Inputs

- Set growth rates (r) for each species
  - Taken from assessments,
  - Mostly approximated by 2x F_{MSY}
- Set initial biomasses for each species
- Turned off T, size, etc. features; assigned to demersal or pelagics

Model Parameterization & Inputs

- Set between guild competition
  - GF:Elasmo = 0.2
  - Pel:Elasmo = 0.02
- Set within guild competition among species within a guild
  - Approximated by diet overlap matrix
- Set predatory losses among all species
  - Informed by diet composition
  - Here only on pelagics

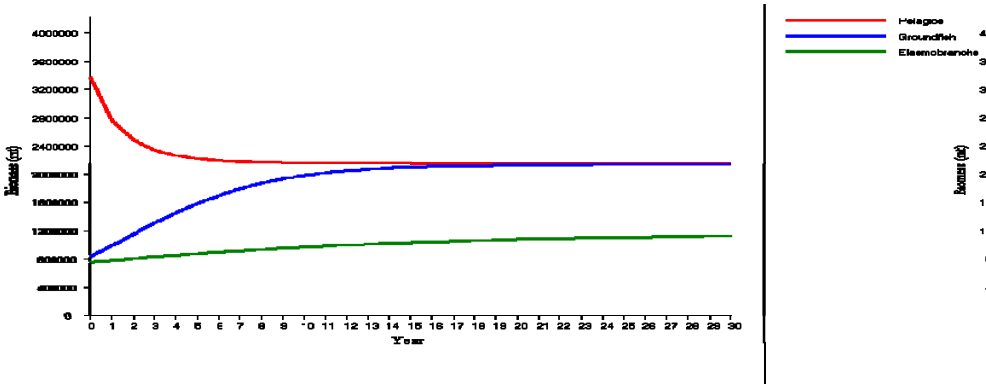
Model Parameterization & Inputs

- Set spatio-temporal overlap among all species
  - Used from survey derived SO matrix
- Set harvest rates
  - Set as 0.1 of B for all species in basal scenarios
- Set extent and resolution of simulation
  - E.g. 30 yrs, annual time step

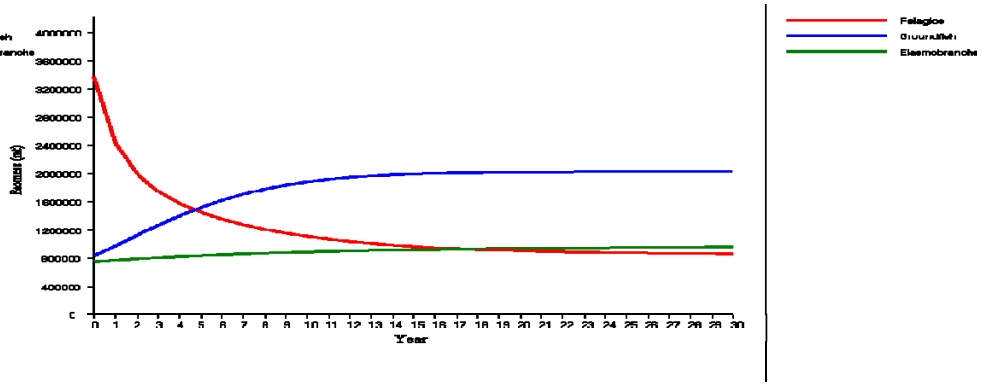
Model Scenarios

- Aggregate Version
  - Harvest on/off
  - Spp interactions on/off
- MS Version
  - Harvest on/off
  - Spp interactions on/off
- Different Harvest Rates (in WP, not shown)
- Differential Harvest Rates (in WP, not shown)

