ABSI CAB
September 28th, 2022

Ed Camp
Fisheries and Aquatic Sciences, University of Florida

Outline of things to go over

1. Disclaimer/disambiguation
2. Background on shell dynamics
3. Why we built depensation into simulation models
4. Assumptions of simulation models shown today
5. Simulation results: depensation, collapse, restoration
   - -Take home points and questions
6. Simulation results: restoration and “sustainable” fishing
   - -Take home points and questions
7. Simulation results: alternative fisheries mgmt.
   - -Take home points and questions
8. Options for future modeling
   - -Better scaling
   - -Spatially explicit (multiple reefs)

1. Disclaimers and disambiguation

1. Disclaimers regarding models

1. Model results are draft—they will change

2. Models shown today are more useful for comparing (across assumptions and strategies) than for predicting absolute values

3. There is massive uncertainty in what I'm showing. Evidence for depensation but we don't know what drives it. That changes everything

1. Disambiguation re: “models”

- Multiple different modeling work I’m doing
  - Stock assessment models—estimating parms
    - Initially traditional fisheries (i.e. no shell dynamics explicit, subsumed with recruitment anomalies)
    - Extended to (try to) estimate shell dynamics (2-stage estimation, not ideal but necessary)
  - Simulation models— “what if” analysis
    - Detailed shell dynamics, but how to inform?
    - Best guesses (lit, data)
    - Inform from newer assessment models
    - *Today you will see simulation models that have been informed by stock assessment models. More formally statistically fit models in future.*
  - Other projects too, not talking about them today

2. Background on shell dynamics

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2. What I mean by “shell dynamics”

- Oysters create shell as they grow
- Oysters leave shell if they die (and aren’t removed)
- Small oysters recruit on shell

- Reef growth requires shell accumulation
- Substrate (shell on reefs or other) required for recruitment
- Recruitment required for population sustainability

2. Possible implications of shell dynamics

- We probably all agree shell dynamics exist
- Questions are:
  - What do they look like
  - Why might they matter

2. Possible implications of shell dynamics

- Shell dynamics (as defined)
  - Imply oysters create their own recruitment habitat

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  - More oysters → more recruitment habitat
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  - Dynamics have different names
    - Depensation, positive density dependence, etc.
  - Dynamics can lead to different things
    - Alt stable states, hysteresis, “fold catastrophe”

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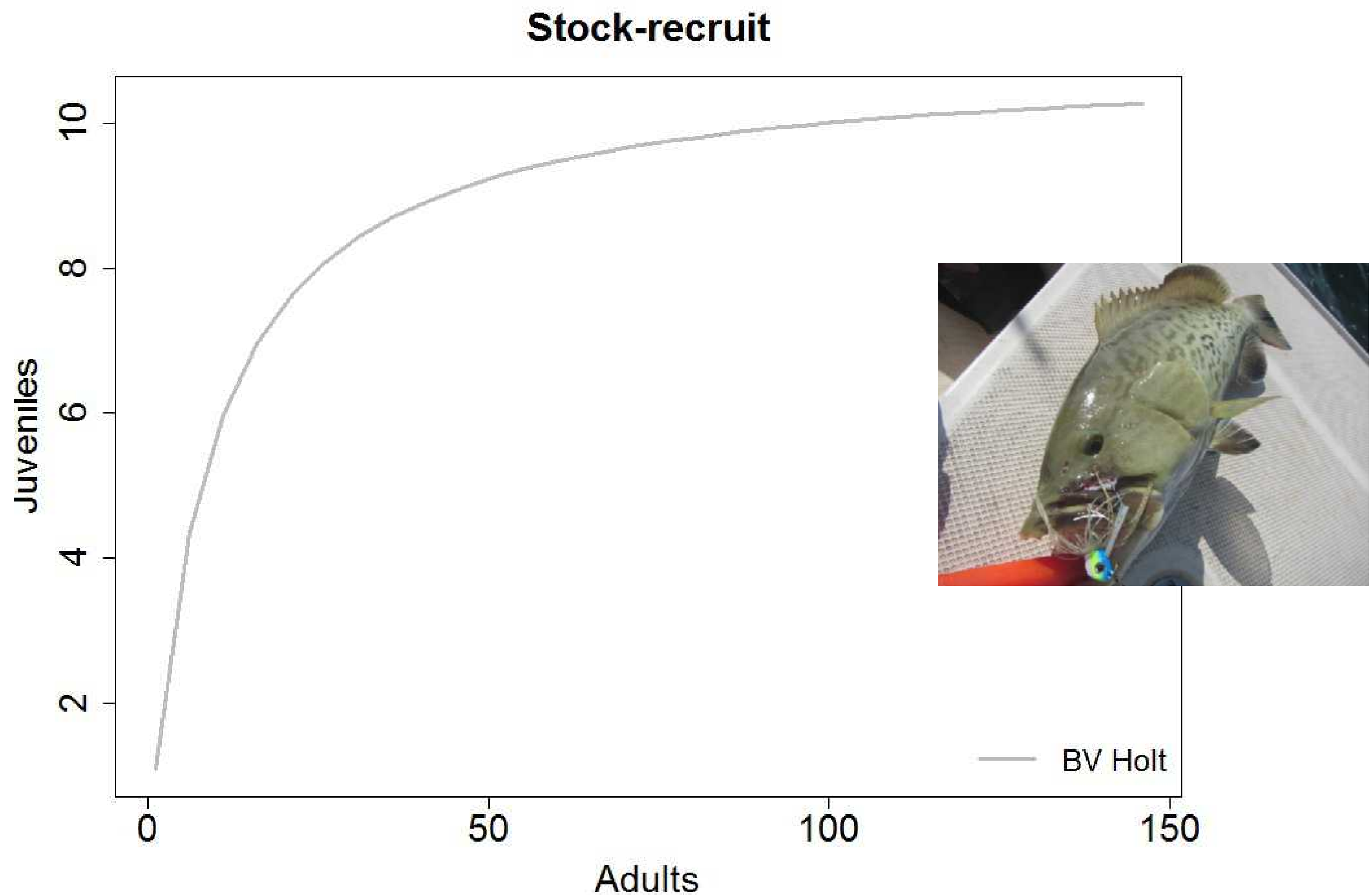
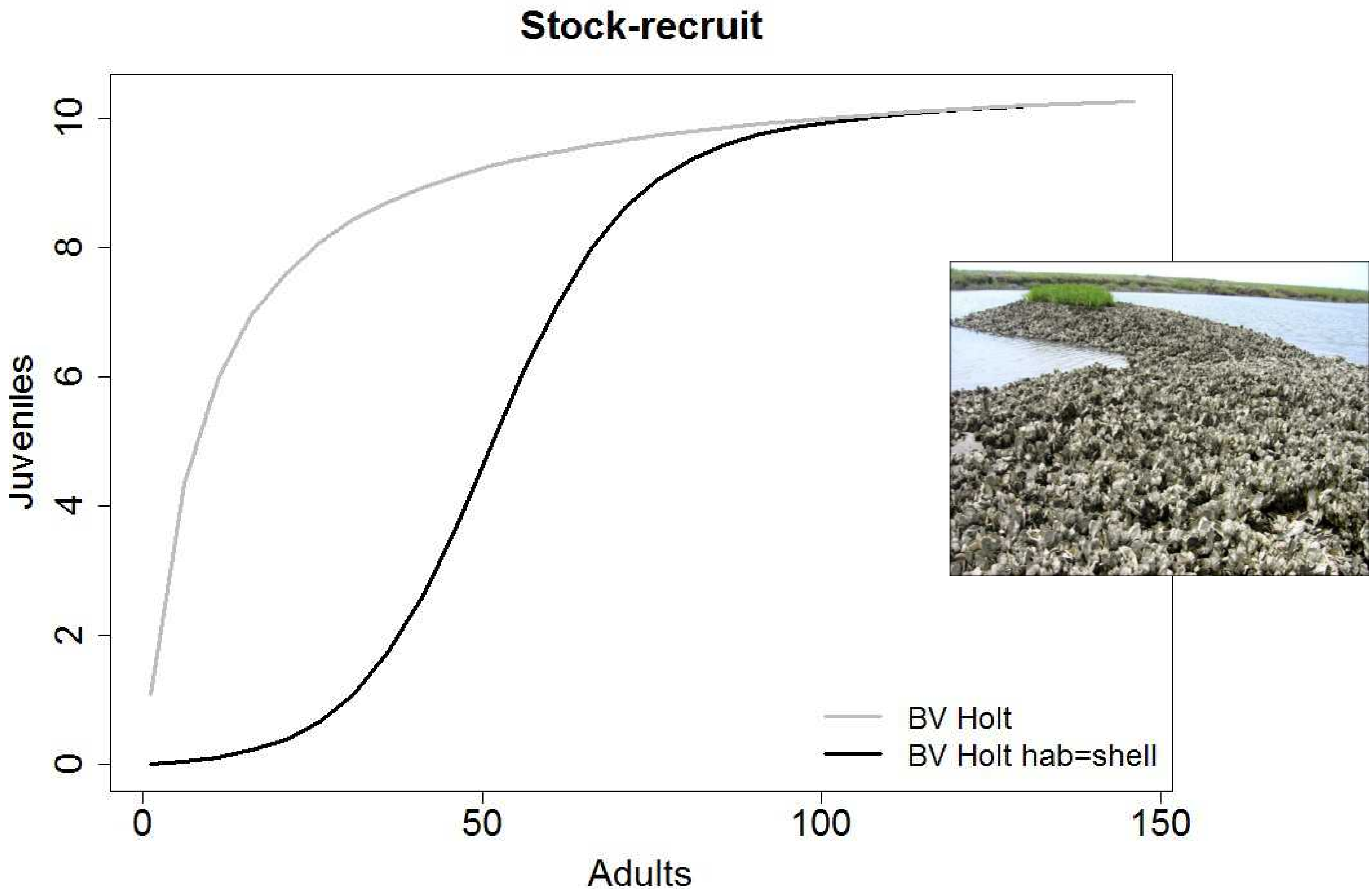
2. Possible implications of shell dynamics

- Putting this in a figure

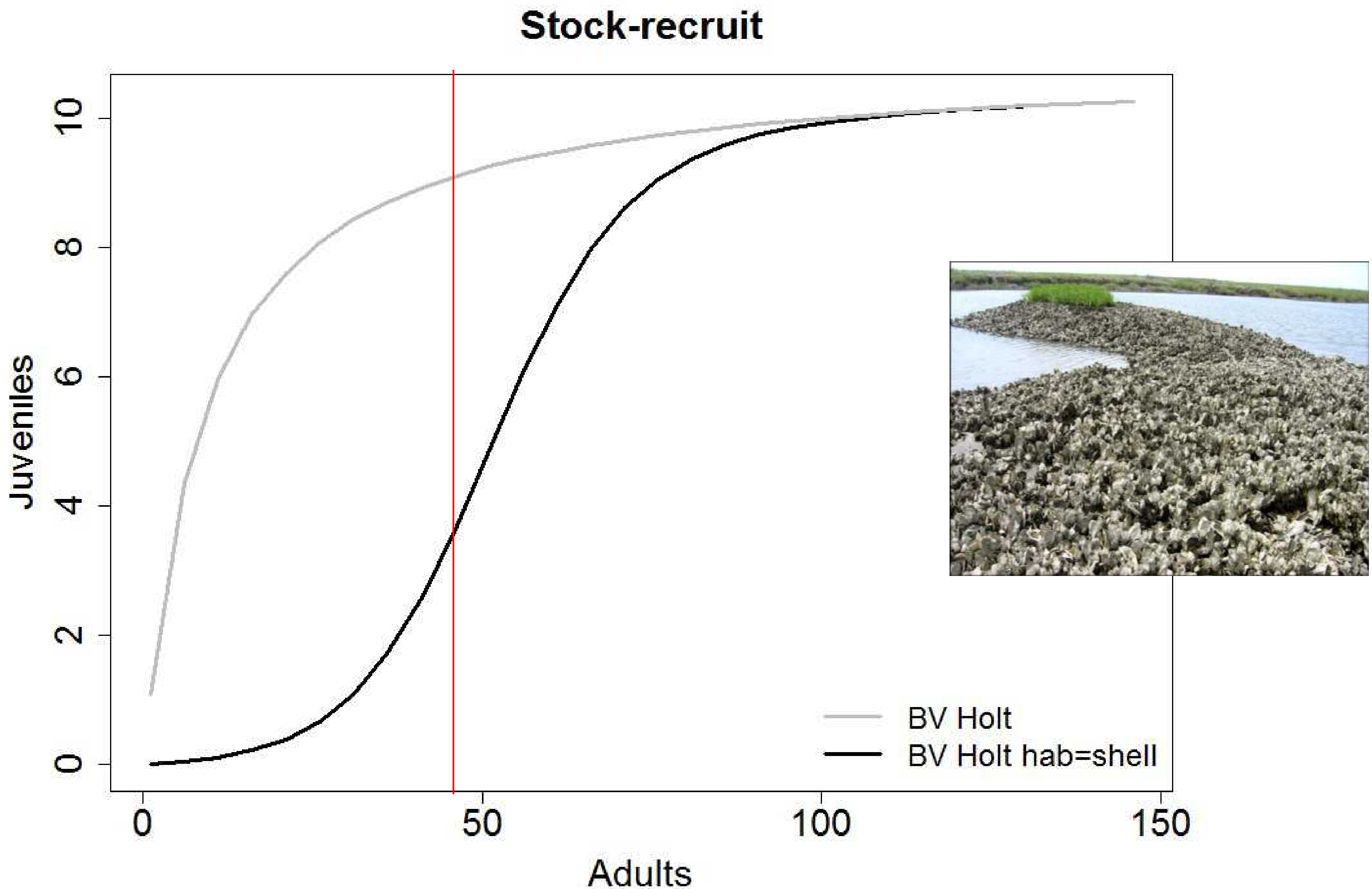
2. Normal finfish stock-recruit relationship



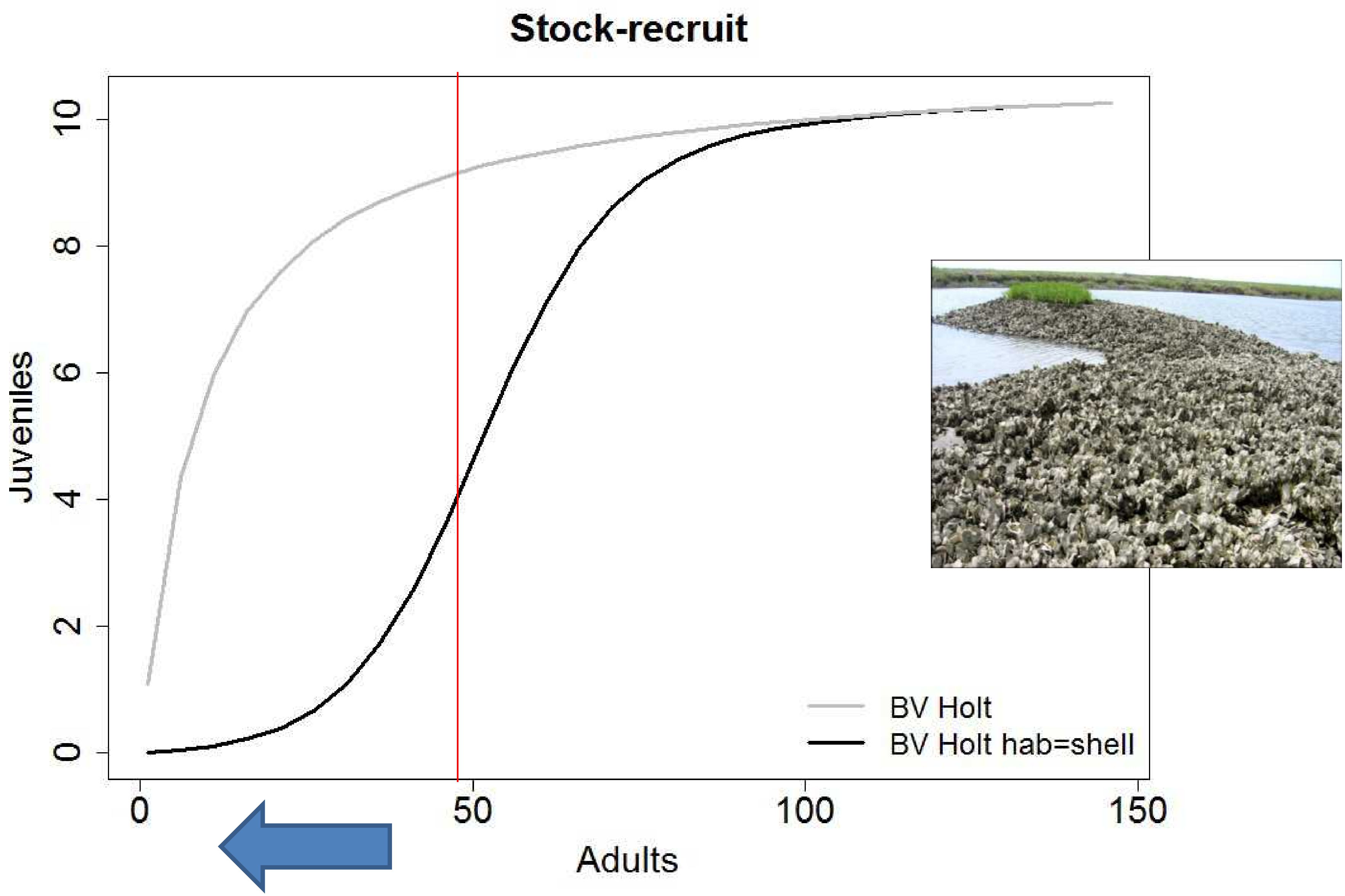
2. Hypothesized oyster stock recruit



2. Inflection point



2. Below inflection point, decline to zero



3. Why we put depensatory shell dynamics in the simulation model

3. Why we built depensation into simulation models

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3. Evidence of depensatory shell dynamics

- Previous papers
  - Wilberg et al. 2013 (autogenic ecosystem engineers)
  - Colden et al. 2017 (reef height drives threshold dynamics in restored oyster reefs)
  - Moore et al. 2018 (oyster rest. w/ positive density dependence)
  - Johnson et al. 2022 (mgmt implication of critical oyster fishery transitions)
  - Others!!

