Linking ADH, CE-QUAL-ICM, and Individual-Based Bioenergetics

(i.e., Hydrodynamics, Water Quality, and Fish Modeling)

P. Soupy Dalyander

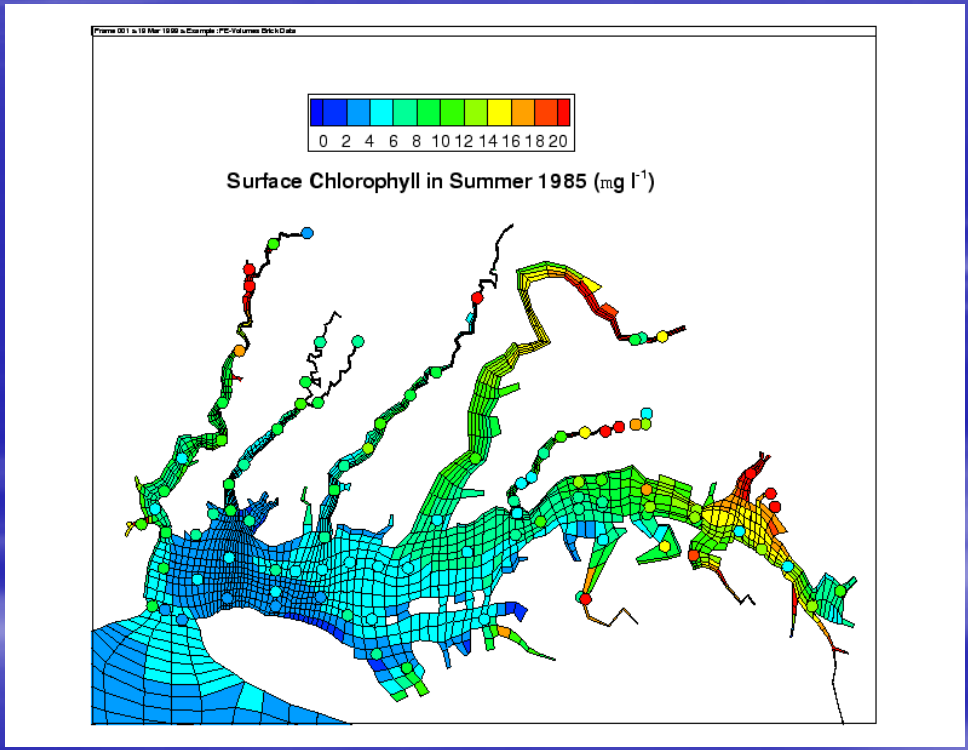
Carl F. Cerco

Ecosystem Health: Management & Modeling

- "Top down" strategy: higher trophic levels (e.g., oysters, menhaden) can effect as well as be effected by H_2O quality
- Water quality model contains nutrients, algae, zooplankton
- Existing phytoplankton consumption models for fish typically spatially/temporally averaged
- Solution: imbed individual-based fish model into water quality model, driven by a hydrodynamics model

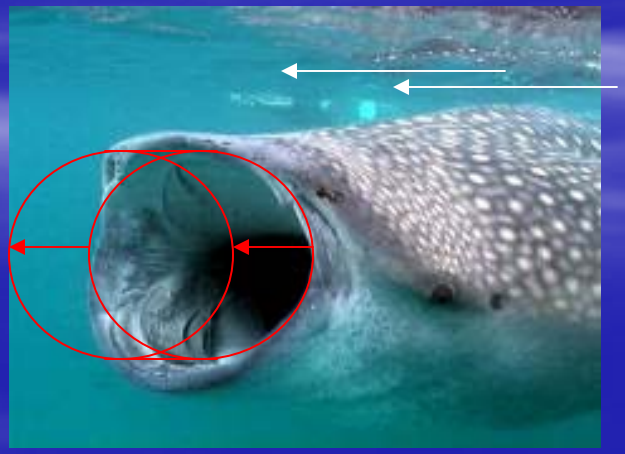
CE-QUAL-ICM Water Quality Model

- Fully 3D, time-variable; links to variety of hydrodynamic models
- Full suite of nutrients and trophic interactions
- Includes SAV, benthos, zooplankton, sediment diagenesis
- Conventional pollutants and contaminants