Aggregate Production



Harvest, no Interactions – Guild Biomass over time



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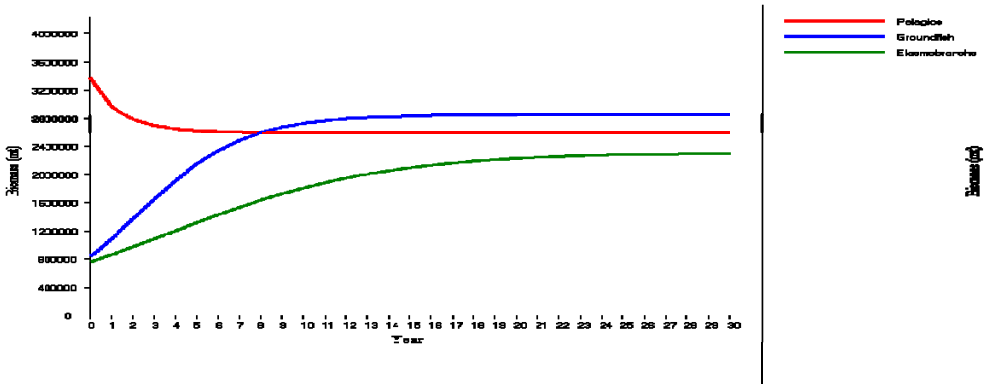

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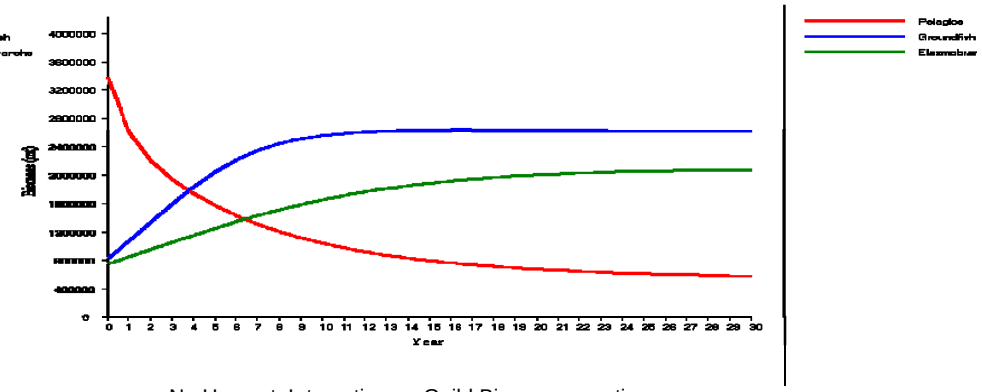
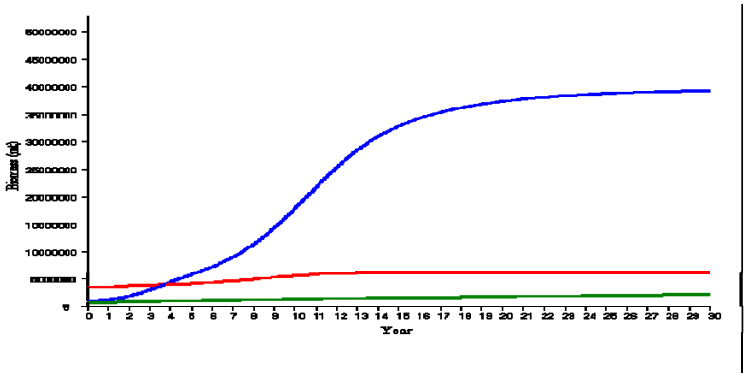


No Harvest, Interactions – Guild Biomass over time

MS Production



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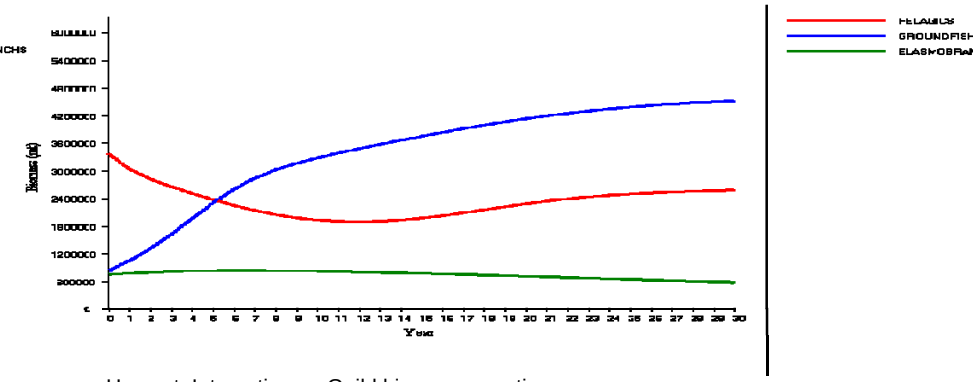