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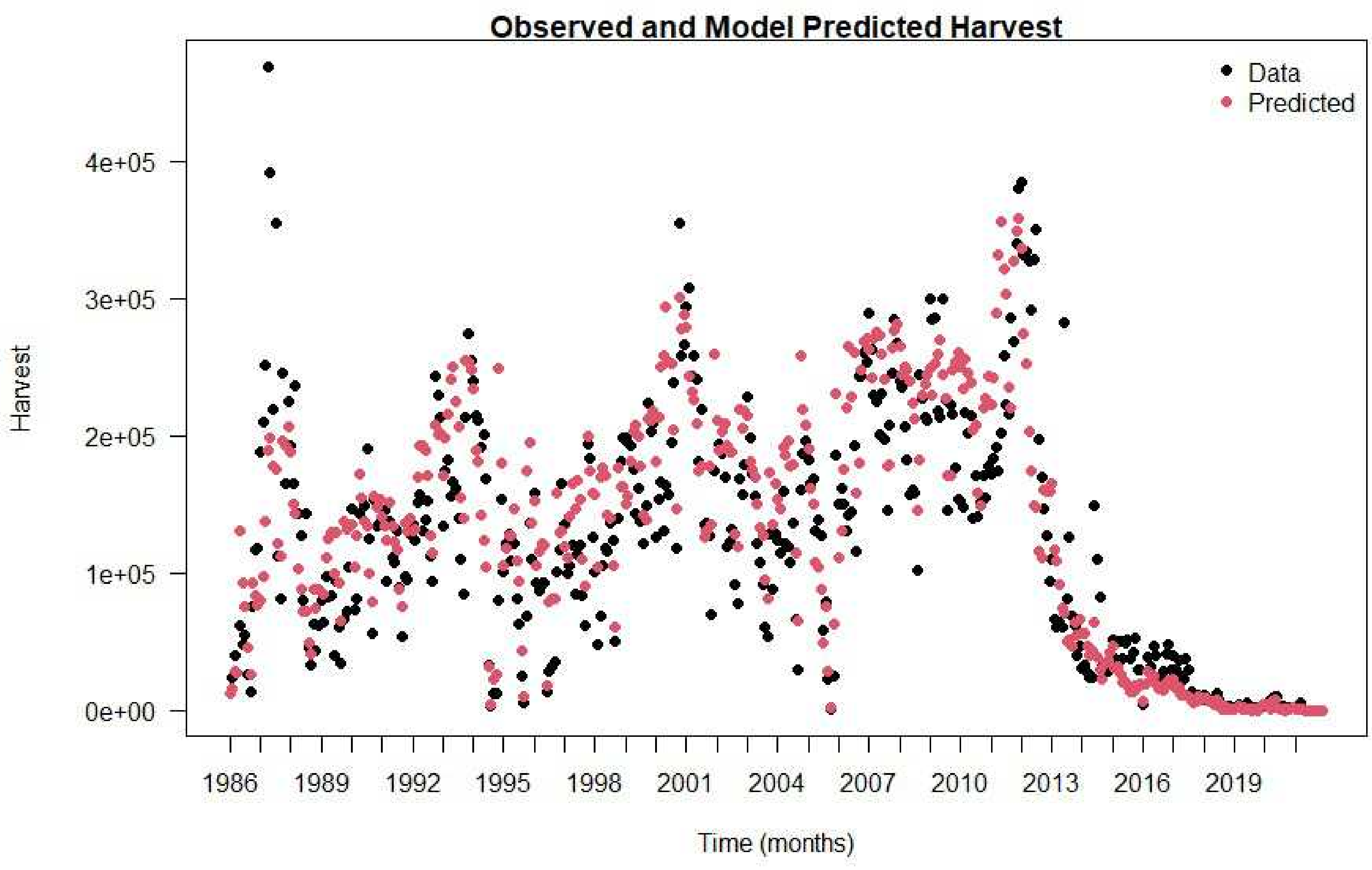
  - Others!!
- Data and estimation (stock assessment models)
  - Use data to estimate recruitment anomalies (annual deviations in survival rate of young oysters)
  - Look at pattern of recruitment anomalies
  - **Worth doing because these models don’t include shell dynamcis**

3. Catch at Size Assessment model—Predictions



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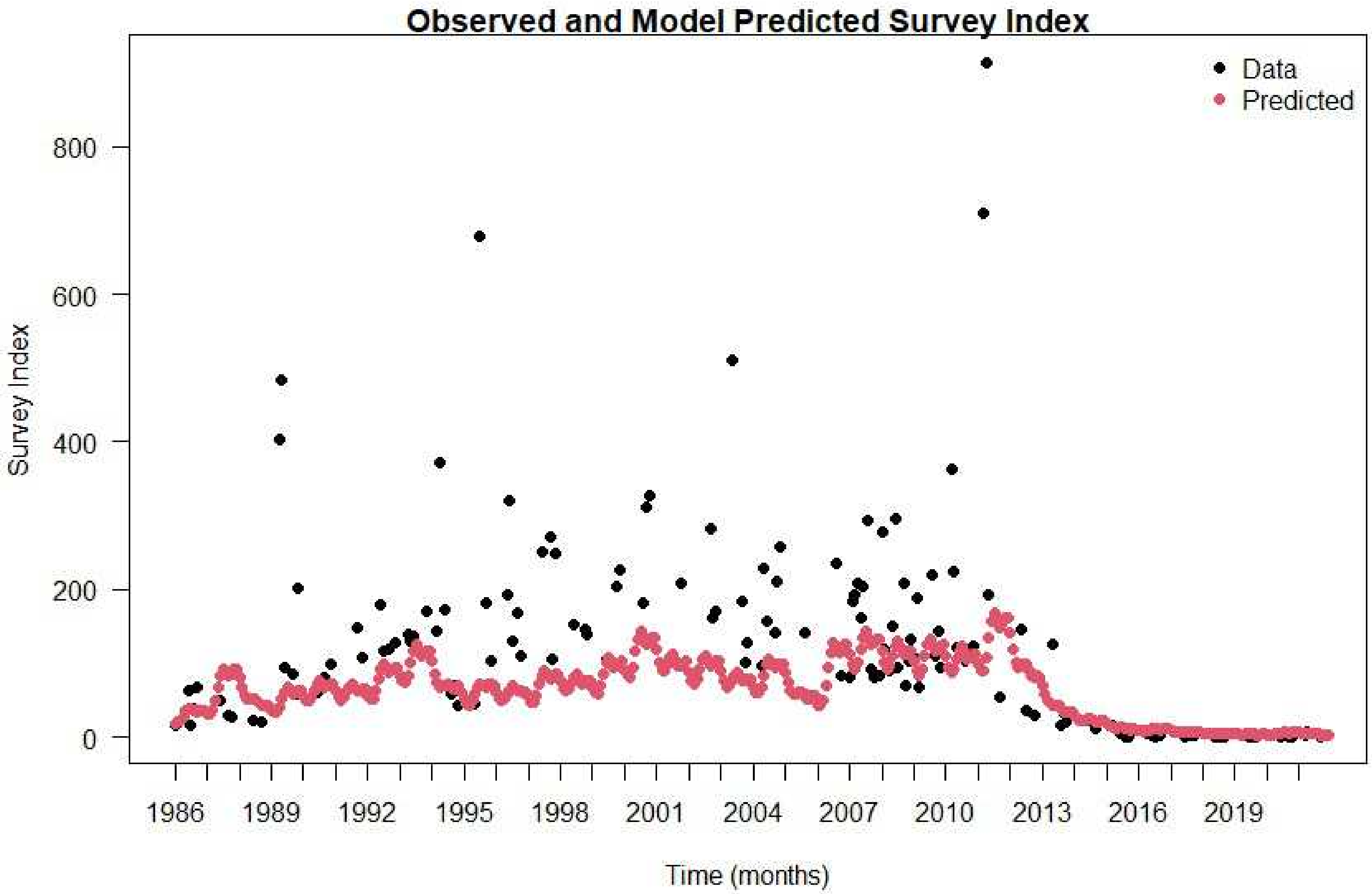
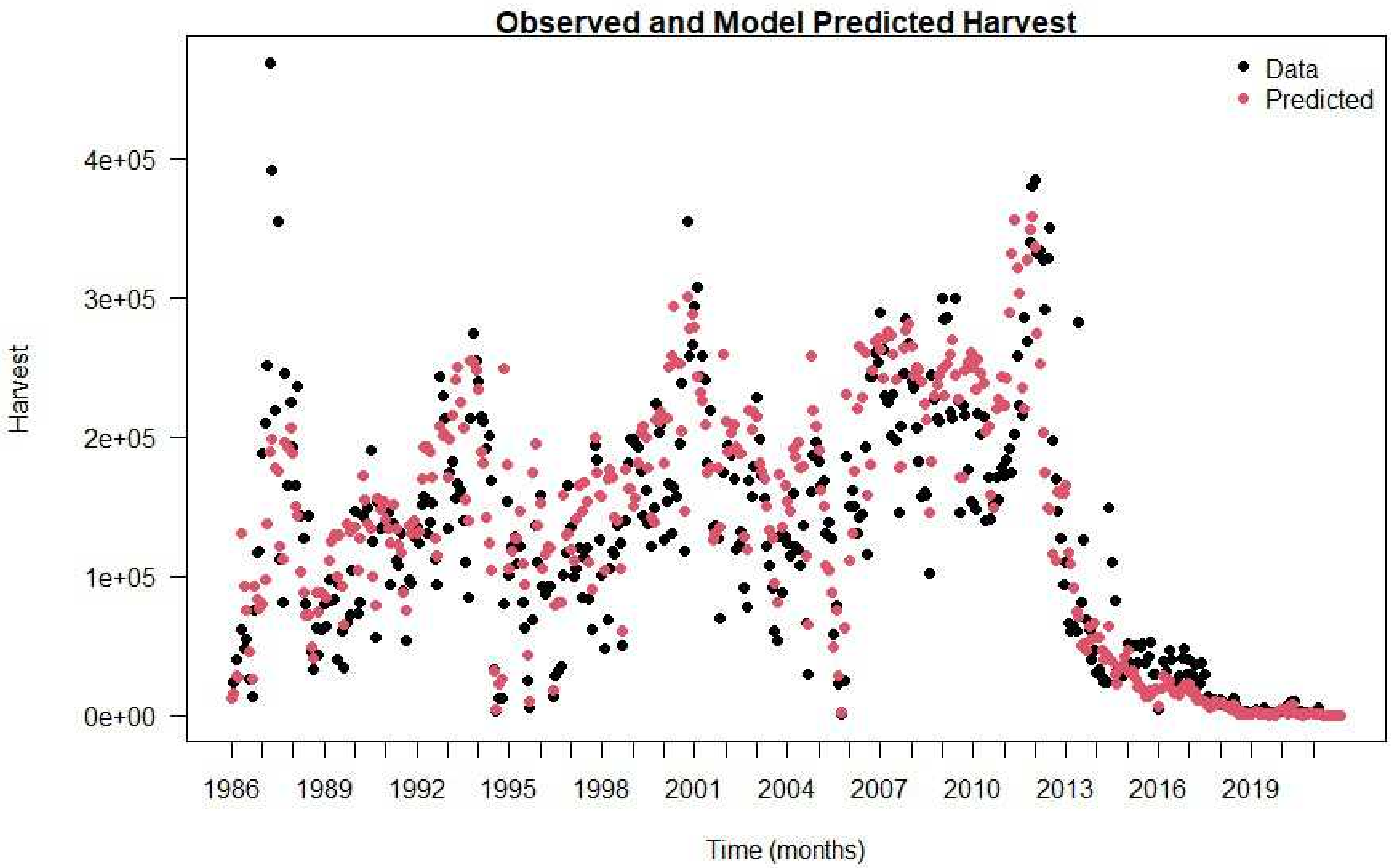
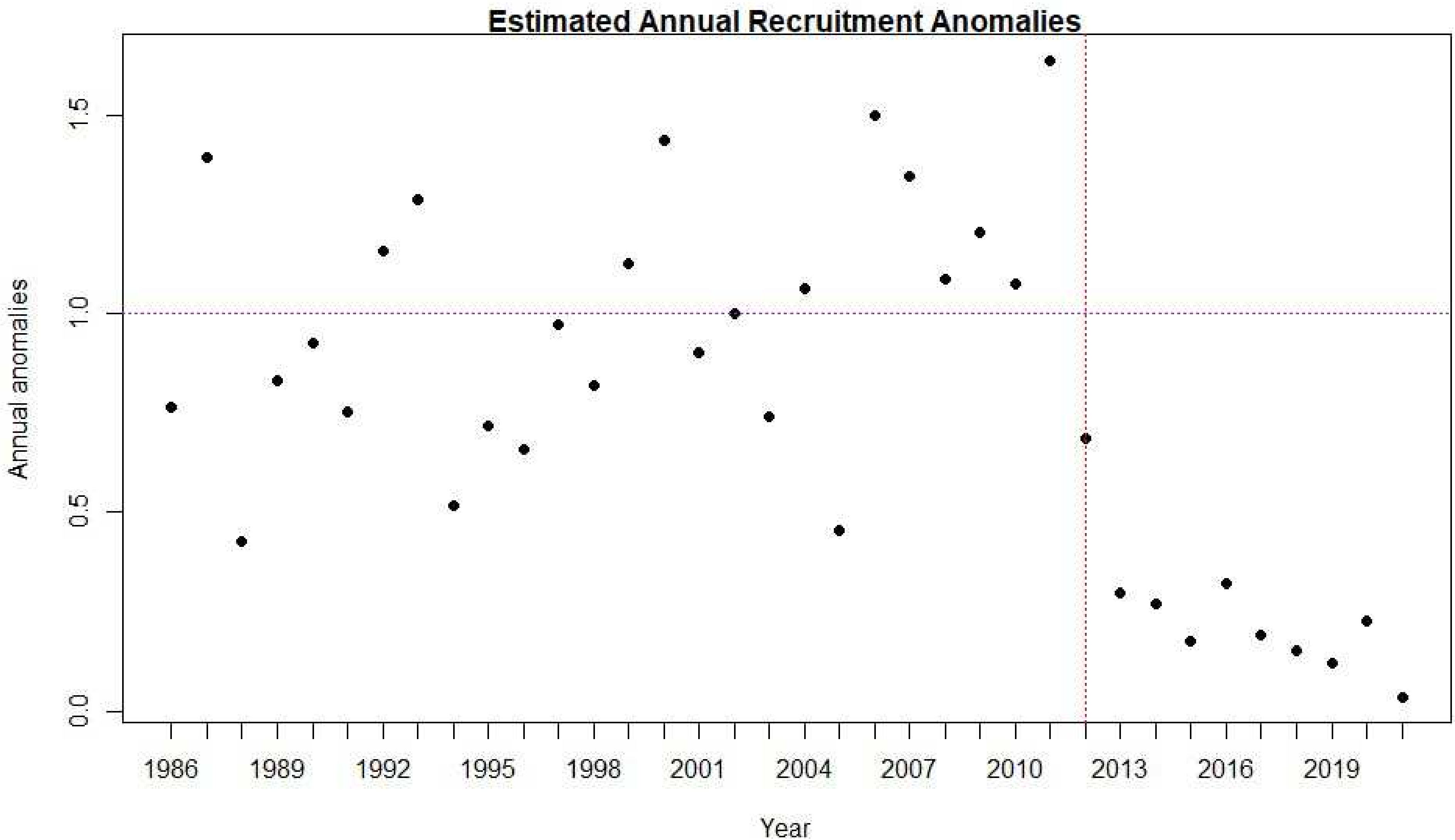


3. What's "driving" these results? Recruitment anomalies because the model does not include shell dynamics (because of convergence issues)

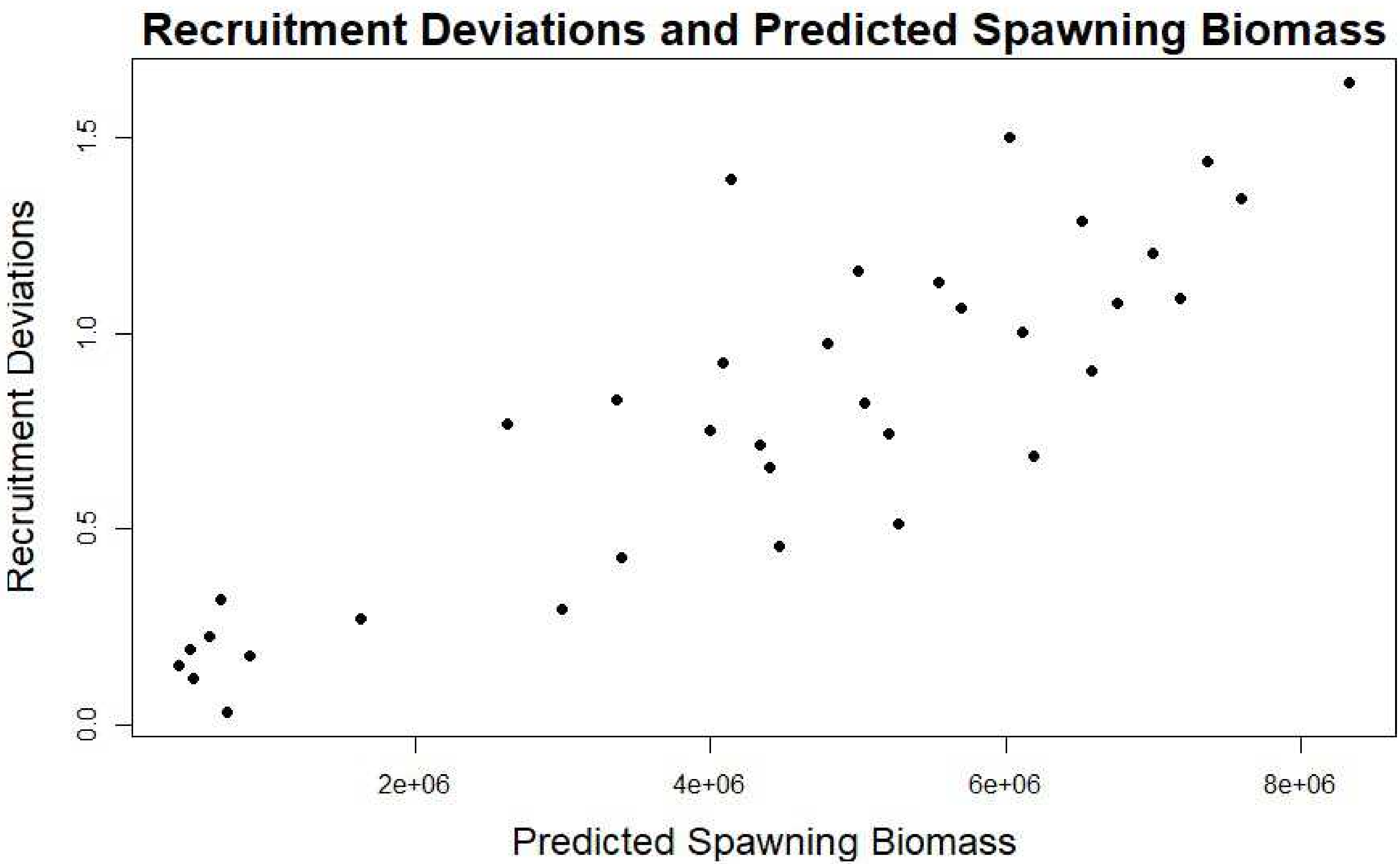


3. Rec. anomalies (juv. oyster surv.) very bad recently



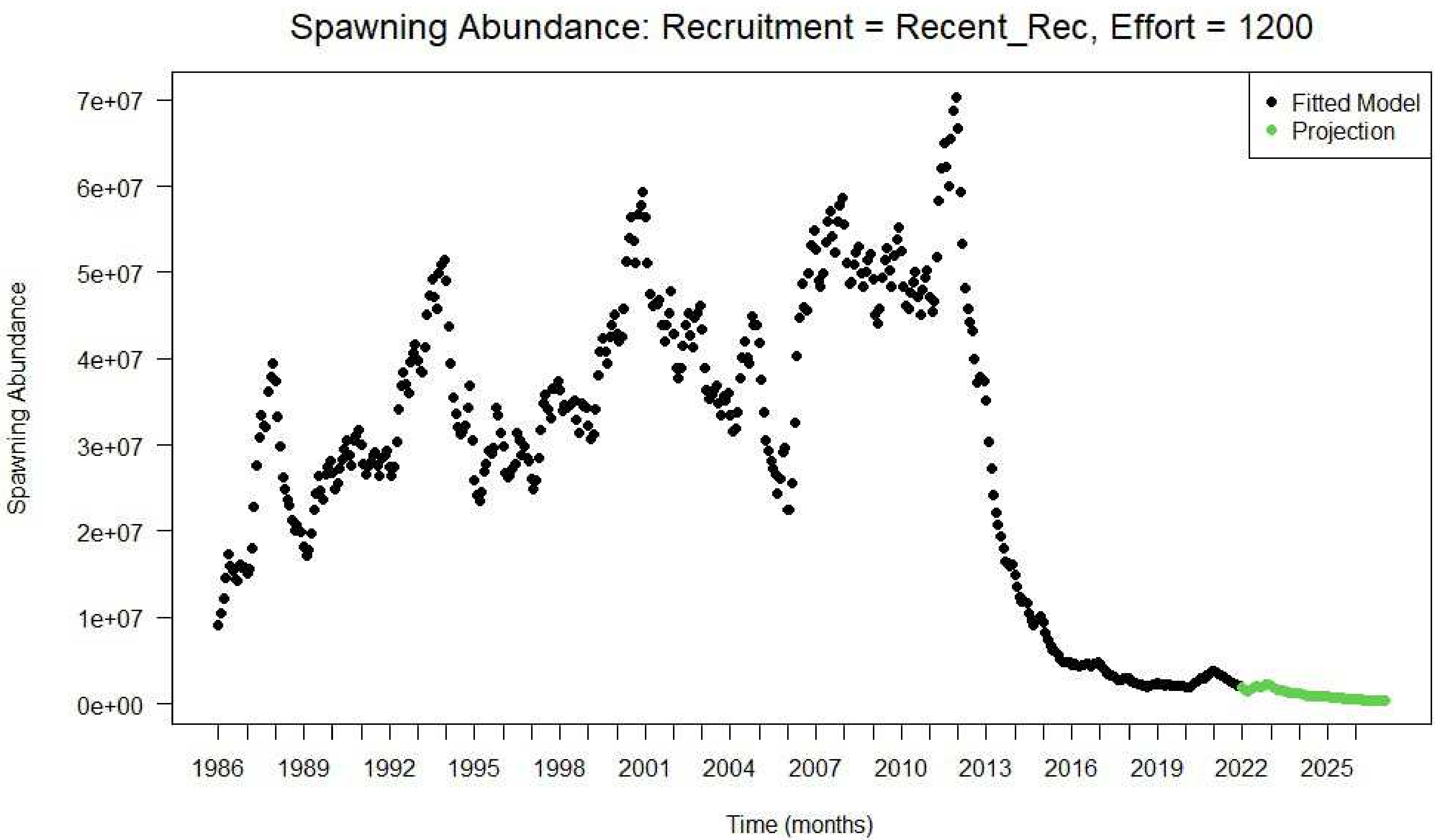
Usually recruitment deviations are expected to be random.
Post-2012 deviations do not *appear* to be random.