Fish Bioenergetics Module

- Wisconsin Fish Model: What goes in, must go out (conservation of energy, C, N, P, O)
- Foraging model for consumption
- Empirical parameters for life processes (respiration, excretion, egestion, mortality)
- What's left? Growth!

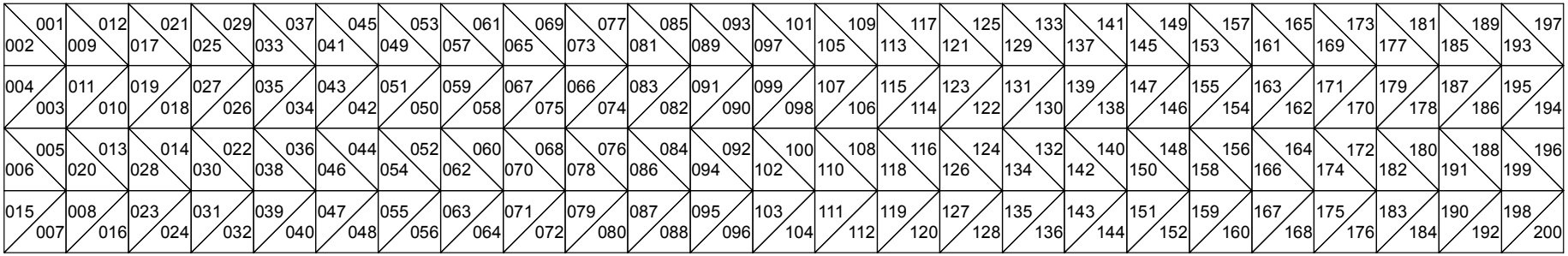


Volume = f(speed, mouth area)

ADH Test Grid Hydrodynamics

- Rectangular channel, 50 km long, 8 km wide
- 200 elements, 329 faces, 130 nodes
- Tidal forcing on LHS, other boundaries closed
- Linkage to ICM through grid, map, and hydrodynamic file translation