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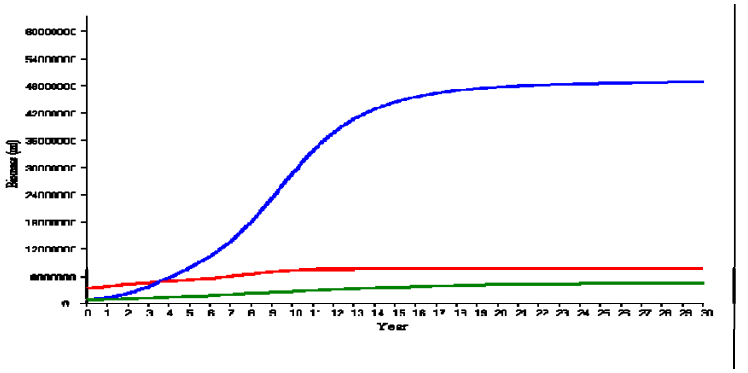

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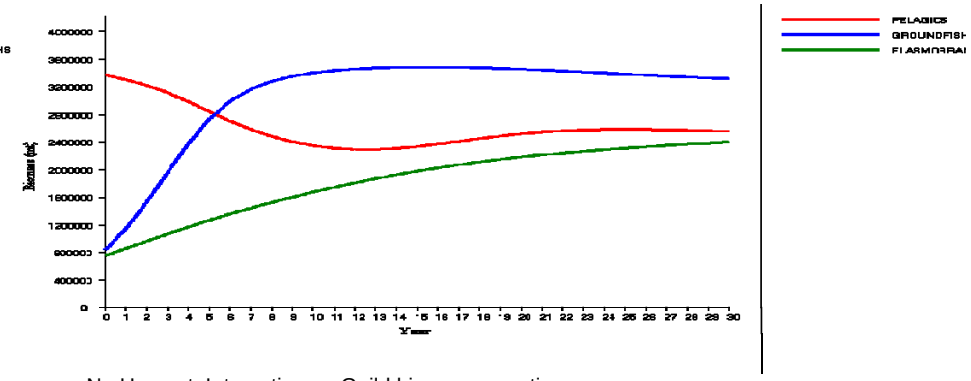

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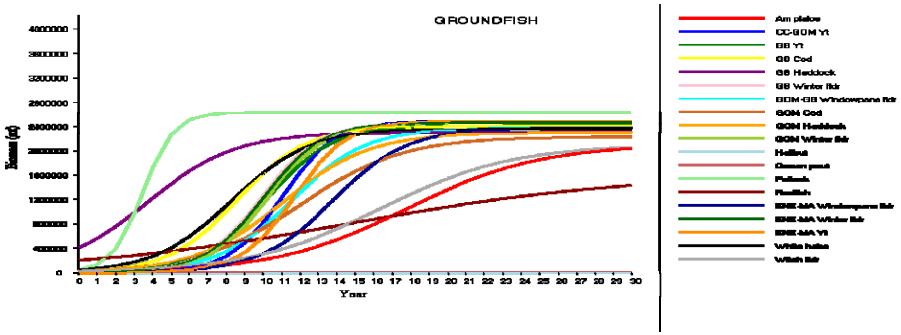
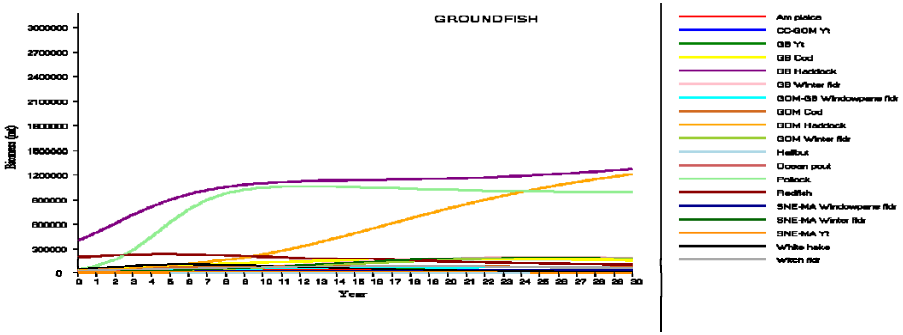