3. Rec. anomalies worse when oysters pops low



This is a disturbing pattern…

3. Leads to bad projections for the future



4. Assumptions of models

4. Assumptions of simulation models shown today

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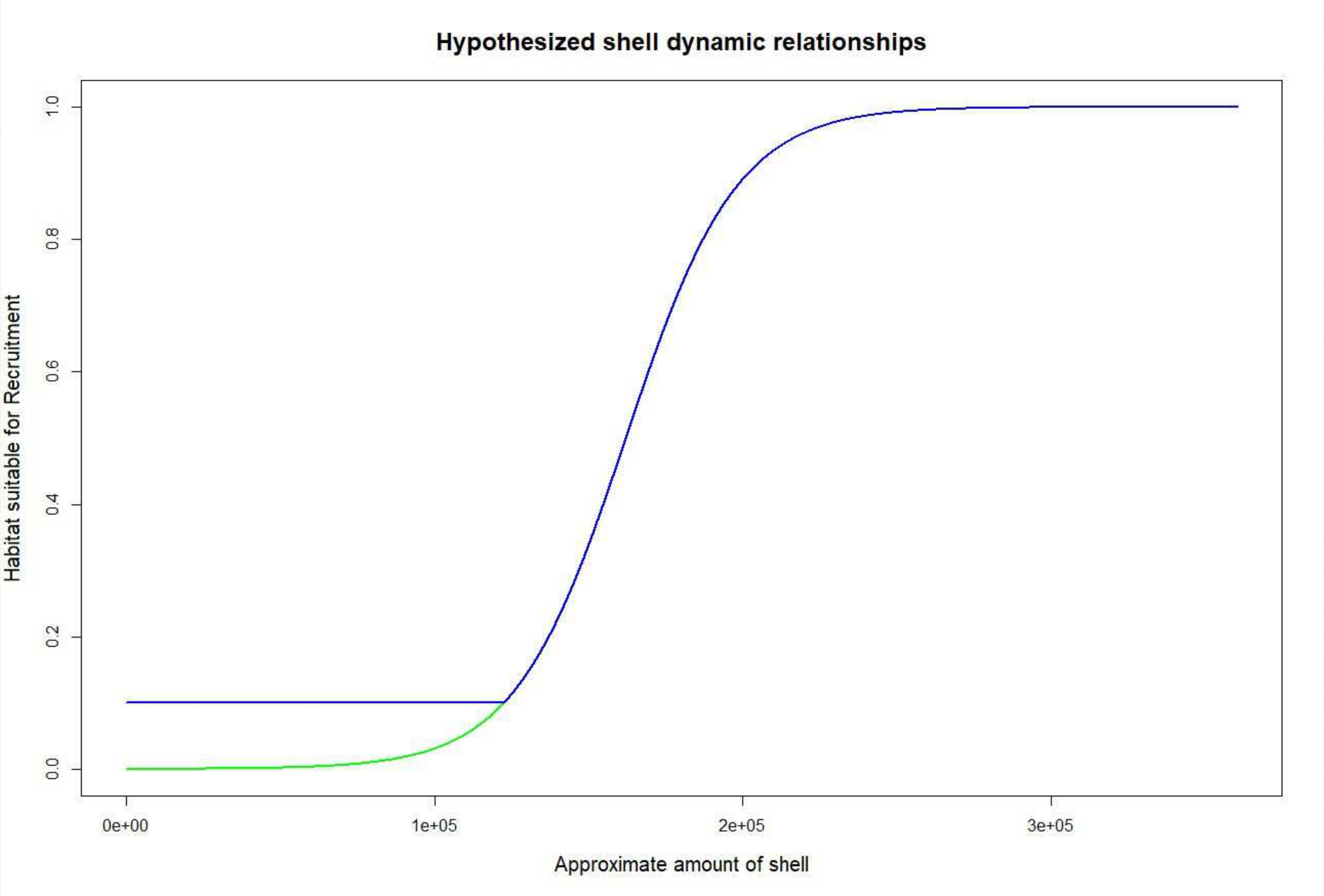
4. Shell dynamic oyster simulations

- “Threshold-safe” assumption—there’s never zero habitat



4. Parameters of interest (1/2)

- Shell dynamics
  - Unfished shell
  - Inflection point (when does depensation start)
  - Steepness of decline (sd of logistic)
  - Threshold “safety”—what minimum
  - “mortality” or decay (wrt recruitment potential) rate of shell
- Scaling parms
  - Ro, q, etc.: ballpark informed from assessment, but represents a smaller reef right now
- Mgmt actions
  - Type of effort (fixed), effort closures and reductions
  - Restoration options (amount, timing, decay rate)

4. Parameters of interest (2/2)

- Other fishery stuff
  - Some discard mortality, but assumed very light (1%) for now
  - Illegal harvest only represented by few sub-legal oysters with vulnerability
  - Assumes oysters in all months but Aug and Sept
    - (based on landings data, can easily change assumptions)
  - Currently assuming 5 bag/person/day
    - Matters most of active harvest mgmt.
  - Assumes effectiveness of unit (hour) fishing goes down as oyster population falls

  - None of these, in my opinion, are major things to worry about right now

5. Simulation results: depensation, collapse, restoration

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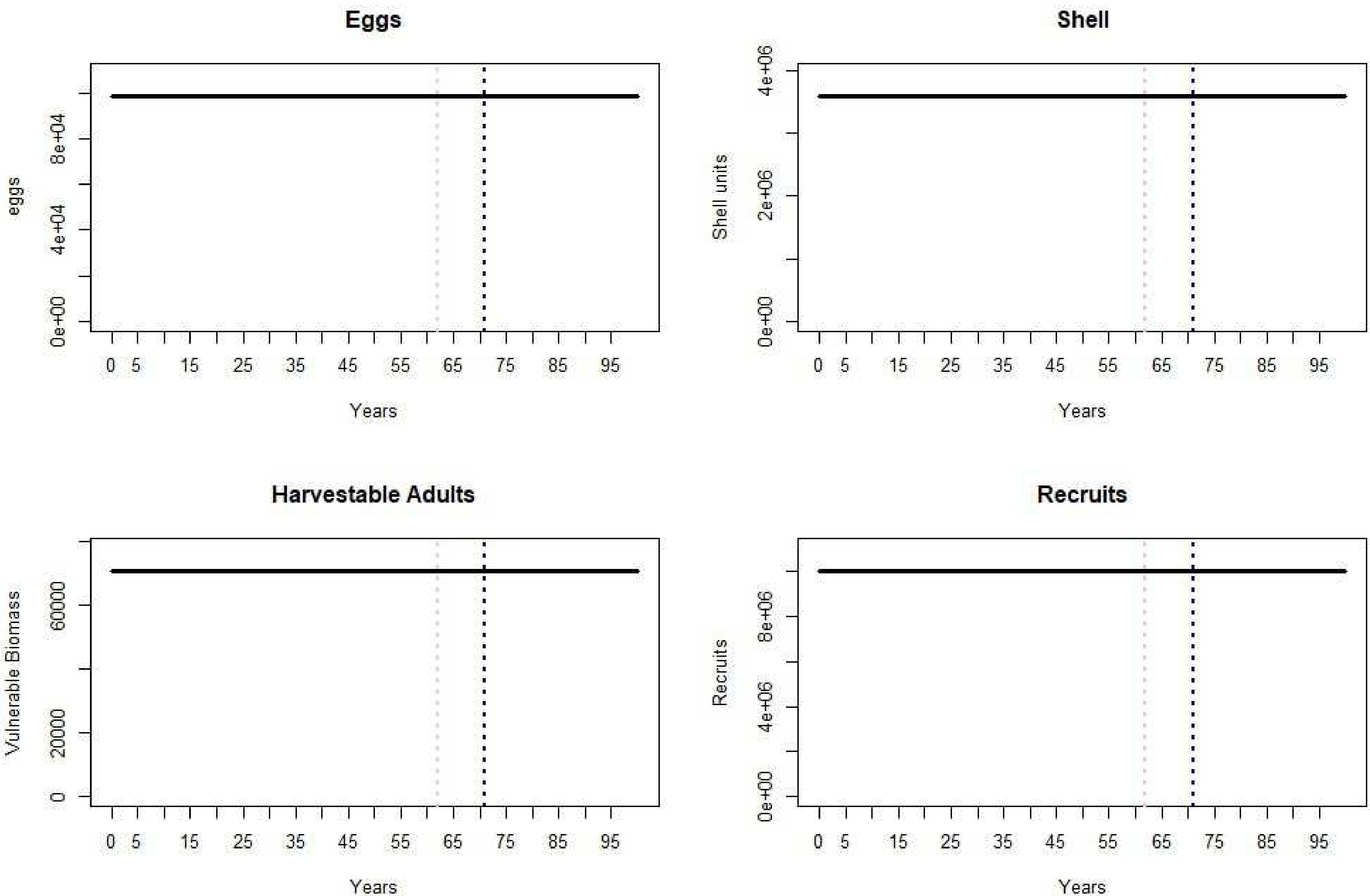
5. Simulation results: depensation, collapse, restoration

- What I'm going to show and why
  - Plots of oyster population metrics
  - Why not catch metrics? Focus on effects of depensation, effort, restoration

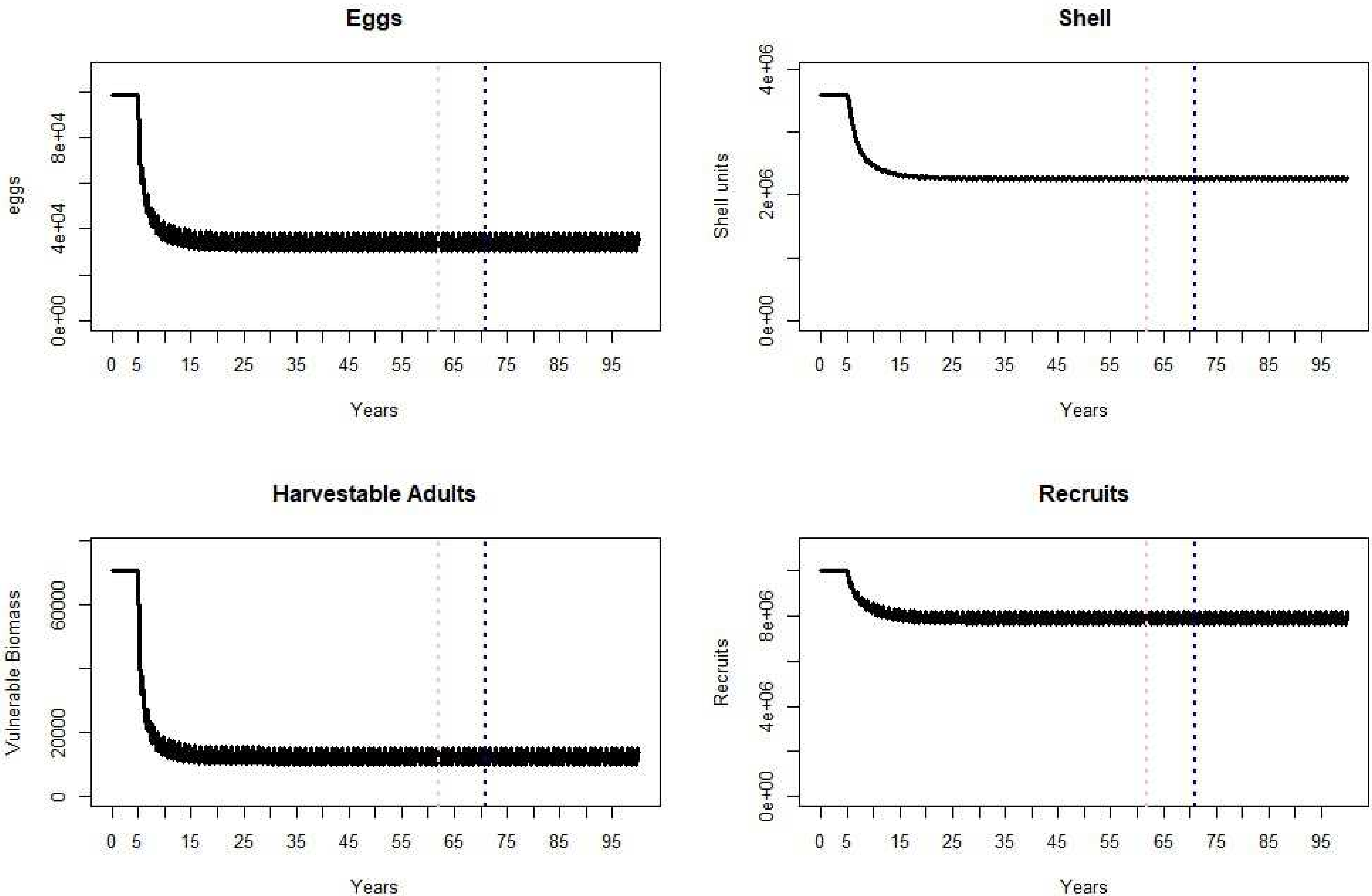
- Key assumptions constant through figures
  - Constant effort (monthly, yearly), not completely realistic but useful
  - Depensatory shell dynamics
  - Length of fishing closures
  - Effectiveness and "type" (kinda) of restoration
  - NO stochasticity (randomness)!

- Key things that change
  - Amount of annual effort—fixed, and rather low (limited entry, why?)
  - Decrease in effort after decline (including closures)
  - Amount of restoration
  - ***if I simulated restoration, I simulated a 5yr closure AFTER restoration***