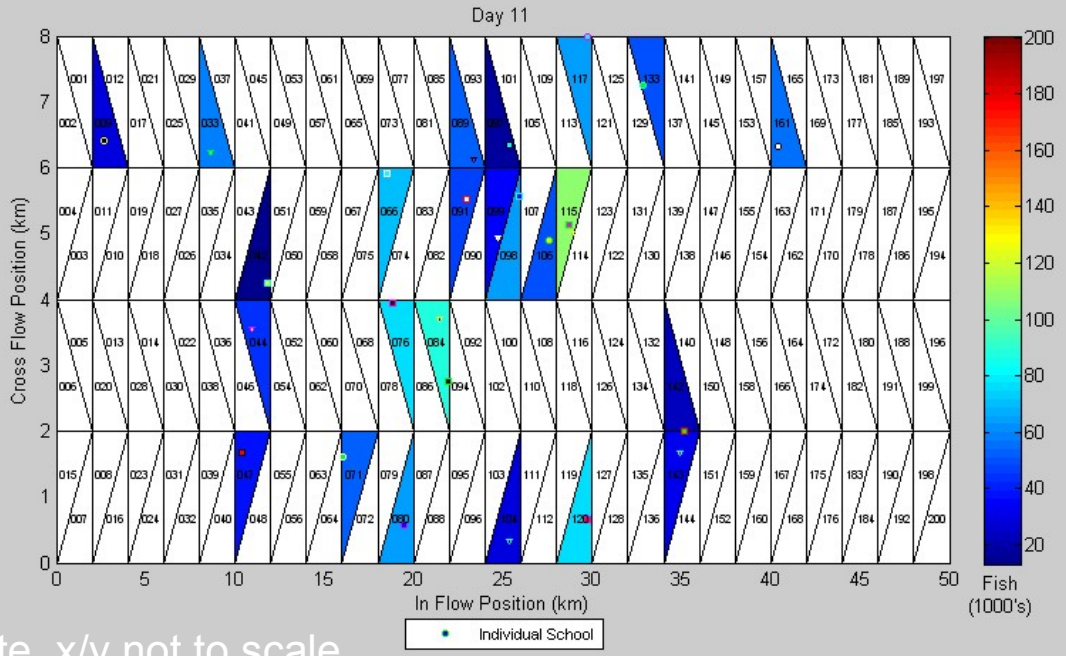
Movie File:
sms.wmv



Tracking Schools: ADH Test Grid

- School migration pattern generated once prior to model run
- Simulates “nursery” behavior with biased random walk
- Position tracked in x/y/z→ box #

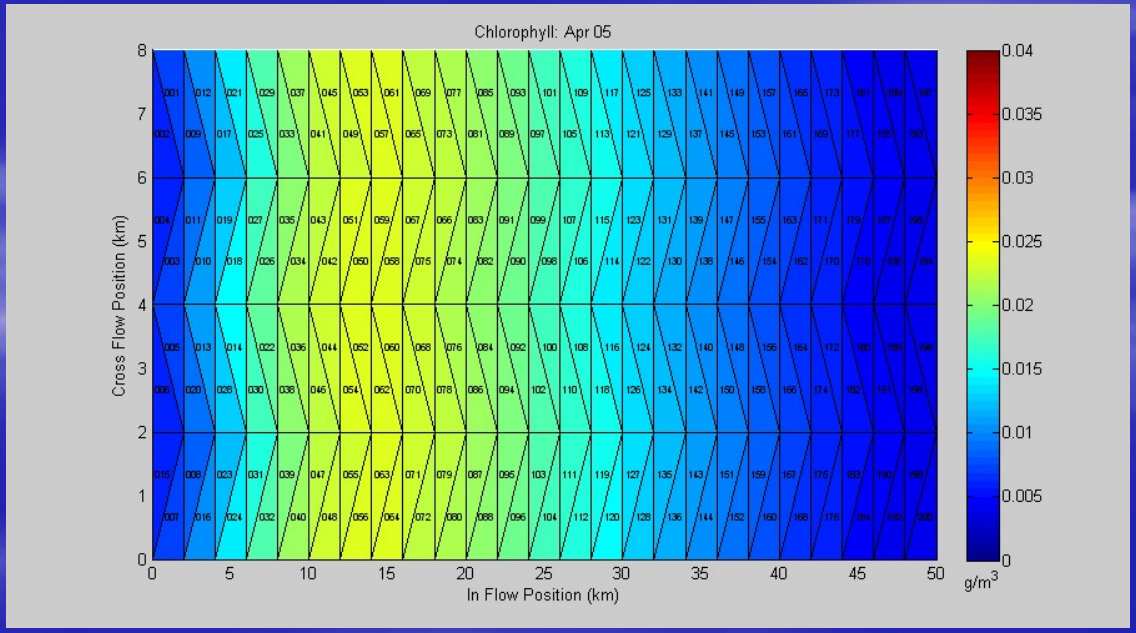
Movie File:
400schools_365days_v3



Note, x/y not to scale

ADH Test Grid: No Fish

- Approximates estuary with seasonally and spatially variant fluvial nutrient influxes
- Particulate/dissolved nutrients, algae, zooplankton, oxygen, T/S, etc. 'on' in model