Harvest, No Interactions – Groundfish biomasses over time



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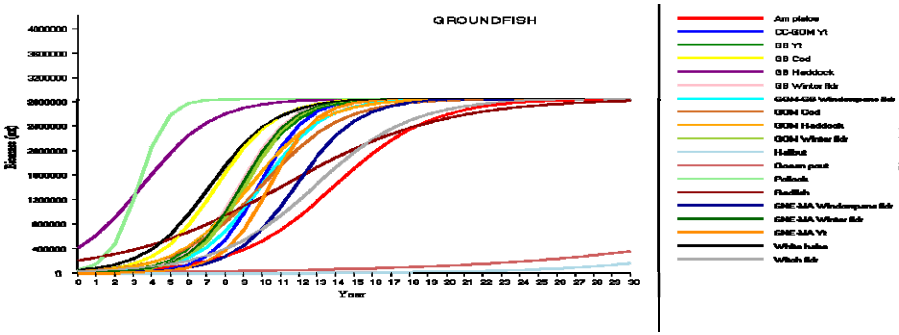

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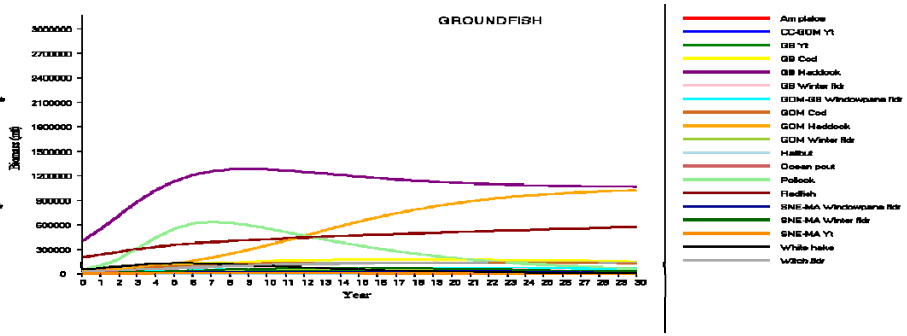
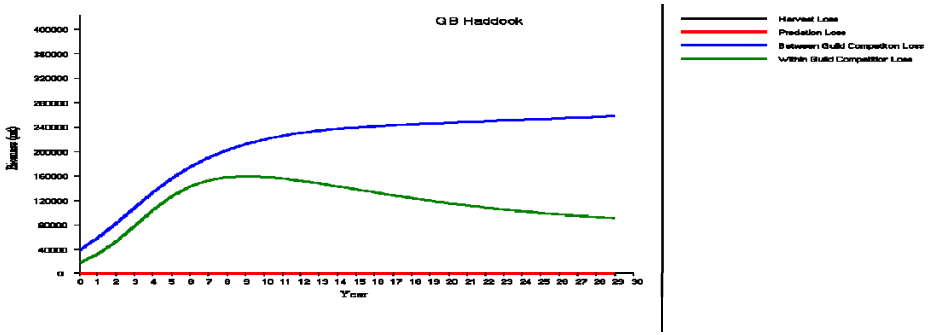
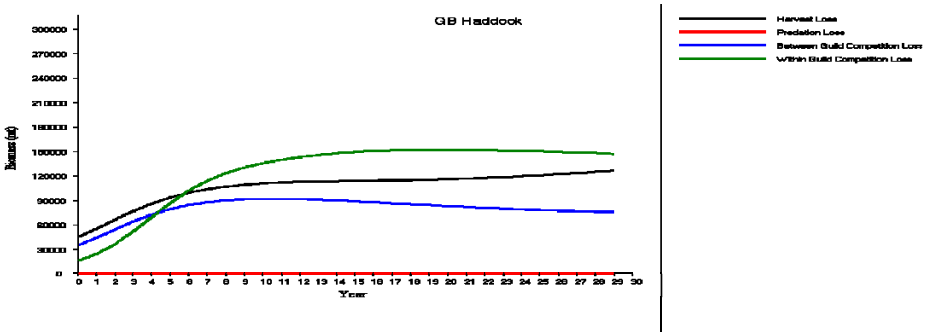