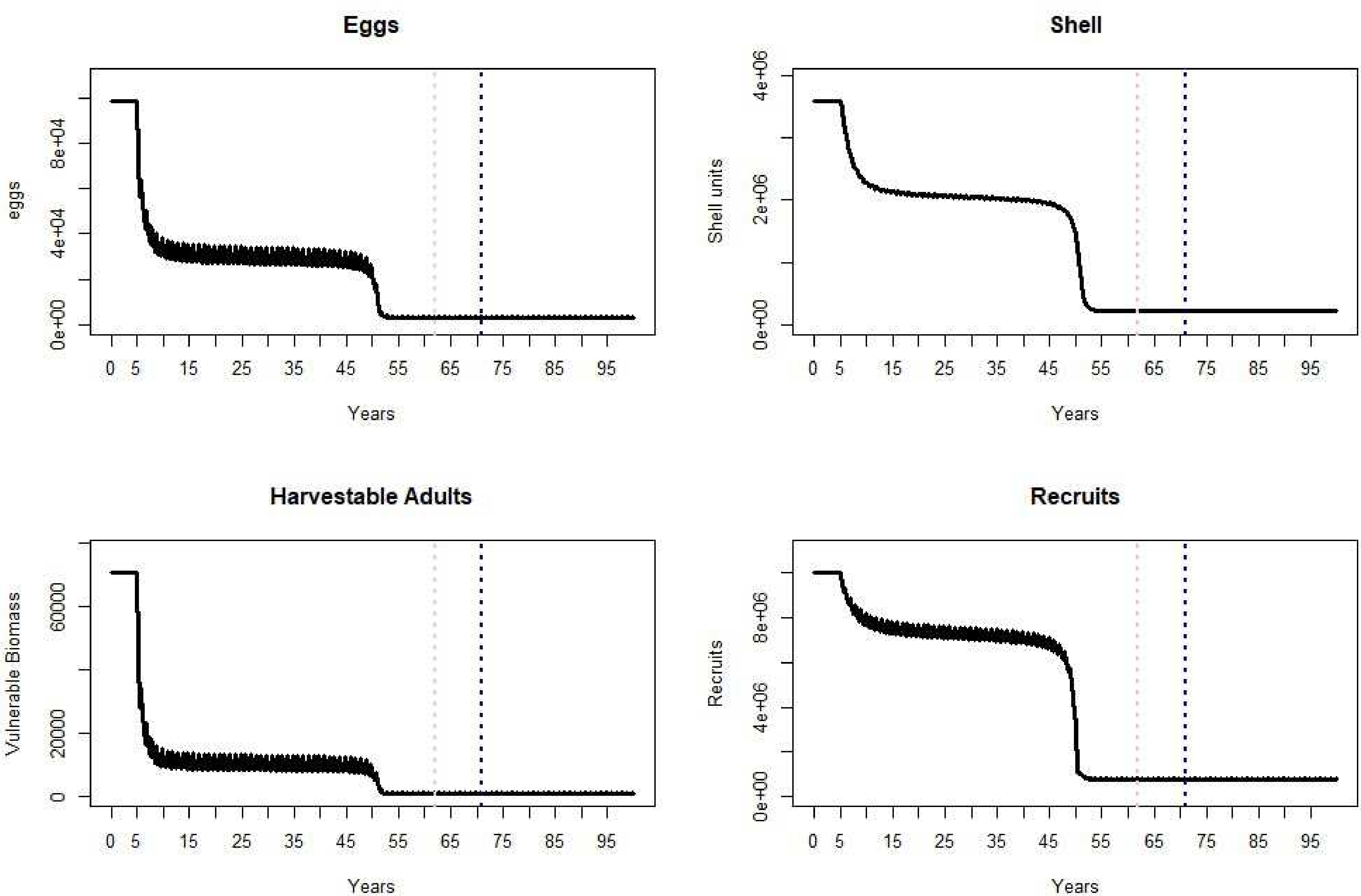
5. Null model, no fishing



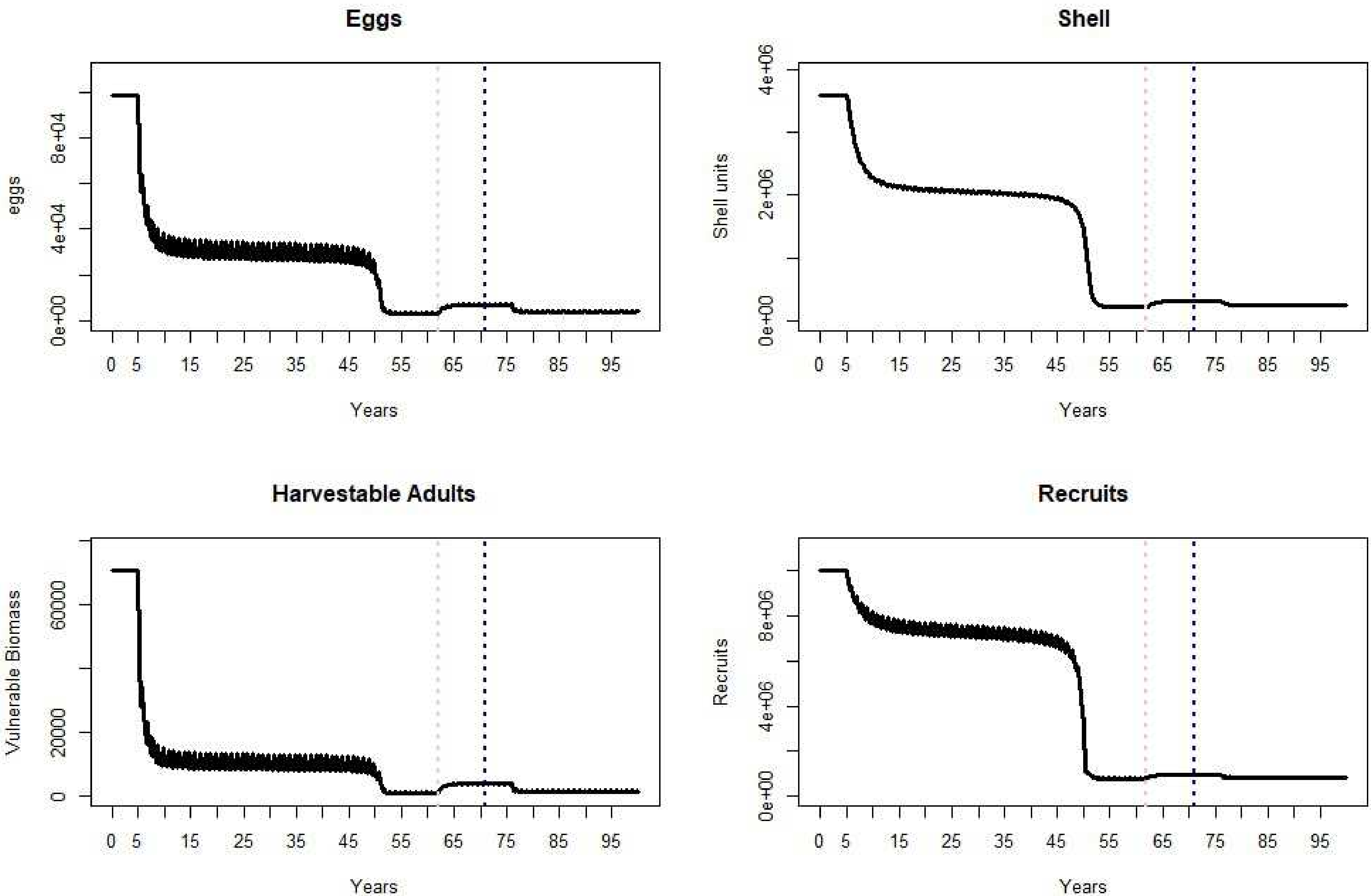
5. Fishing, but no “collapse”…yet



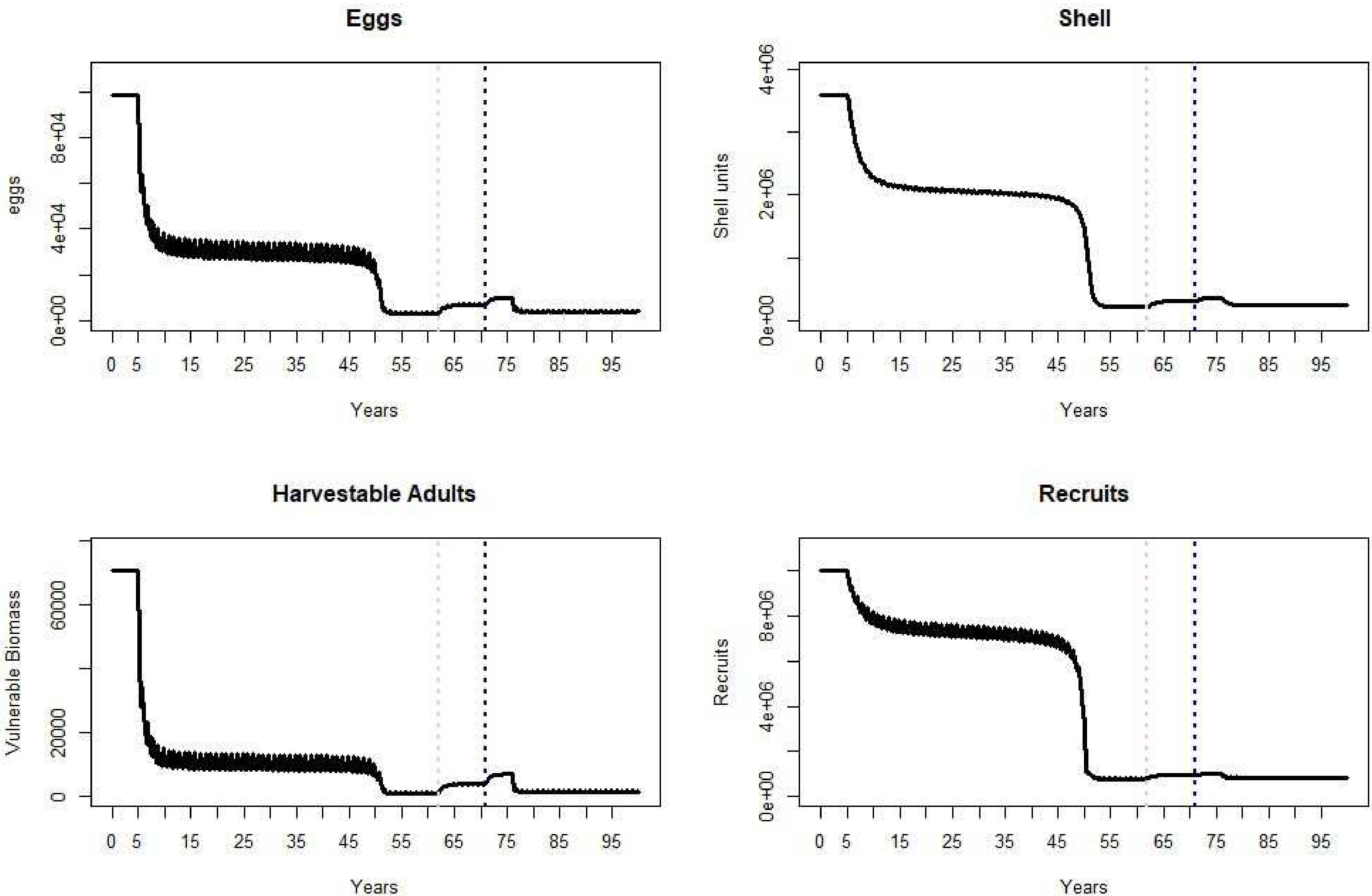
5. More effort, collapse



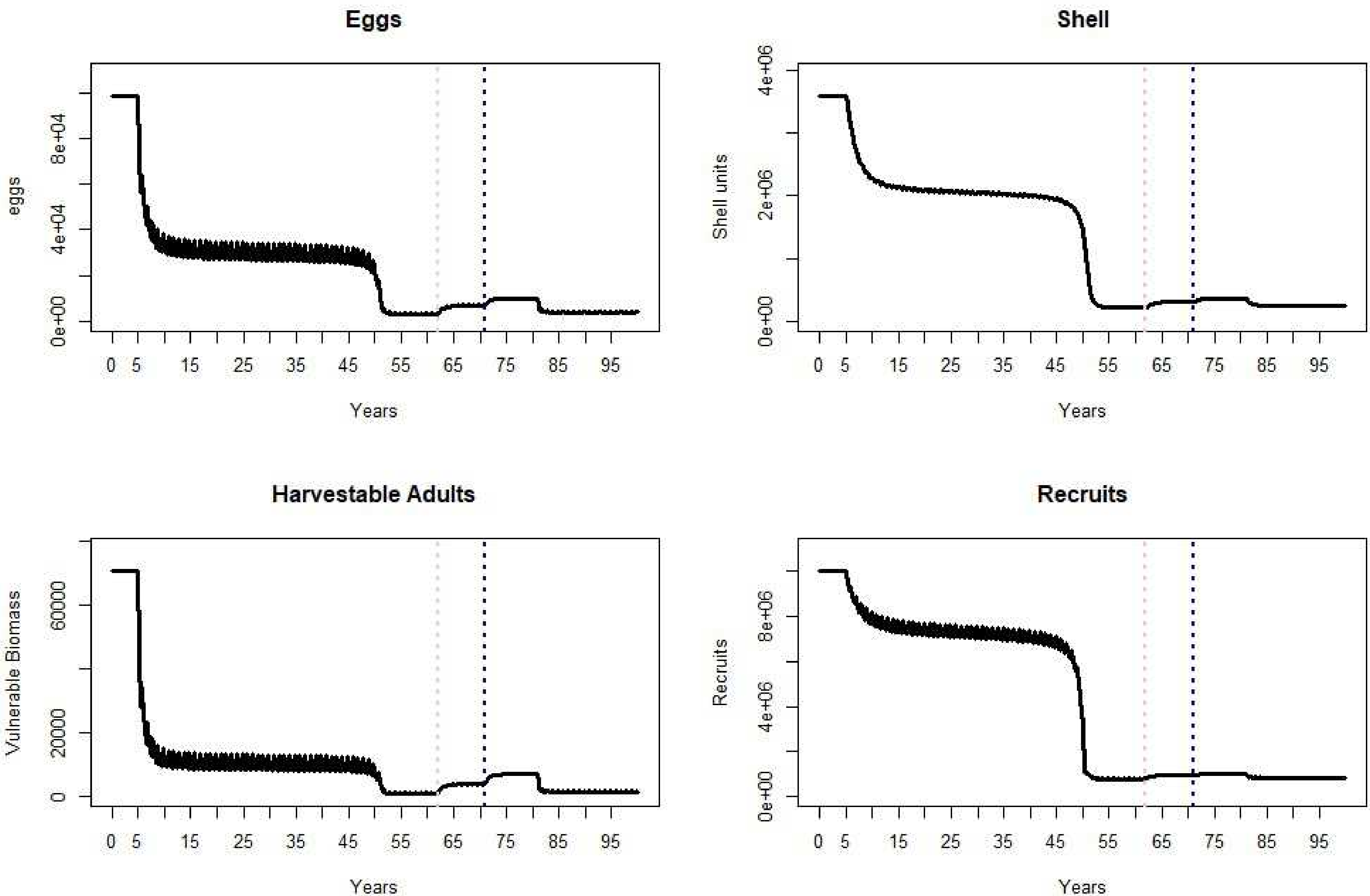
5. More effort, collapse, effort reduction



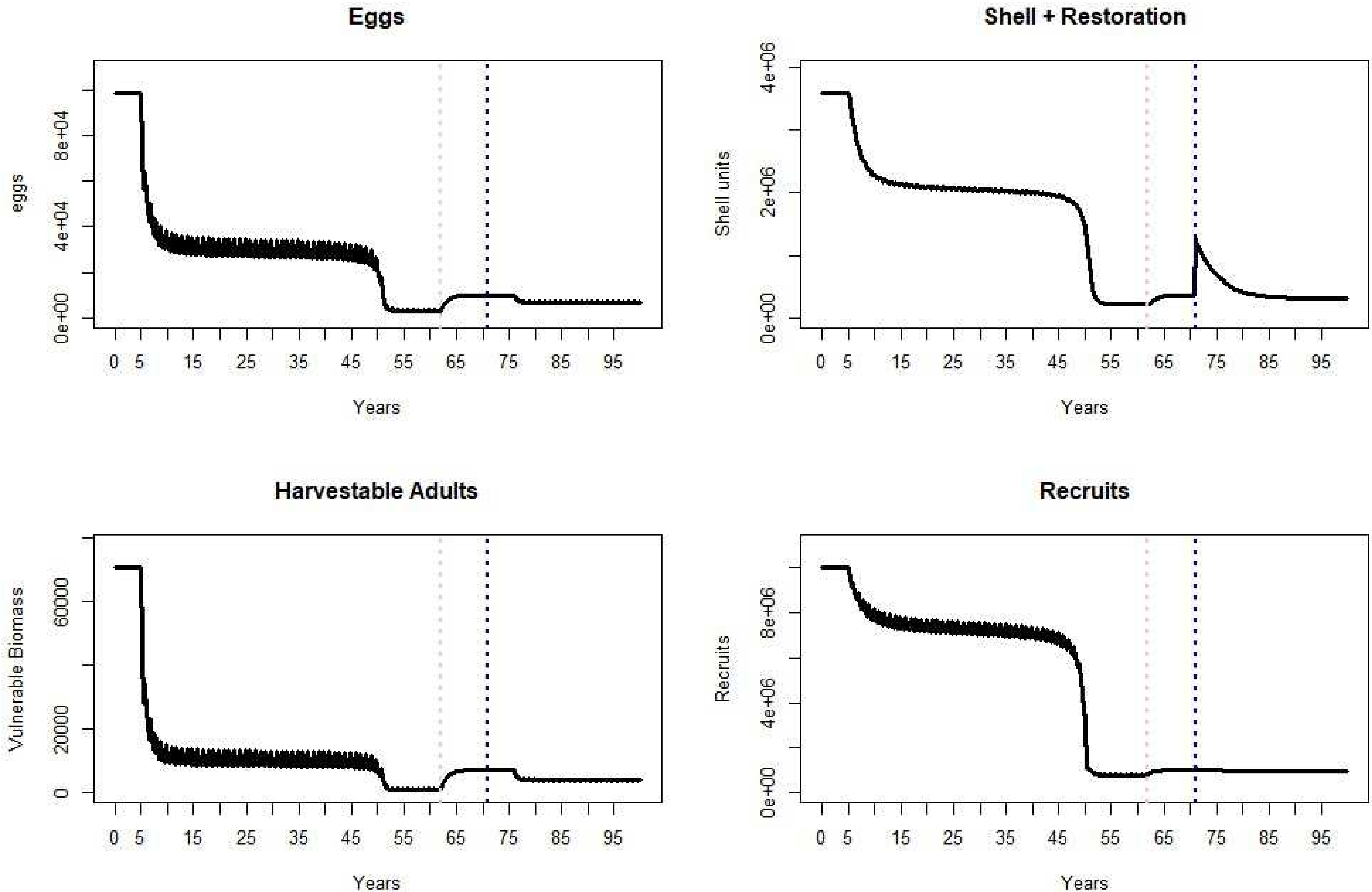
5. Collapse with eff. reduction, 5yr closure, 50% eff thereafter



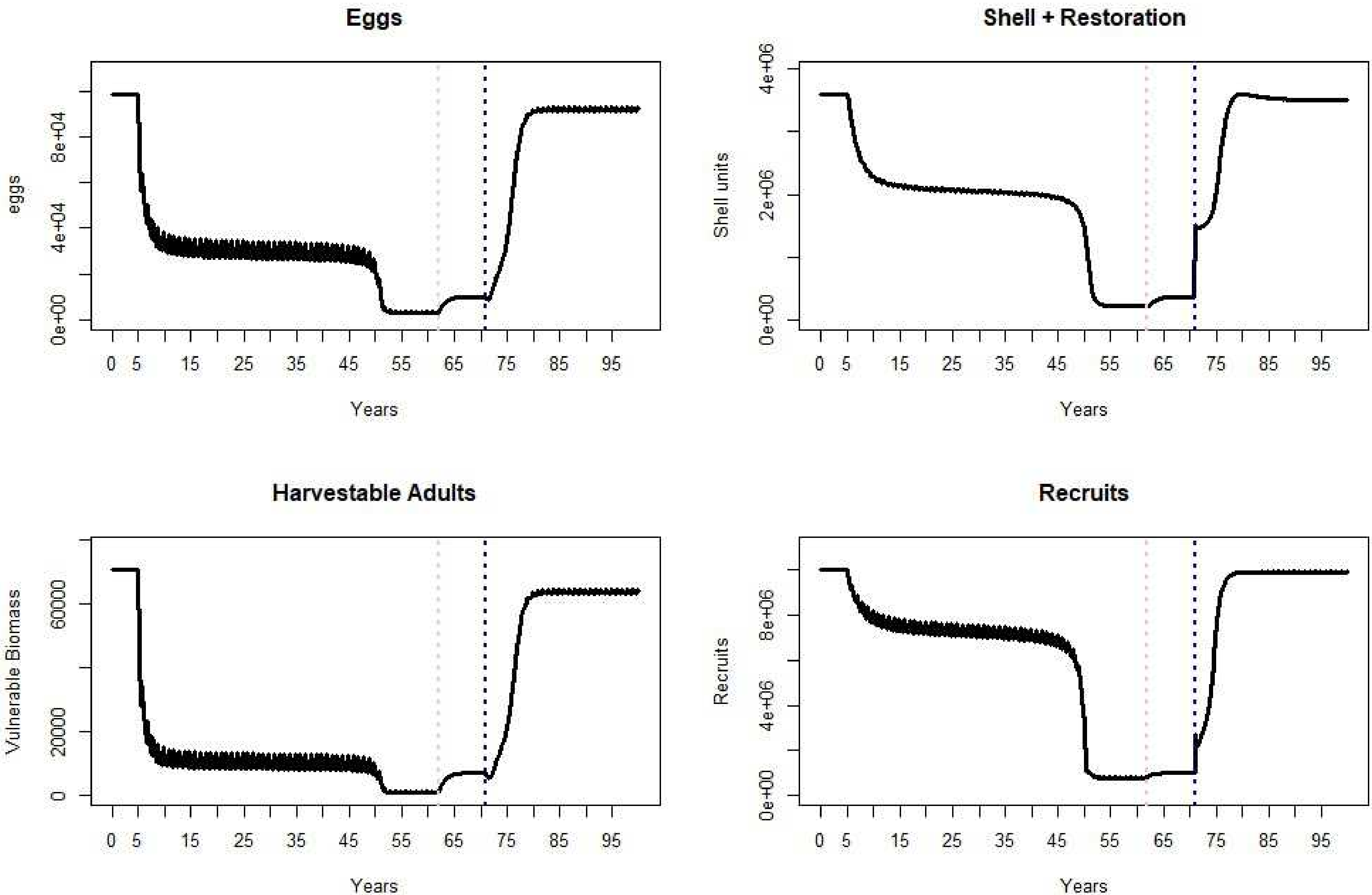
5. Collapse with eff. reduction, 10yr closure, 50% eff. after



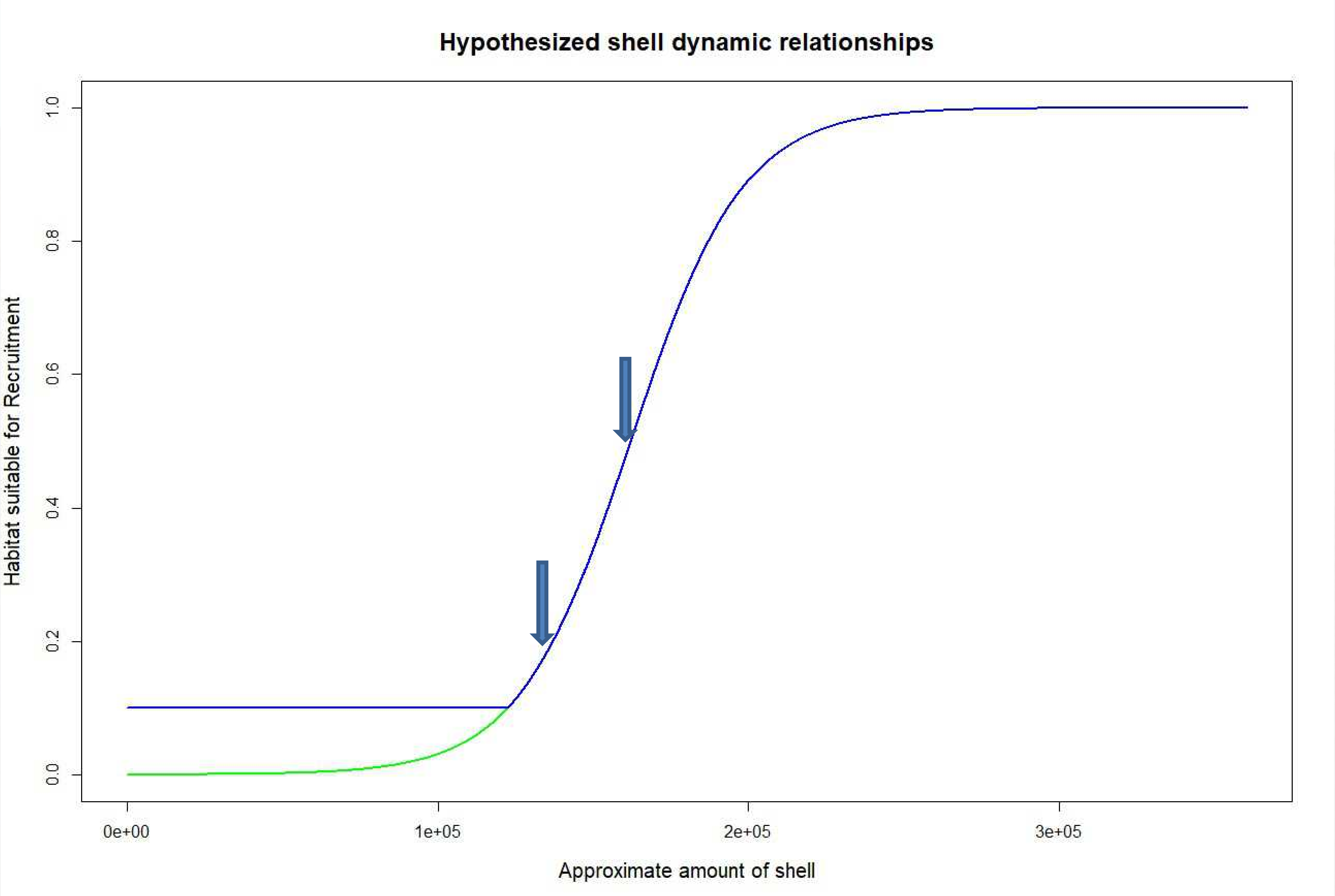
5. Eff. Reduction, 5yr closure, major restoration (~900k ‘units’), post-restoration effort 10% original



5. Eff. Reduction, 5yr closure, major restoration (~1.1m 'units'), post-restoration effort 10% original



5. Shell dynamic oyster simulations



5. Caveats and notes on this

- 1. That relationship between shell and habitat suitable for recruitment is critical, and very uncertain.
  - Hard to estimate (statistically tricky)
  - No near-unfished data
  - No measurements quantifying habitat change, only anecdotal
- 2. Relationship uncertain in 2 ways
  - How “sharp” it is (affecting suddenness of success/failure)
  - Where inflection point is (here probably too conservative, why I did that)
- 3. A much greater uncertainty looms—is it even habitat that matters?
  - Other things besides habitat can drive low survival (preds, disease, env)
  - Sometimes one thing changes a system and another sustains that change (cod)
  - Habitat is almost certainly *a* driver, doesn’t mean it’s the only one
  - Note habitat and preds can be linked, that is expected
  - See Johnson et al. 2022 for more detail on this

5. How should you think of all this?

- My job is not to tell you what to think. It's to tell you what I think given what I've scientifically tested/assessed/explored.