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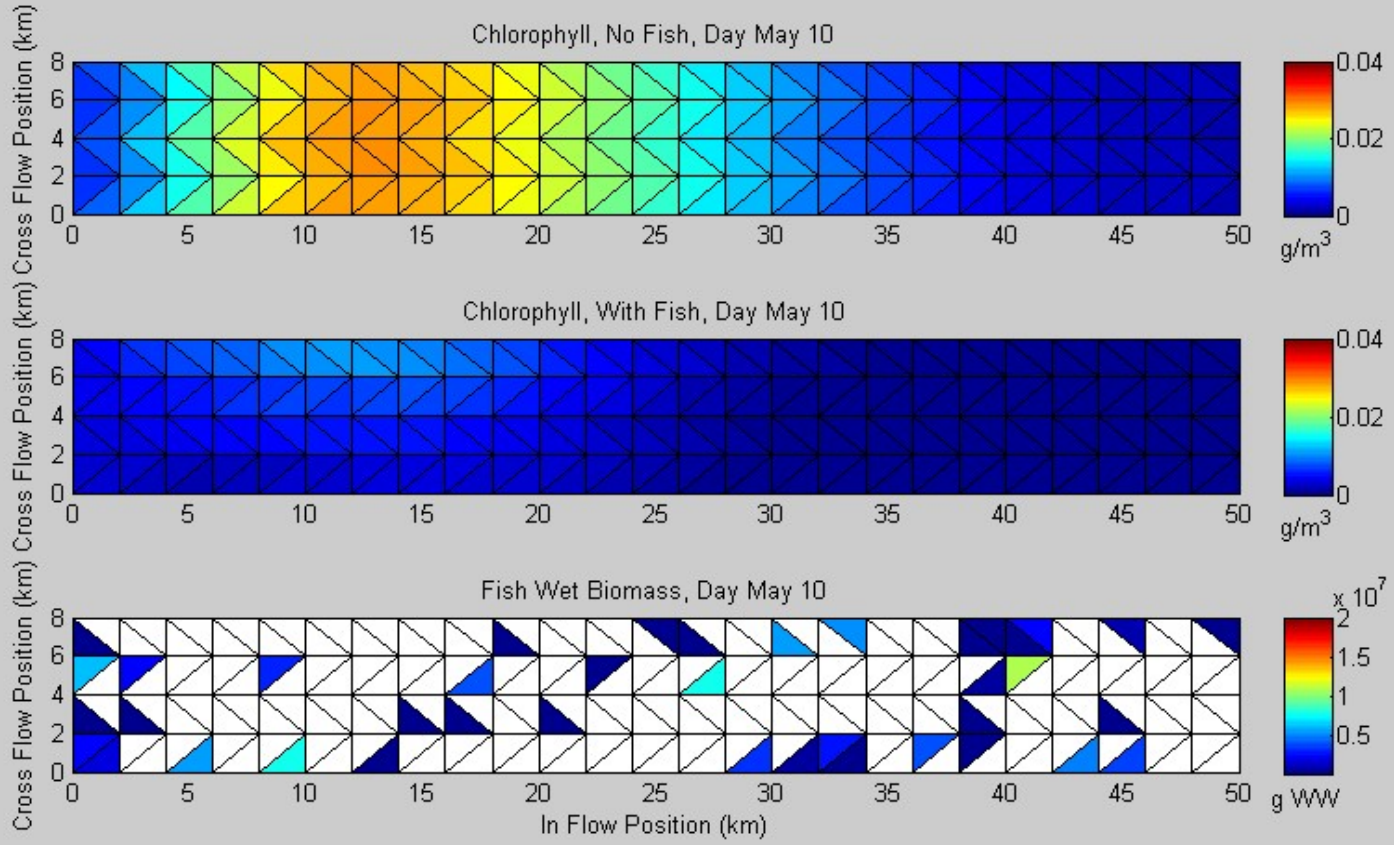
ADH Grid: Atlantic Menhaden