No Harvest, Interactions – Groundfish biomasses over time

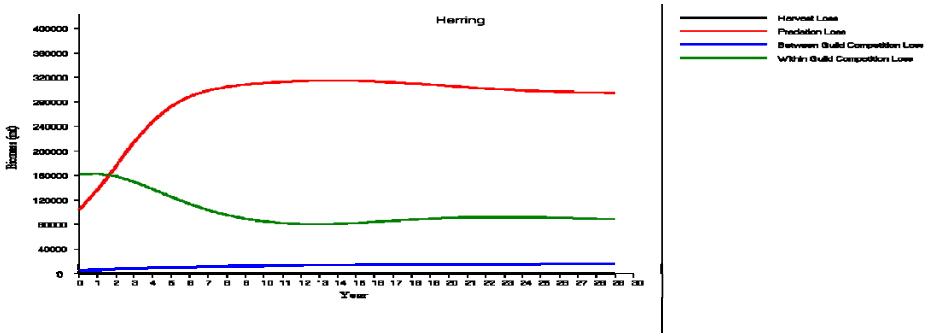
MS Production



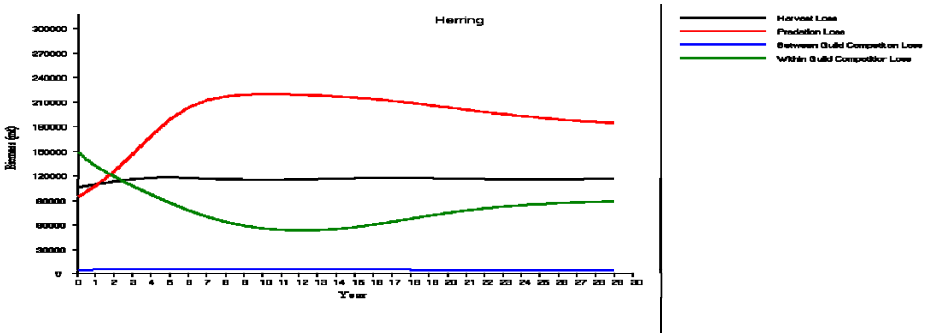
No Harvest, Interactions – Losses of GB-Haddock biomass



Harvest, Interactions – Losses of GB-Haddock biomass



No Harvest, Interactions – Losses of Herring biomass



Harvest, Interactions – Losses of Herring biomass

Summary Observations

Aggregate Production

Harvest	Interactions	Ending ~Total Fish Biomass
Y	Y	3.9 M mt
Y	N	5.4 M mt
N	Y	5.4 M mt
N	N	7.5 M mt

Summary Observations

MS Production

Harvest	Interactions	Ending ~Total Fish Biomass
Y	Y	7.7 M mt
Y	N	48 M mt
N	Y	8.1 M mt
N	N	63 M mt

Summary Observations

- Assuming no fishing and enough food, it still takes a long time for species to reach K, if at all
- With Fishing turned on, lower biomasses
- With Species Interactions turned on, lower biomasses still
  - Also less stable biomass trajectories and slower time to K, if at all

Summary Observations

- Aggregate groups more stable than individual (multi) species
- Aggregate simulation results lower than Aggregated MS simulation
  - (N spp x N at K, particularly with no interactions)
- Differential harvest and different harvesting rates (not shown in this ppt) showed
  - Spp respond differently to harvest
  - There is some within guild and systemic compensation

Summary Observations

- It is possible to have many members of a group at or close to their K (and by extension B_{MSY})…
- … but not all, and…
- … not all groups at that level (K or K/2) simultaneously unless there are some unreasonable assumptions made
  - Like very limited harvest and no spp interactions
- Caveats over specific parameter values aside, these results highlight the importance of spp interactions