- I'm not certain things will go exactly like this
  - How much needs to be restored
  - How sudden things will be
  - Not even <u>certain</u> habitat is the main driver

- I do *think* things will go somewhat like this
  - I think it's likely habitat is driver, but not proven.
  - Restoration will be key for repaired fishery
  - Restoration may need to be more substantial than ever before
  - Effective restoration *may* bring back fishery quickly

5. Suggested take-home points

- 1. It’s not surprising to see depensation in oysters
  - Implies alt stable states, very slow natural recovery
- 2. Potential evidence of depensation, alt stable states in AB oysters
  - Compatible, not conclusive
- 3. Depensatory shell dynamic parm. values critical and uncertain
  - Threshold level—what’s minimum habitat “amount” needed
  - Akin to minimum reef height from Colden et al. 2017
- **If believe assumptions, very possible to do a lot of restoration and not enough to bring back system**
  - Even with carefully controlled/managed effort
  - Asymmetrical risk—much better to restore too much than too little

Likely critical amount or types of restoration, but we are not sure what they are

5. Discussion and questions (so far)

6. Simulation results: restoration and “sustainable” fishing

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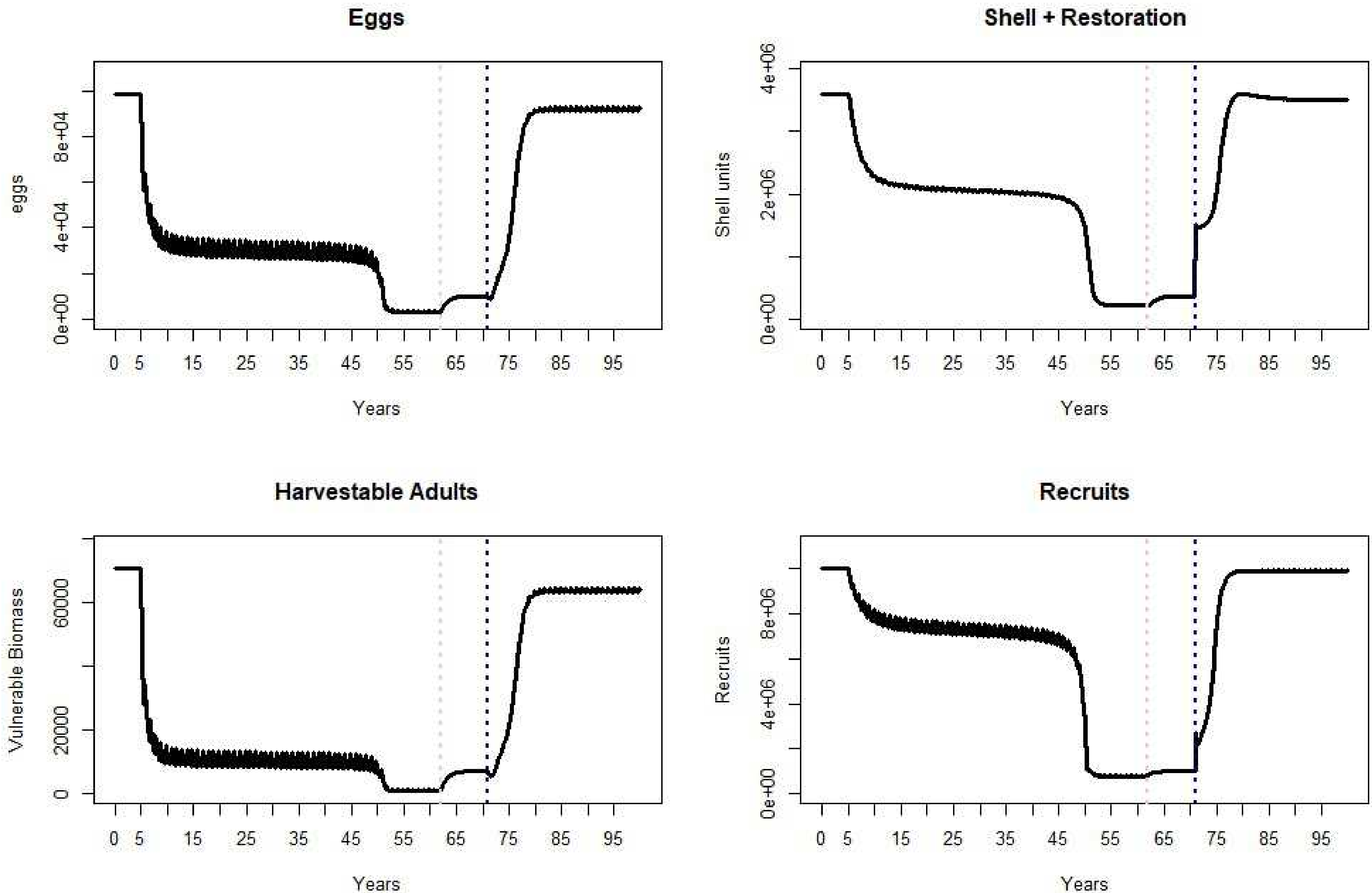
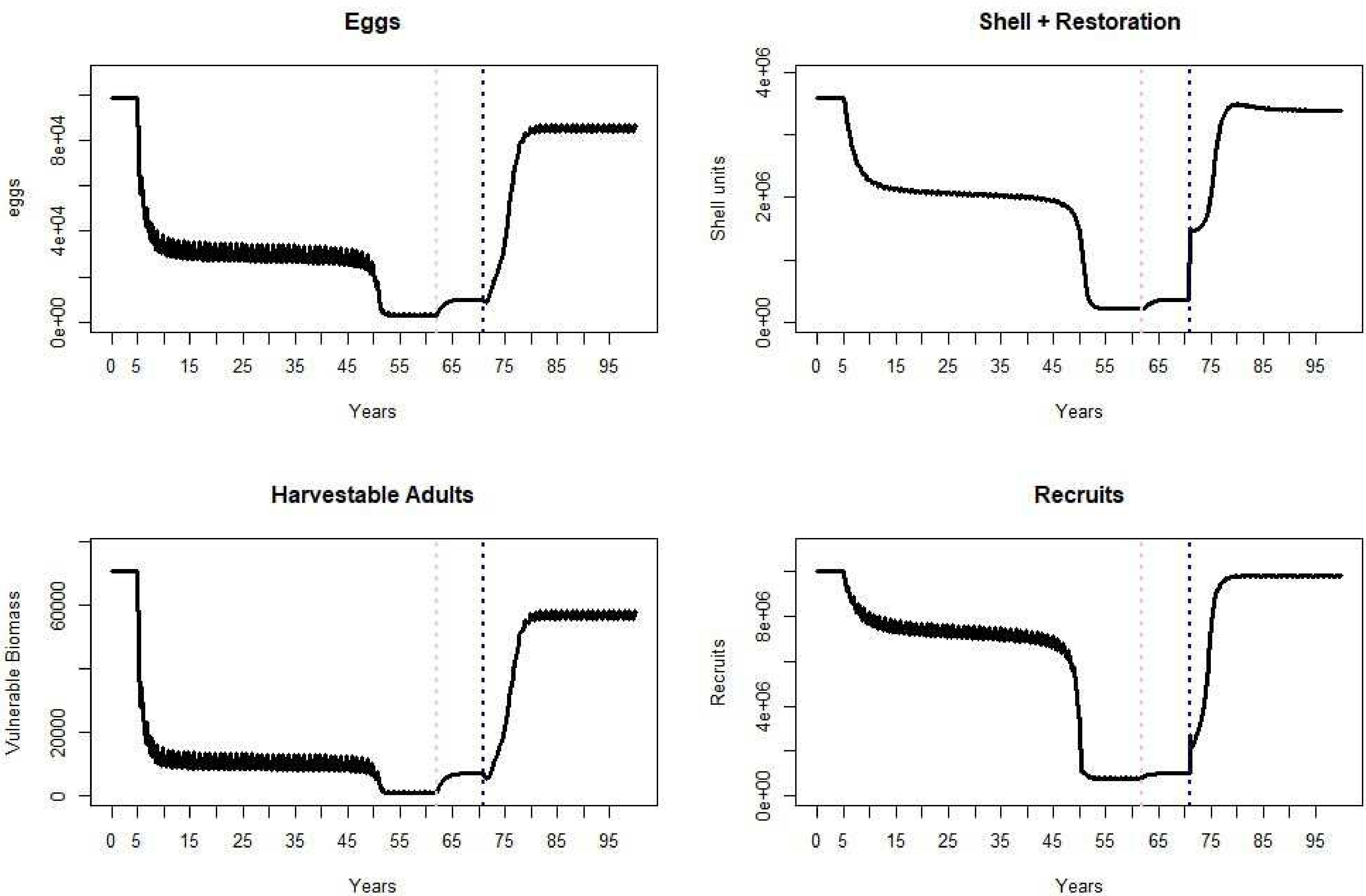
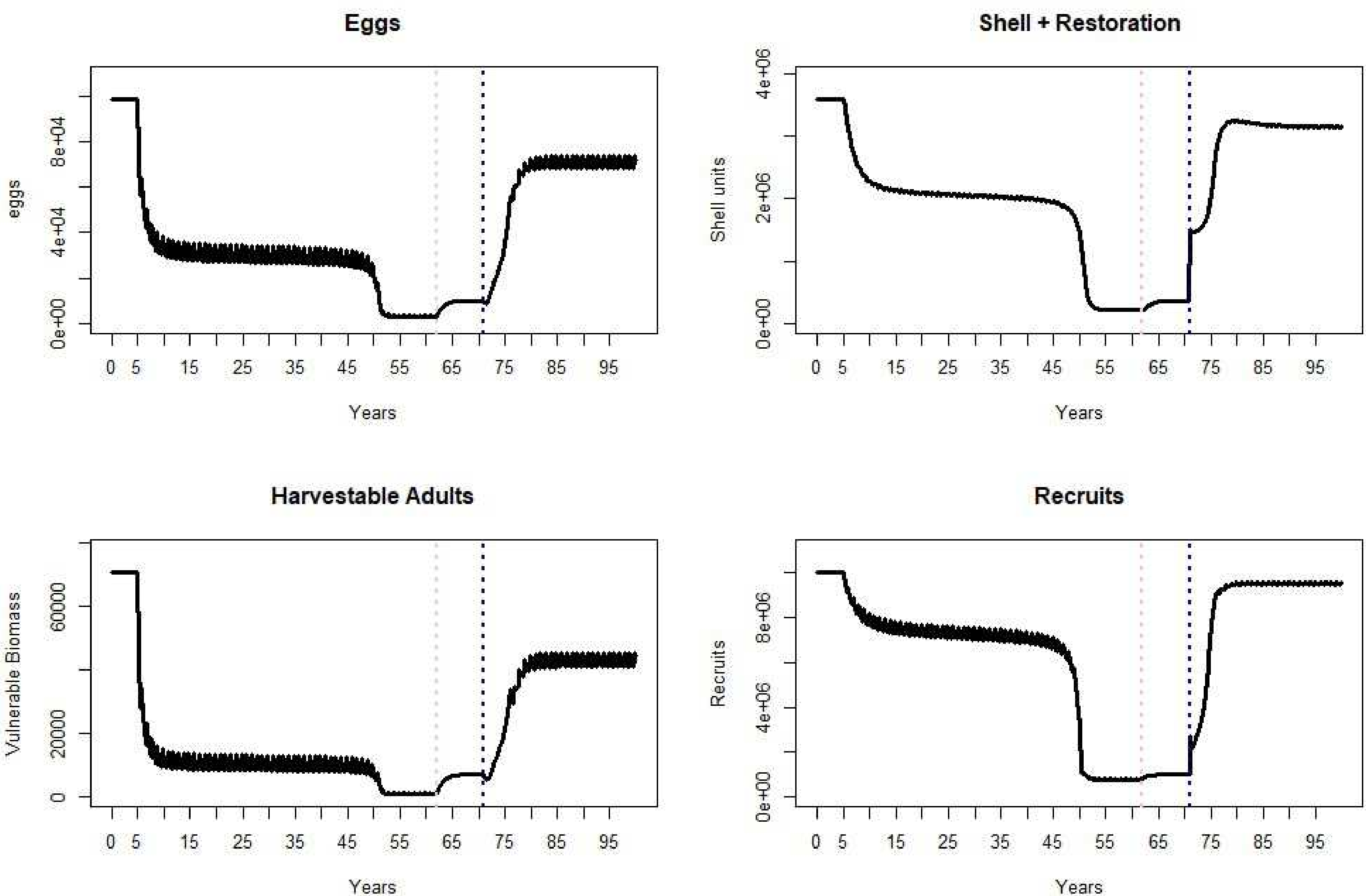
5. Post-restoration effort 10% original