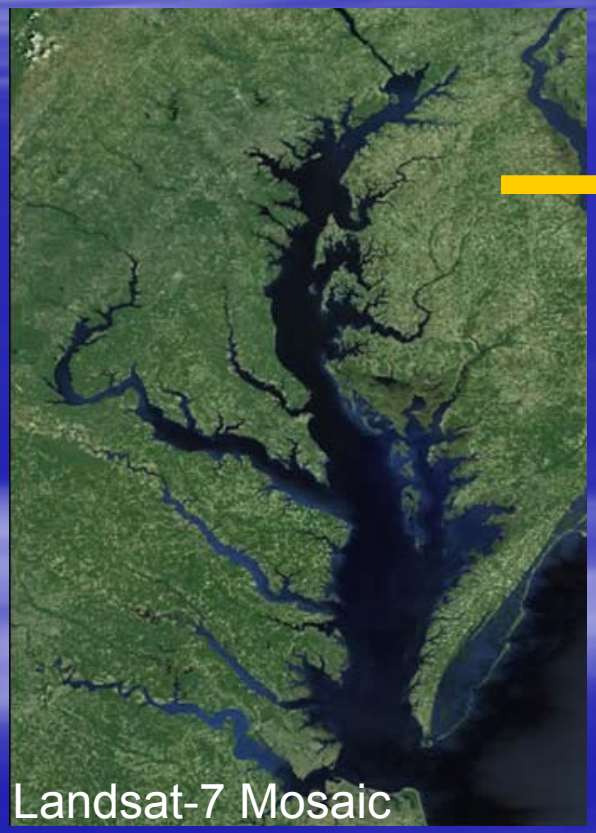
Movie File:
compChl

Fish Movement: San Diego Bay

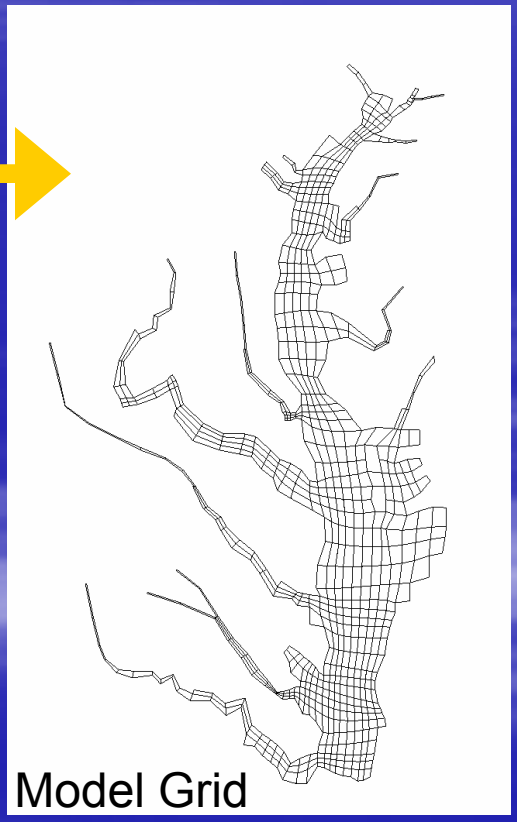
Demonstrates fish movement on realistic ADH grid

Movie File:
400schools_30days_v2

Real World Pilot Application: Chesapeake Bay



20 miles



Chesapeake Bay:

- Largest estuary in US
- >3600 species aquatic animals, 2700 plant species
- Historic battle with eutrophication

CE-QUAL-ICM:

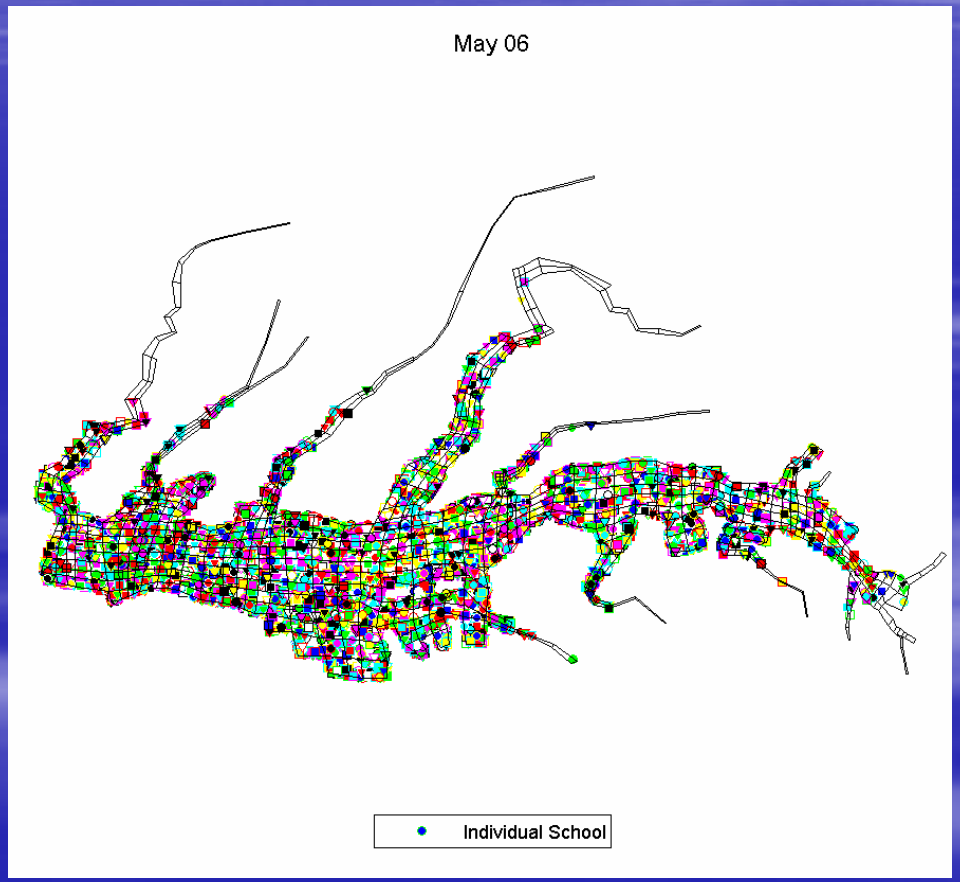
- Spatially/temporally explicit
- Temperature, salinity, carbon, nitrogen, phosphorus, algae, zooplankton
- CH3D hydrodynamics

Atlantic Menhaden

- Spawn off Atlantic coast
- Larvae move into estuaries, grow into juveniles
- Juveniles/adults = filter feeders
- Travel in dense schools of 100,000+ members
- Potential for phytoplankton control, nutrient export