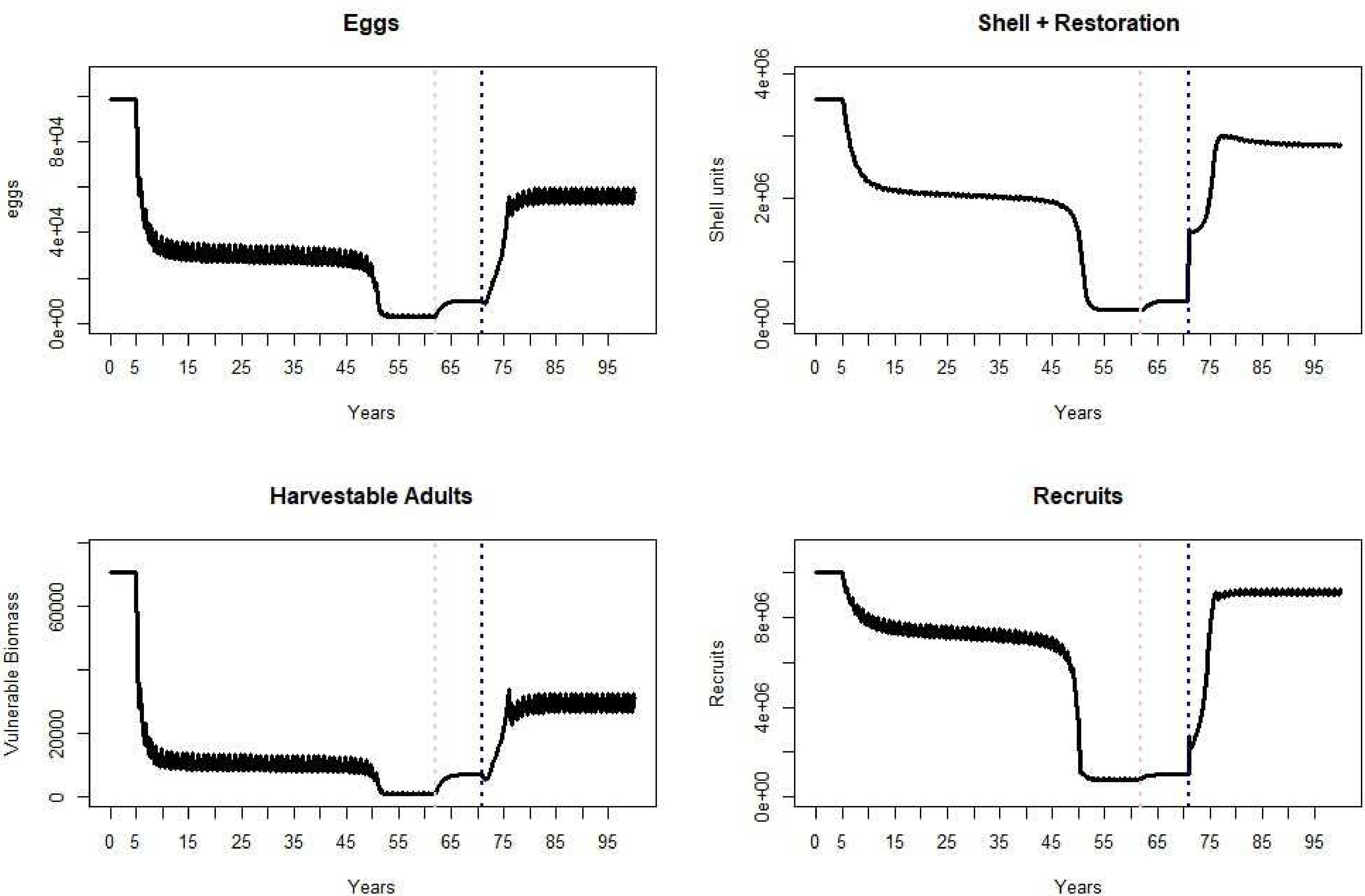
5. Post-restoration effort 20% original



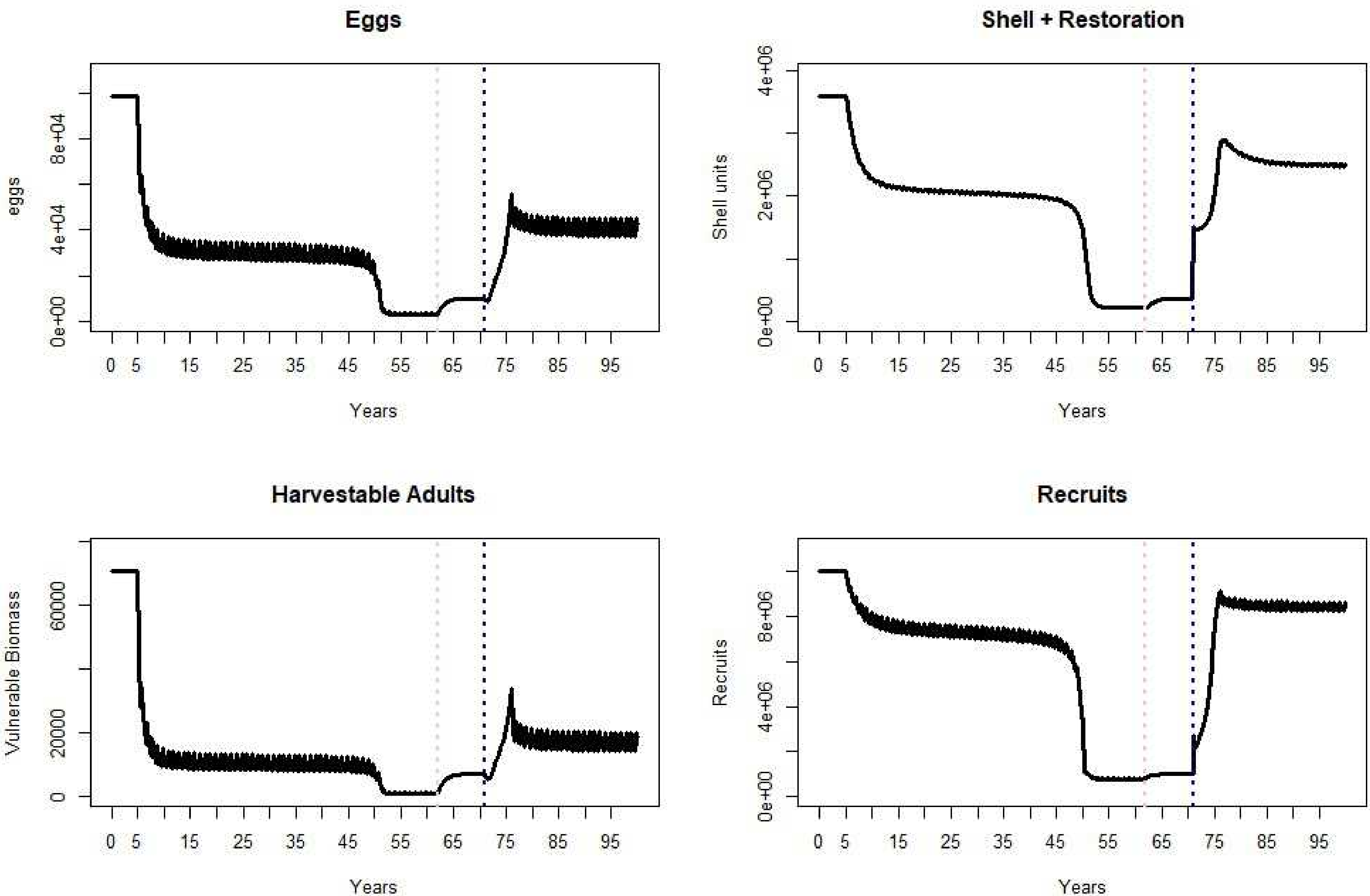
5. Post-restoration effort 40% original



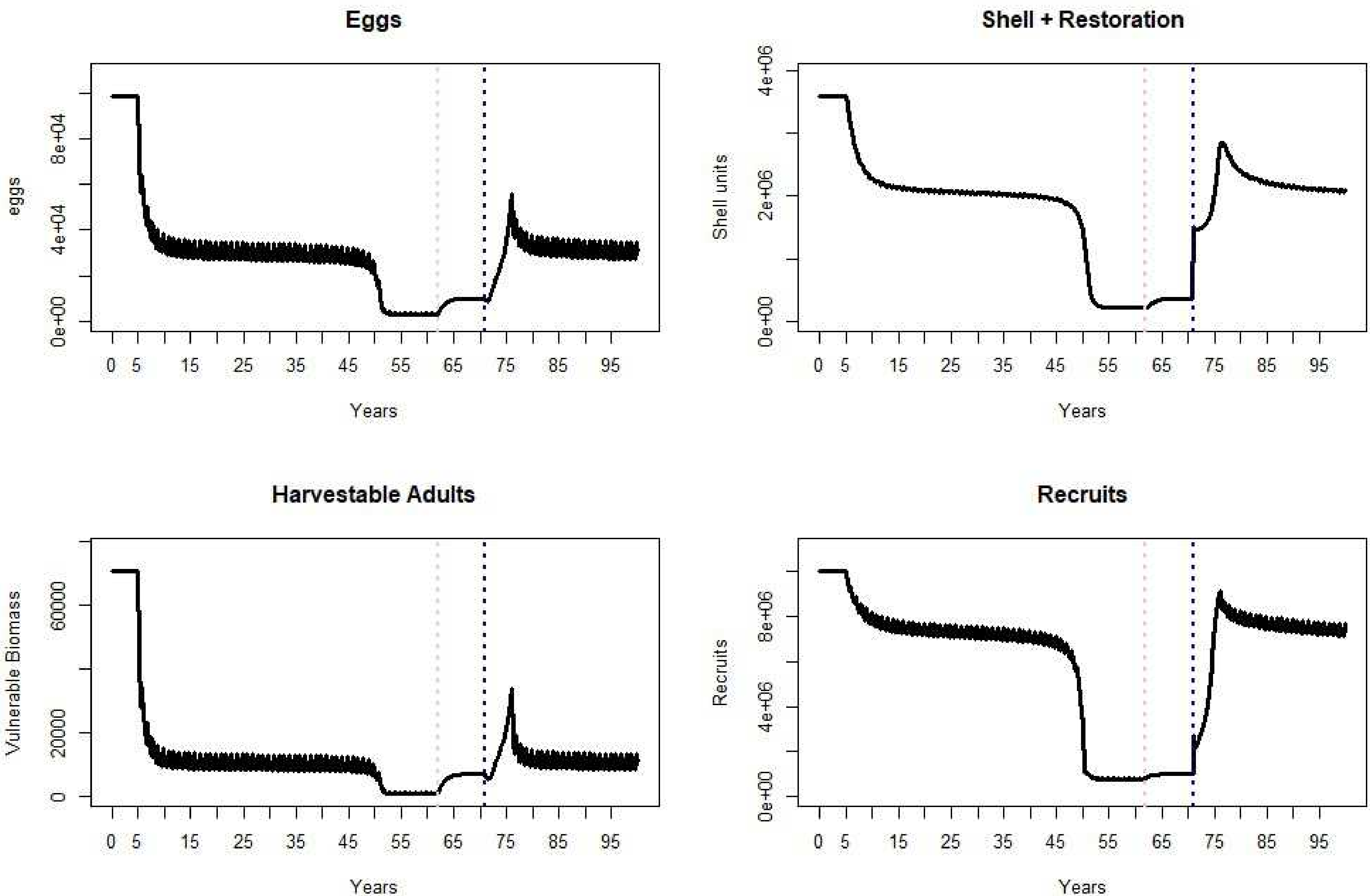
5. Post-restoration effort 60% original



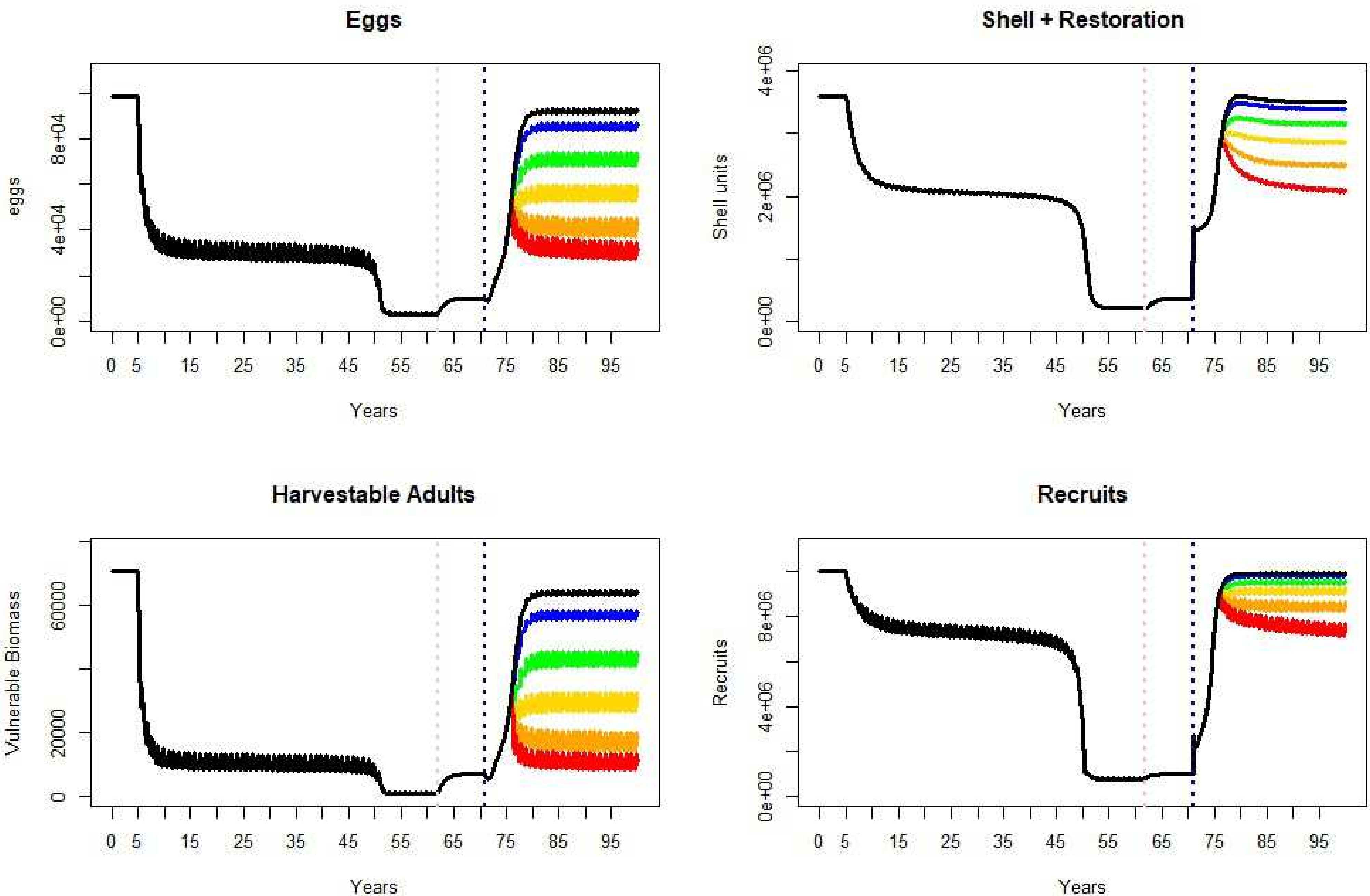
5. Post-restoration effort 80% original



5. Post-restoration effort 100% original



5. Post-restoration effort 10-100% original

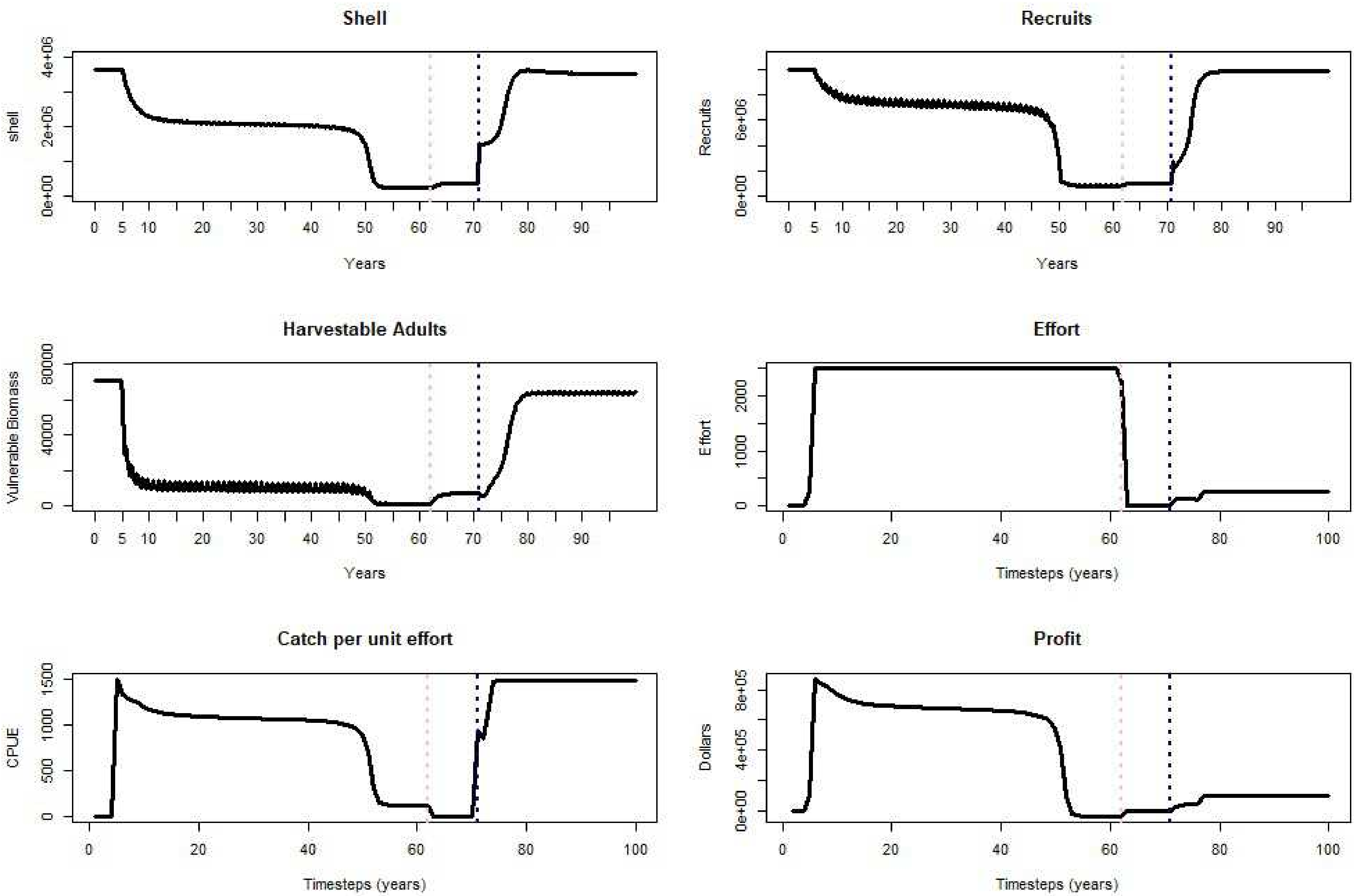


6. So what does that mean?

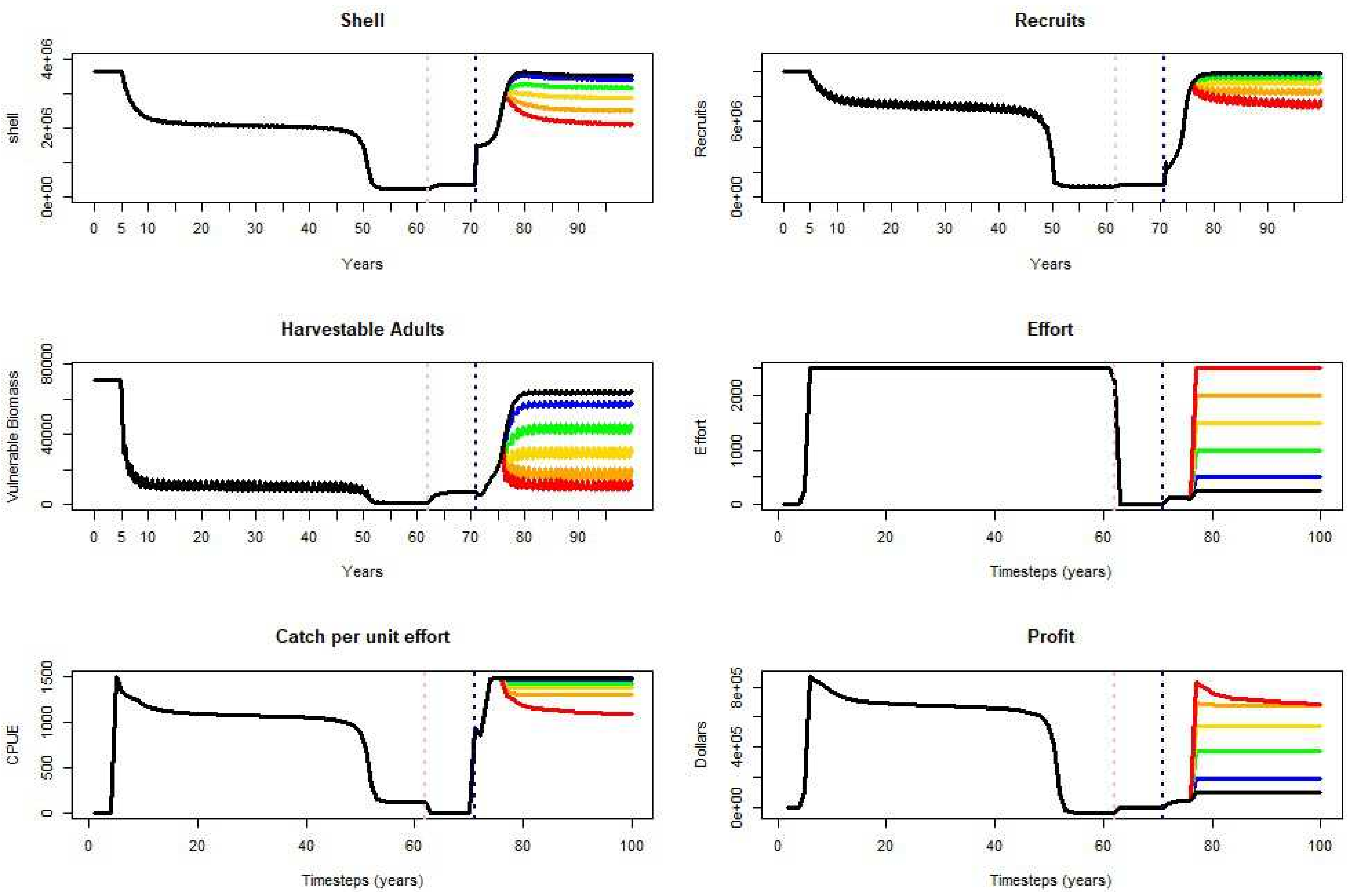
- More effort, fewer eggs, shell, recruits, oysters
- Less oysters, less ecosystem services
- More effort, more harvest though
- Supposed to be looking at multiple metrics…

- PLEASE remember, “original” effort here is still quite low for ease of seeing results!!!
- 100% of original effort means effort used in start of simulation, not the heyday of AB effort!!

6. Post-restoration effort 10% original, bioecon



6. Post-restoration effort 10-100% original, bioecon



6. Sustainable effort take home points

- For a reef (or series of reefs)…
  - IF the restoration is “successful”
    - Oyster harvest will increase
    - Oysters (Ecosystem services) will increase
    - BUT trade-off between them—the more you increase one, the less you increase the other
    - AND high enough effort will eventually lead to another crash

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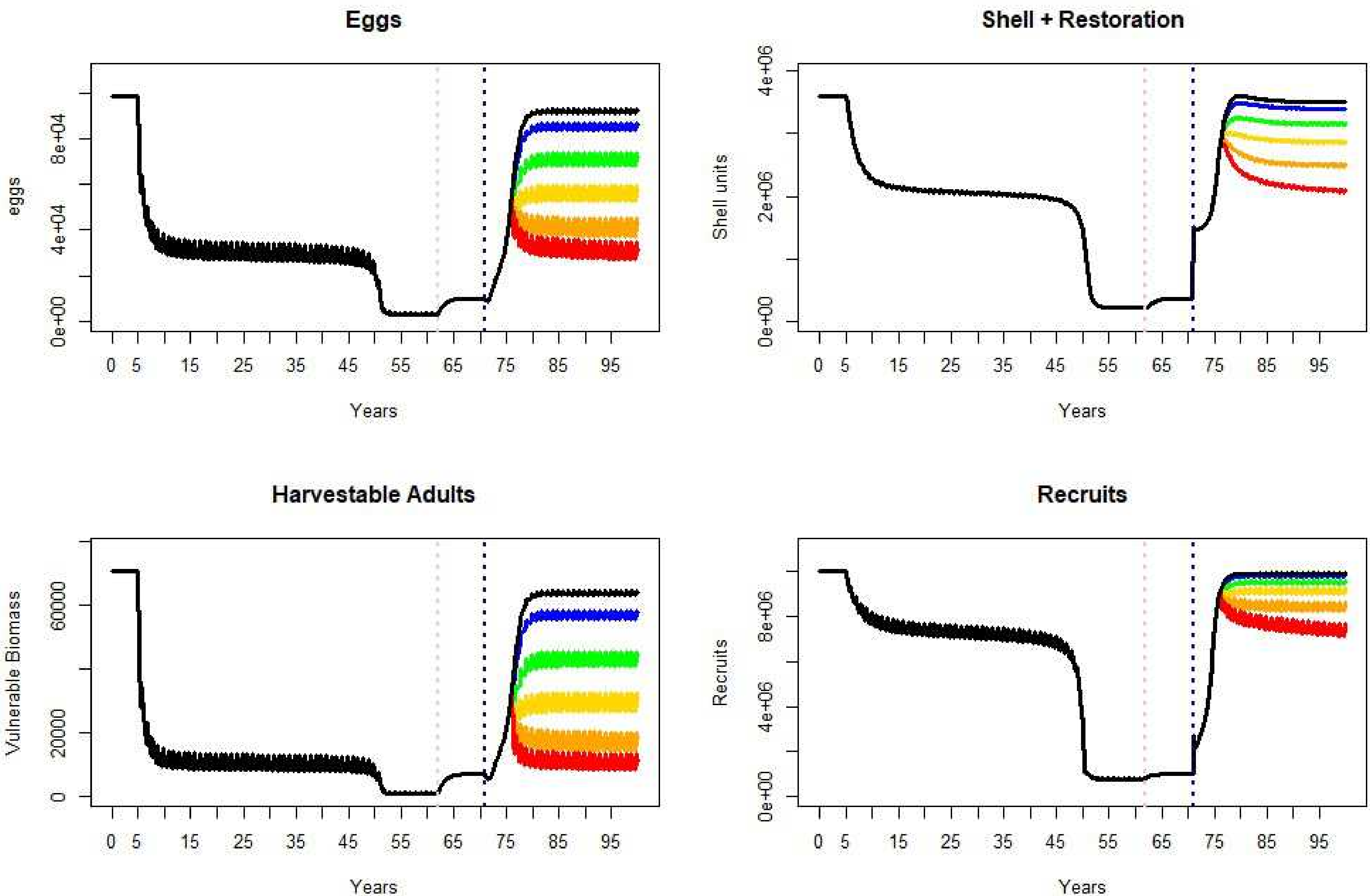
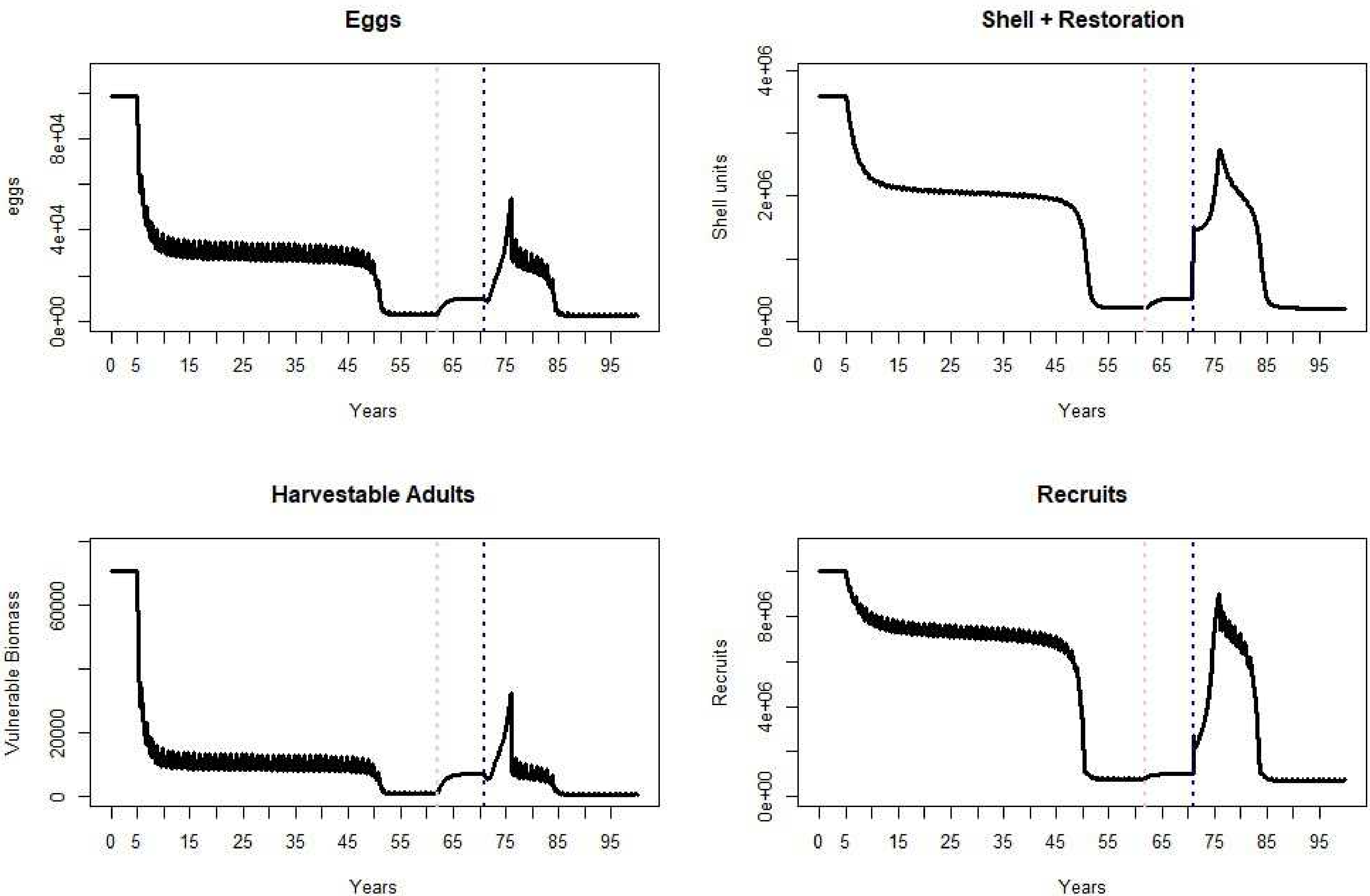


7. Open access effort (let the market decide!)

- ONLY applied to AFTER restoration (explain)
  - Assume bioeconomic equilibrium—if you’re making more money than you’re spending, you’re going oystering
    - Some implications of opportunity costs
    - Assumptions
      - Cost=$50/trip (maybe too low)
      - Price=$90/bag (maybe too high)
      - Bag=300 mostly legal oysters (maybe too law-abiding?)
      - Fishers base decisions on last months oyster pops (assuming harvesters have some idea of oyster populations)

7. Post-restoration open access



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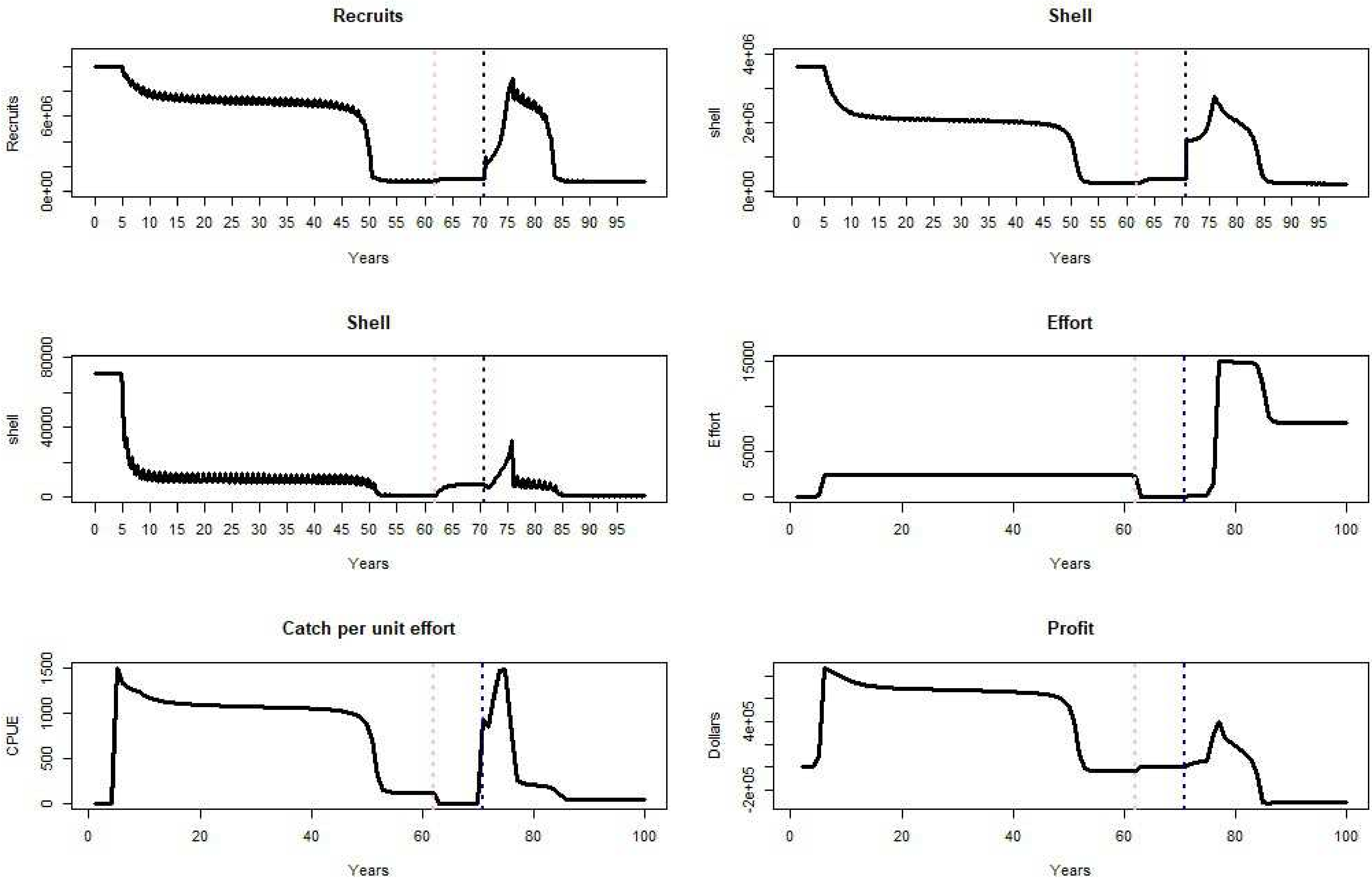
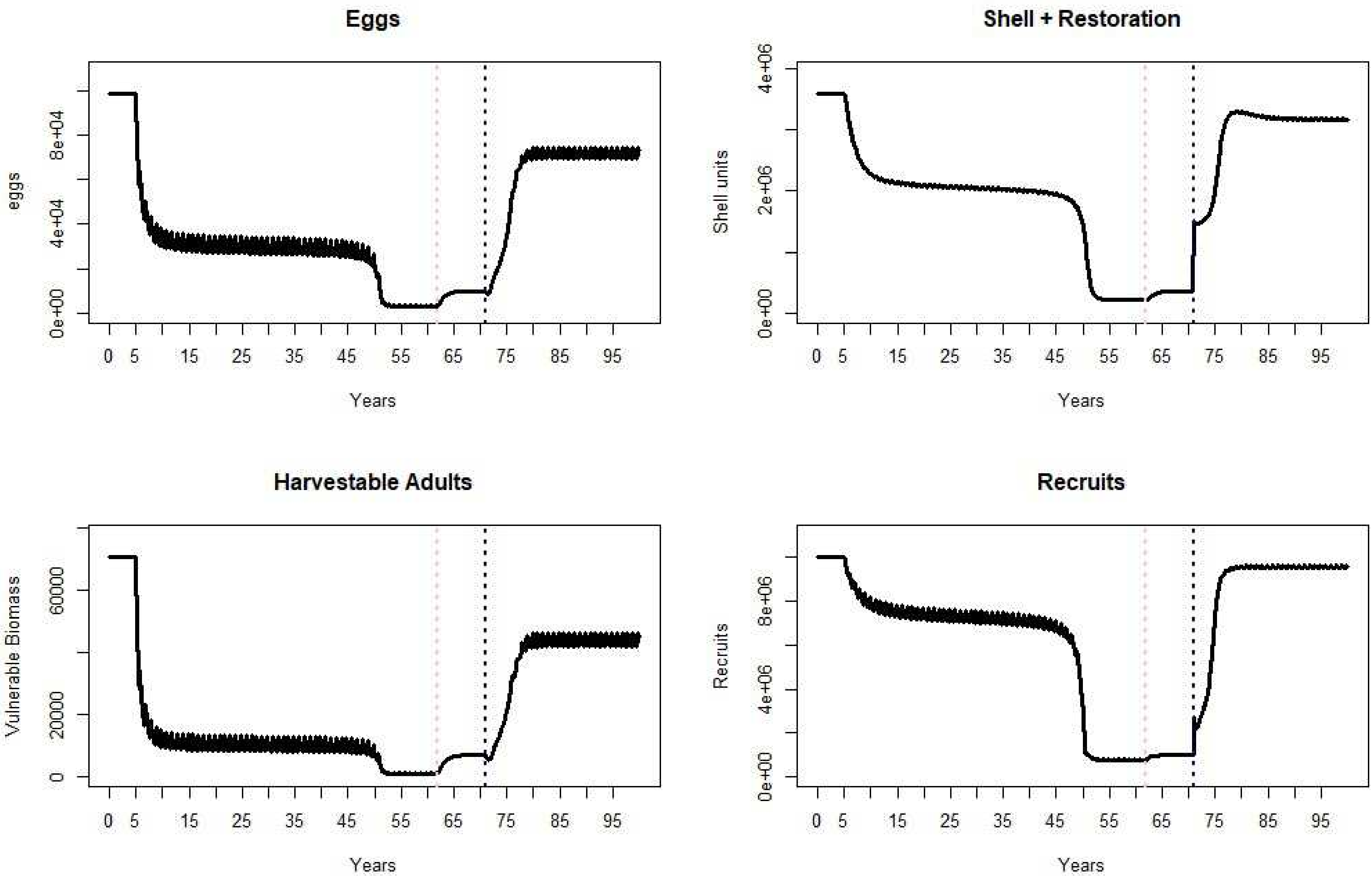


7. Active harvest mgmt.

- ONLY applied to AFTER restoration
- Rough process:
  - Assume mgmt knows oyster pops each month
    - (Explain why this is optimistic)
  - Mgmt sets prop legal oysters that can be harvested (e.g., 10%, like DE, or 30% like AL)
  - Mgmt calcs number of trips to get this **assuming** trips catch their bag limit
    - (Explain why this can be improved and isn’t perfect)

- Remember, these models do not have stochasticity (randomness) in them! That means active harvest not as useful as it is in real world.

7. Post-restoration active harvest mgmt. (10% legal oysters)



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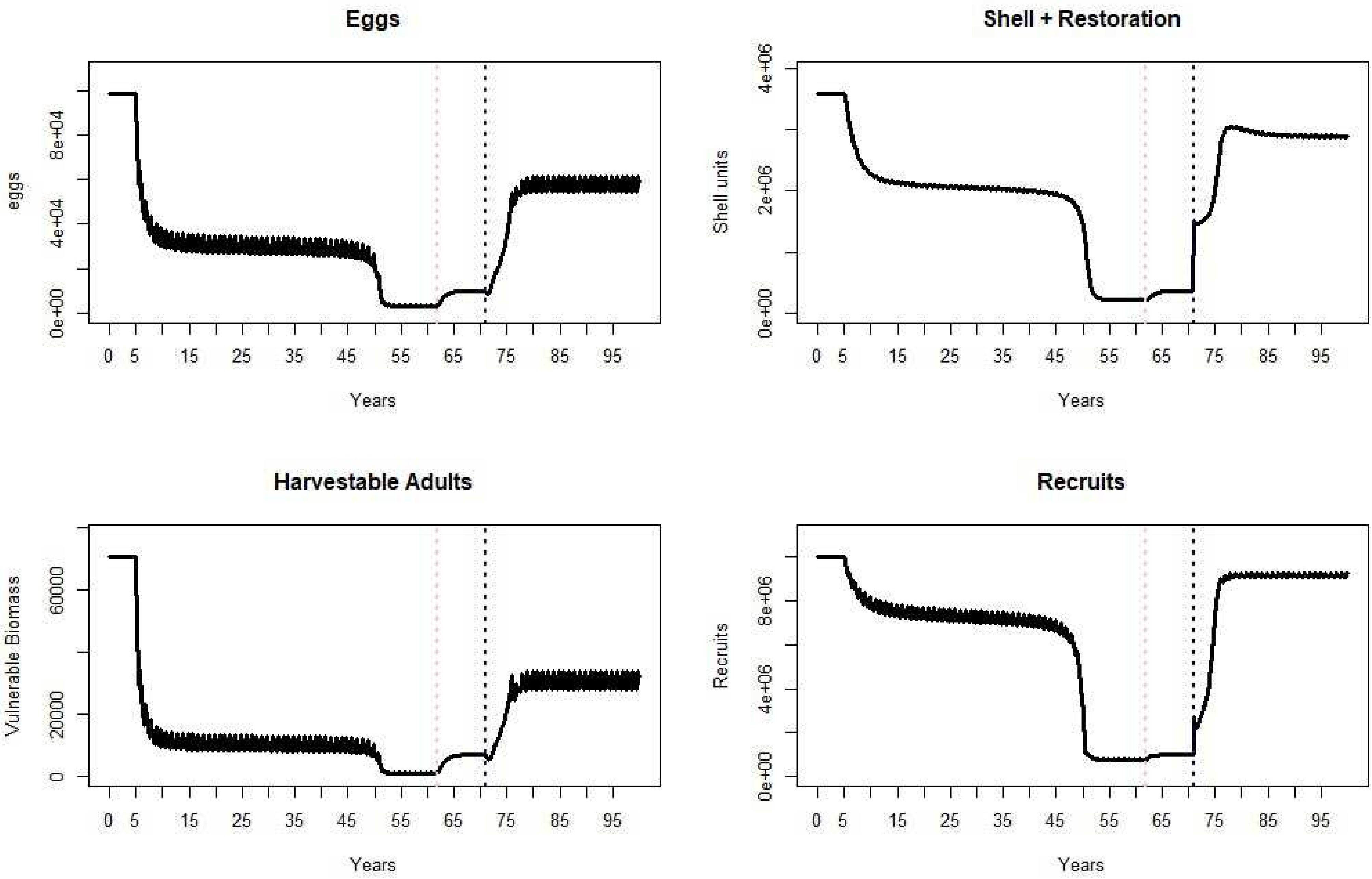