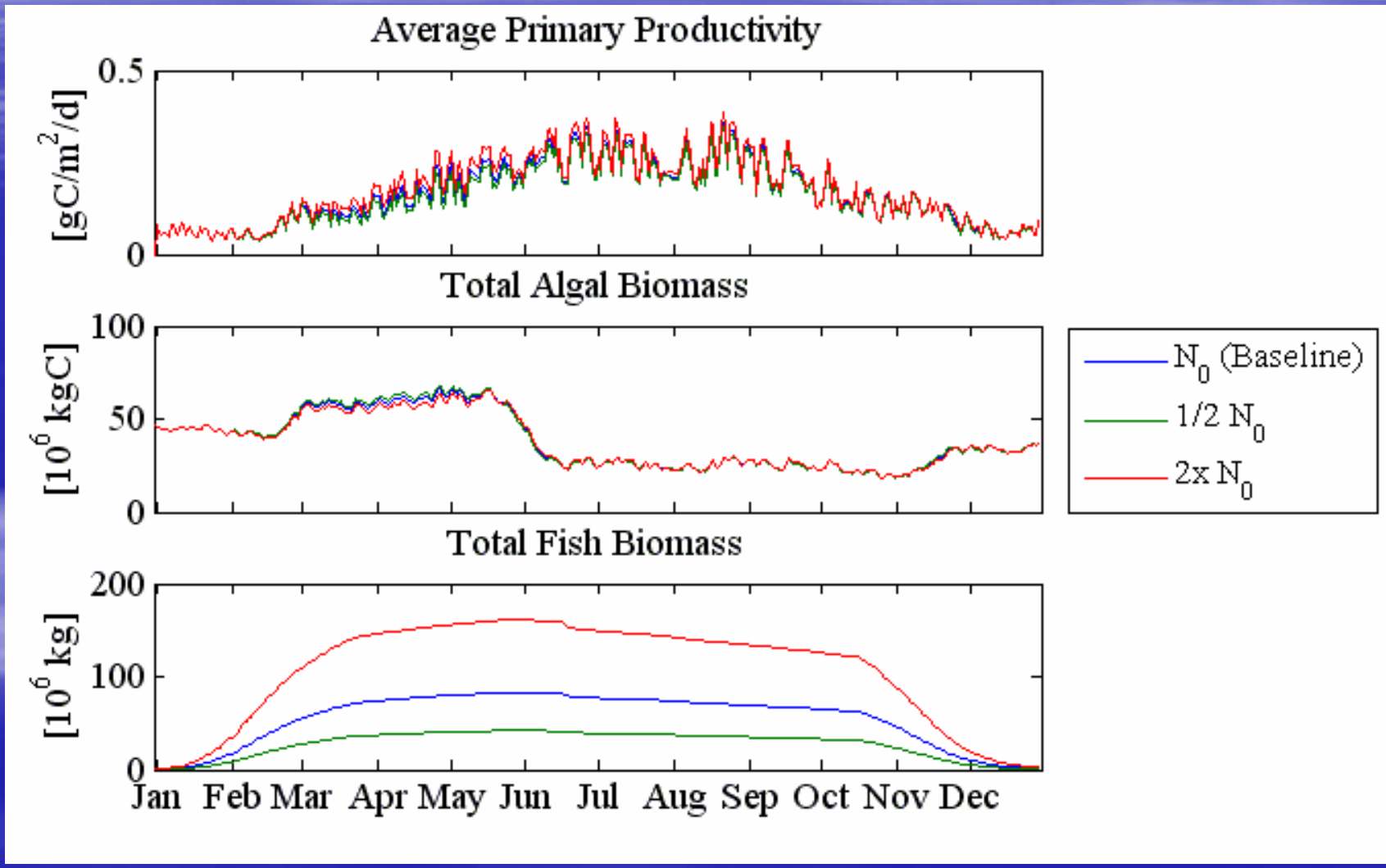
Migration Pattern

- 4,000 schools of ~400,000 members
- Delineated by age class
- Varying entry dates, each school enters at same weight for its age
- Spatially variant biased random walk to replicate migration in/out of the bay
- Parametric study varying initial population, fishing mortality

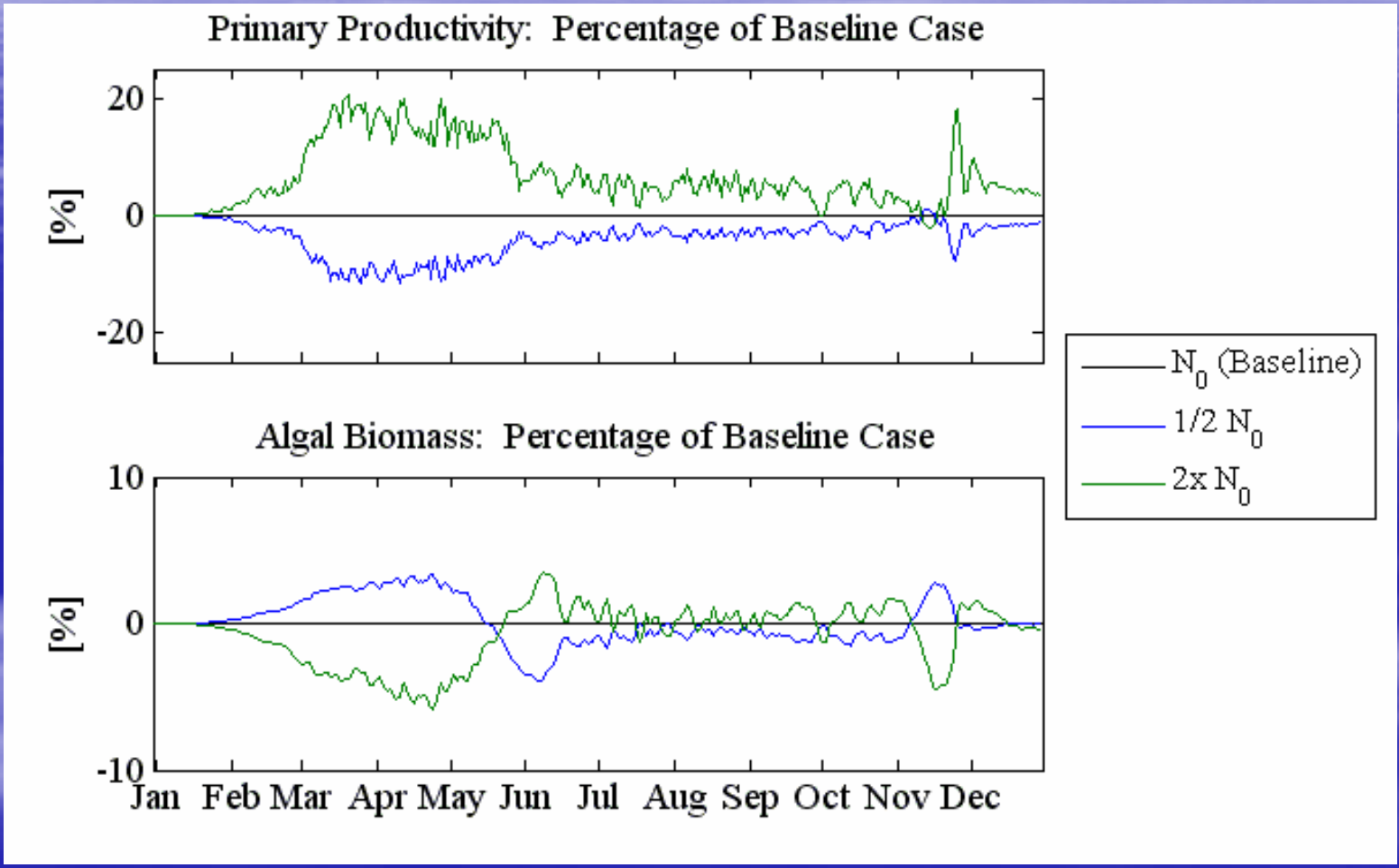


Movie File:
cb_4000_schools

Algae Consumption



Comparison to Baseline



- Algae → local/seasonal problem; Fish → local/seasonal consumer
- Primary productivity *increases*, net algae may *increase* OR *decrease*

Key Points

- Feedback of fish to water quality (CB result: menhaden increase primary productivity, but decrease overall algae biomass)
- Fish modeled as discrete individuals (could add multiple levels of prey/predator species)
- Fish are seasonally/spatially variable consumers of seasonally/spatially variable problem (algae)…captured in model
- Fish extremely proficient at removing highly concentrated algal blooms (this effect is smoothed out in spatial/temporal averaging)

Future Directions?

- Algae as discrete particles in water quality model (replicate localized patches/blooms)
- “Smarter” fish: more accurate migration pattern, behavior responses to algae/O_2
- Tackle other fish, places, and problems
- More integrated coupling between ICM and ADH