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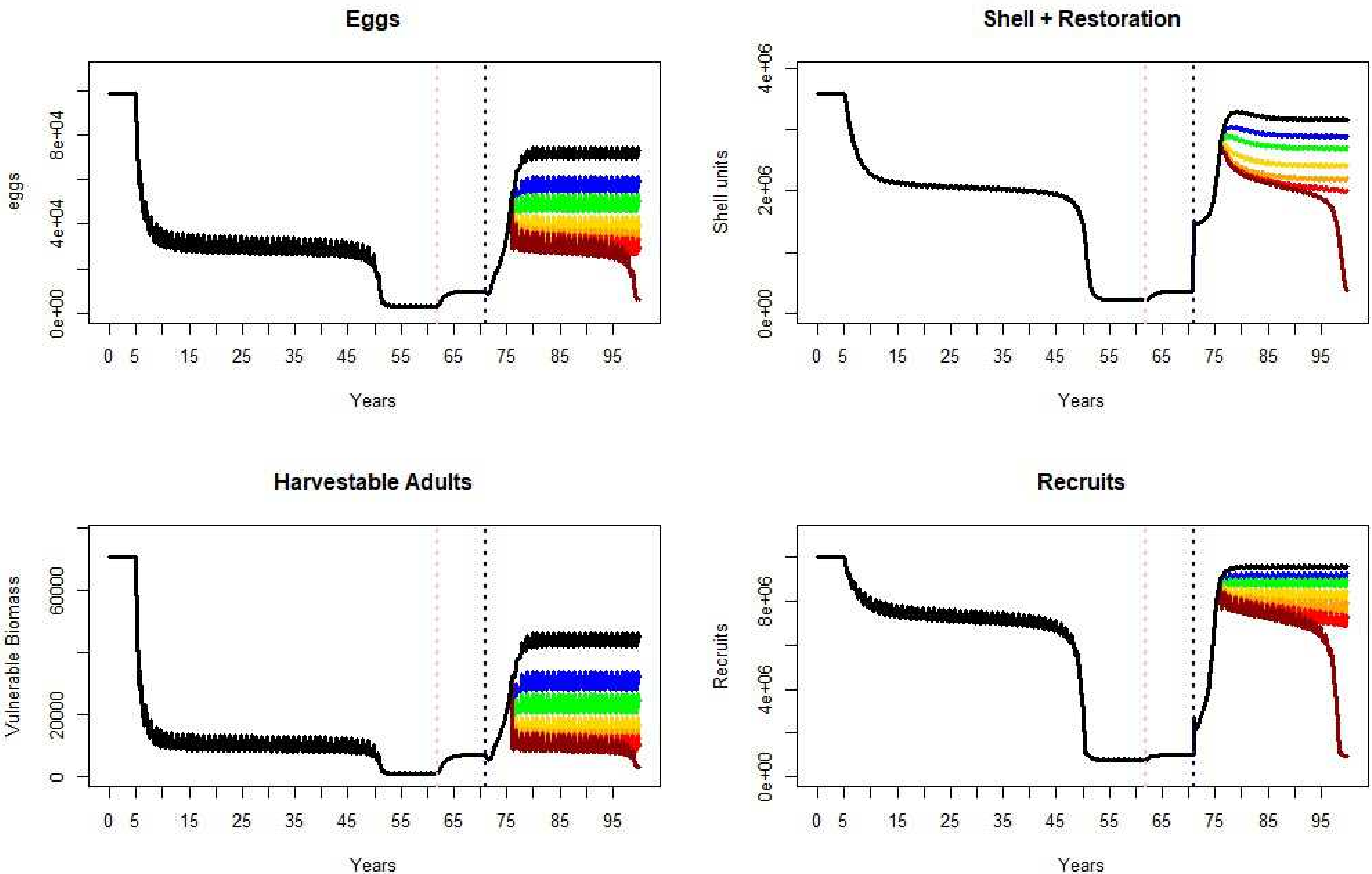


7. Sustainable effort take home points (1/3)

- Limited entry should be sustainable IF reasonable levels
- Open access would be expected to crash fishery, possibly soon (within a couple decades)
- Active harvest mgmt. should be sustainable IF good measurements and appropriate levels
- Levels of limited entry and active harvest mgmt present trade-offs
  - More effort, more revenue econ. Activity
  - Also less oysters, ecosystem services, and greater chance of collapse

7. Sustainable effort take home points (2/3)

- PLEASE PLEASE PLEASE PLEASE PLEASE PLEASE PLEASE recognize the limitations of these models
    - Scaling—represents a small area of a single “bar”
        - (Explain why that may not be unrealistic but is imperfect)
    - No stochasticity—doesn’t let random things to go good or bad
        - (Explain why that would affect active harv. Mgmt. the most)
    - These results WILL change some
    - I do not *expect* the general patterns to change a lot
        - Limited entry, active mgmt., should be better than open access at keeping oysters around
        - Will be a trade-off between revenue from harvest and oyster ecosystem services, realized by how much effort is allowed.

7. Sustainable effort take home points (3/3)

- Remember, this recovery doesn’t happen unless restoration works, and works better than any we’ve seen in AB since 2012.

5. Discussion and questions (so far)

8. Options for future modeling

1. Disclaimer/disambiguation
2. Background on shell dynamics
3. Why we built depensation into simulation models
4. Assumptions of simulation models shown today
5. Simulation results: depensation, collapse, restoration
    -Take home points and questions
6. Simulation results: restoration and “sustainable” fishing
    -Take home points and questions
7. Simulation results: alternative fisheries mgmt.
    -Take home points and questions
8. Options for future modeling
    -Better scaling
    -Spatially explicit (multiple reefs)

8. At least three things to work on

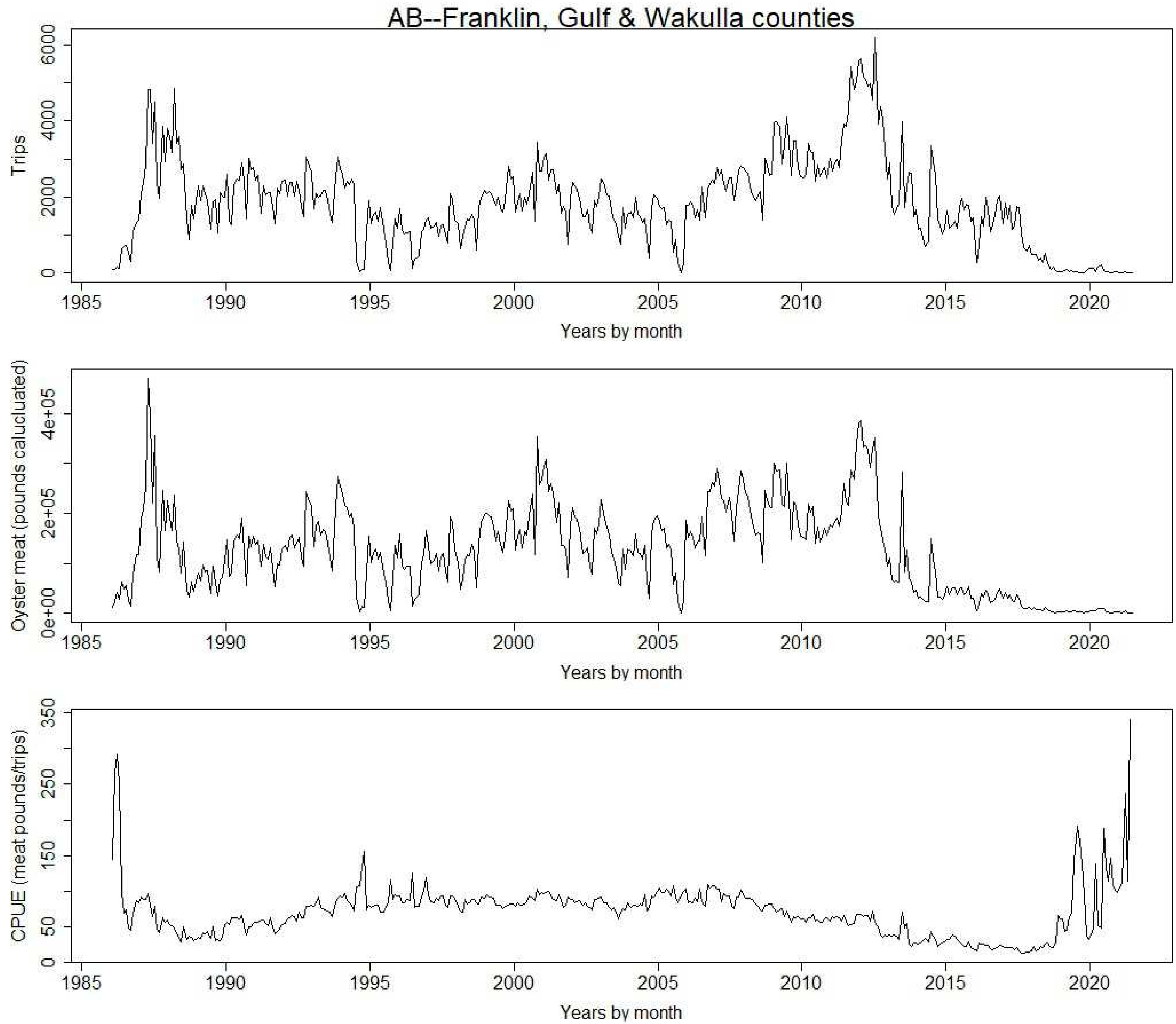
- Scaling and fit of simulations—larger reefs, fit to historical effort
  - Increase confidence in "levels"
  - Cannot overcome issues of uncertainty wrt depensation
- Stochasticity—adding in random "noise" in
  - Process, e.g., recruitment
  - Fishing (maybe with open access?)
  - How mgmt. "sees" fishery (active harvest mgmt.)
- Spatially explicit structure (multiple bars at once)
  - Can be done, will take some time

8. Other things that I can work on

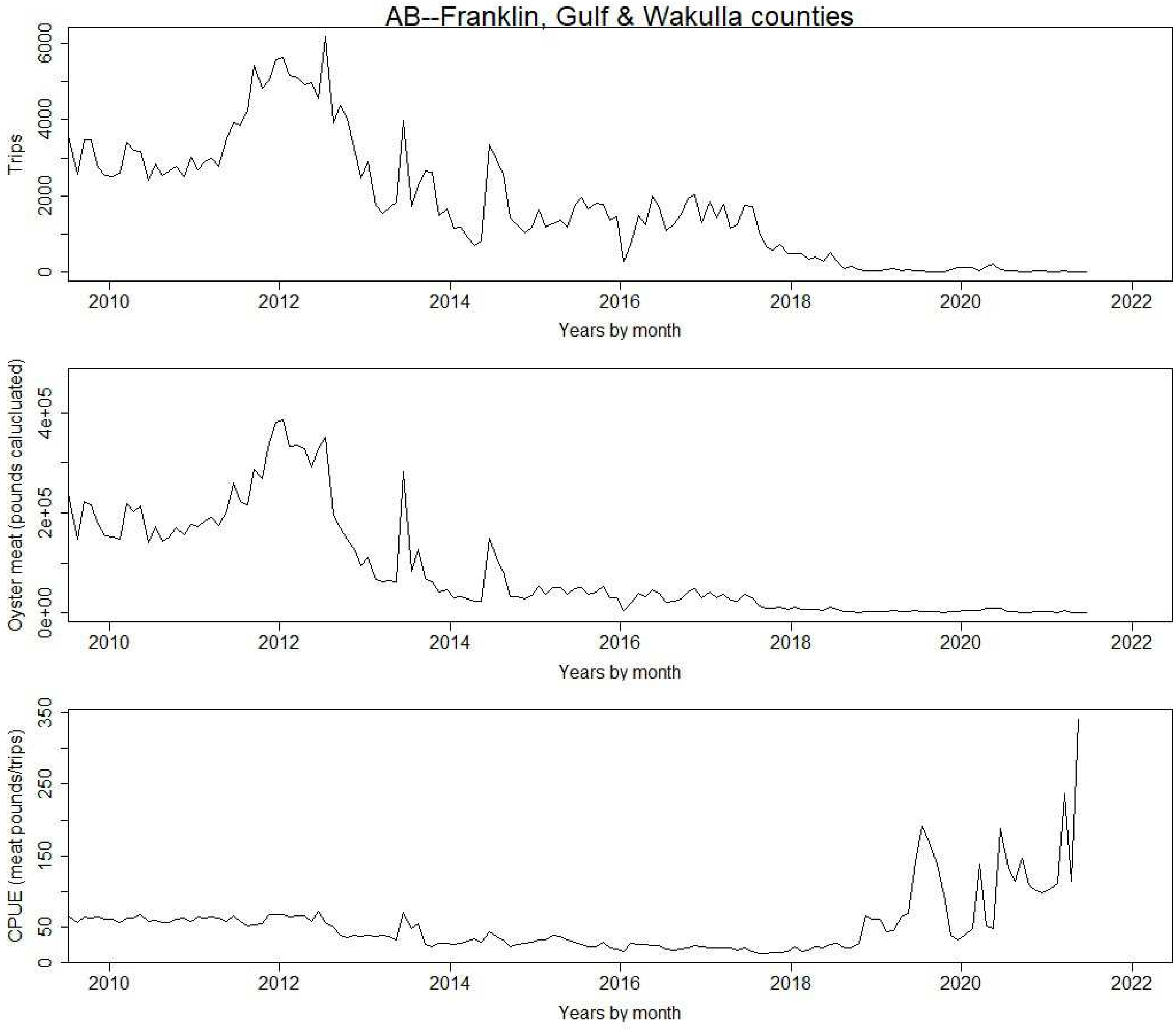
- Adding in “put and take”
  - Why I didn’t do this yet
- More detailed “head to head” comparisons
  - Implies precision we just do not have

Thank you for your patience!

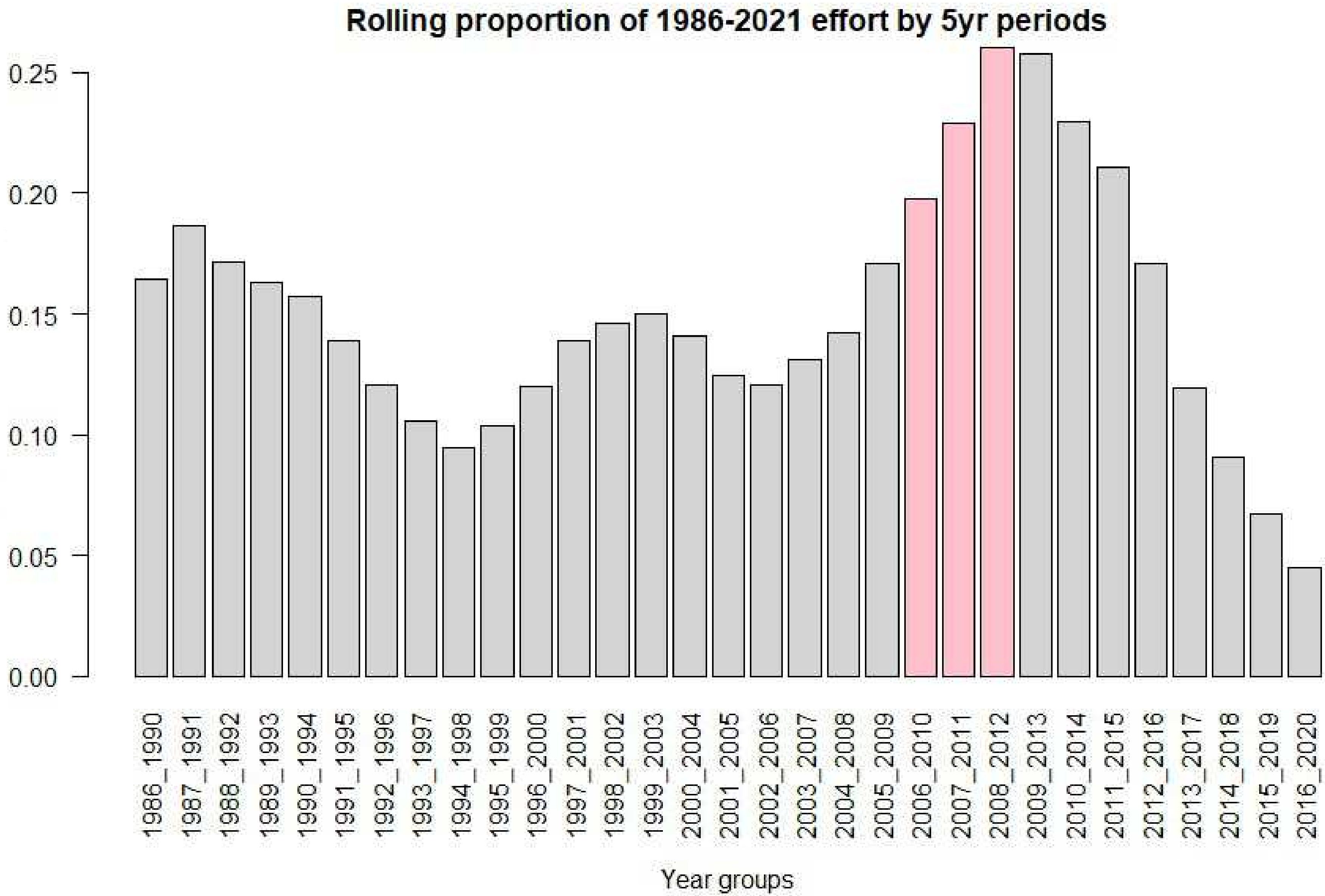
Data: fisheries dependent data



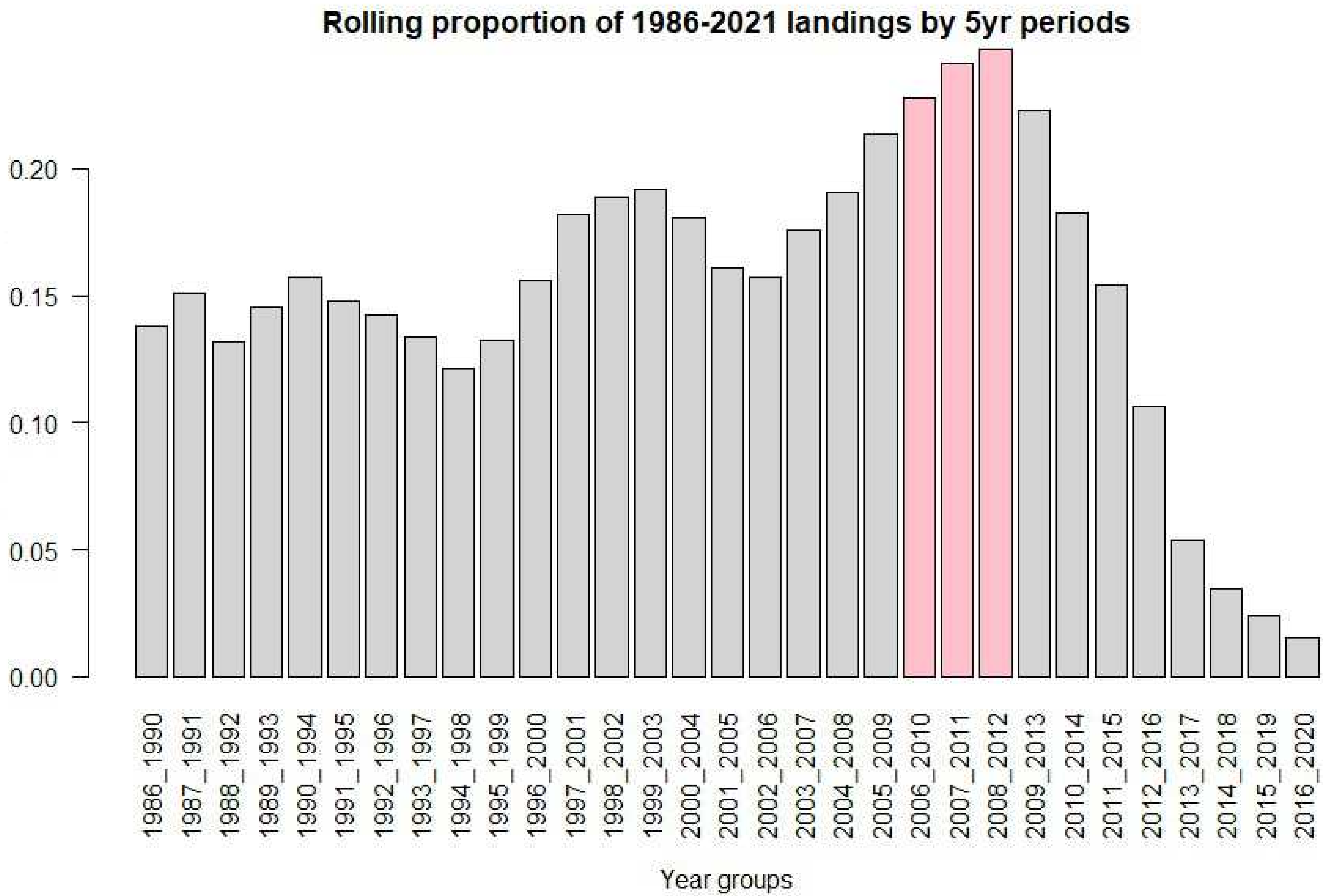
Data: fisheries dependent data (2010 forward)



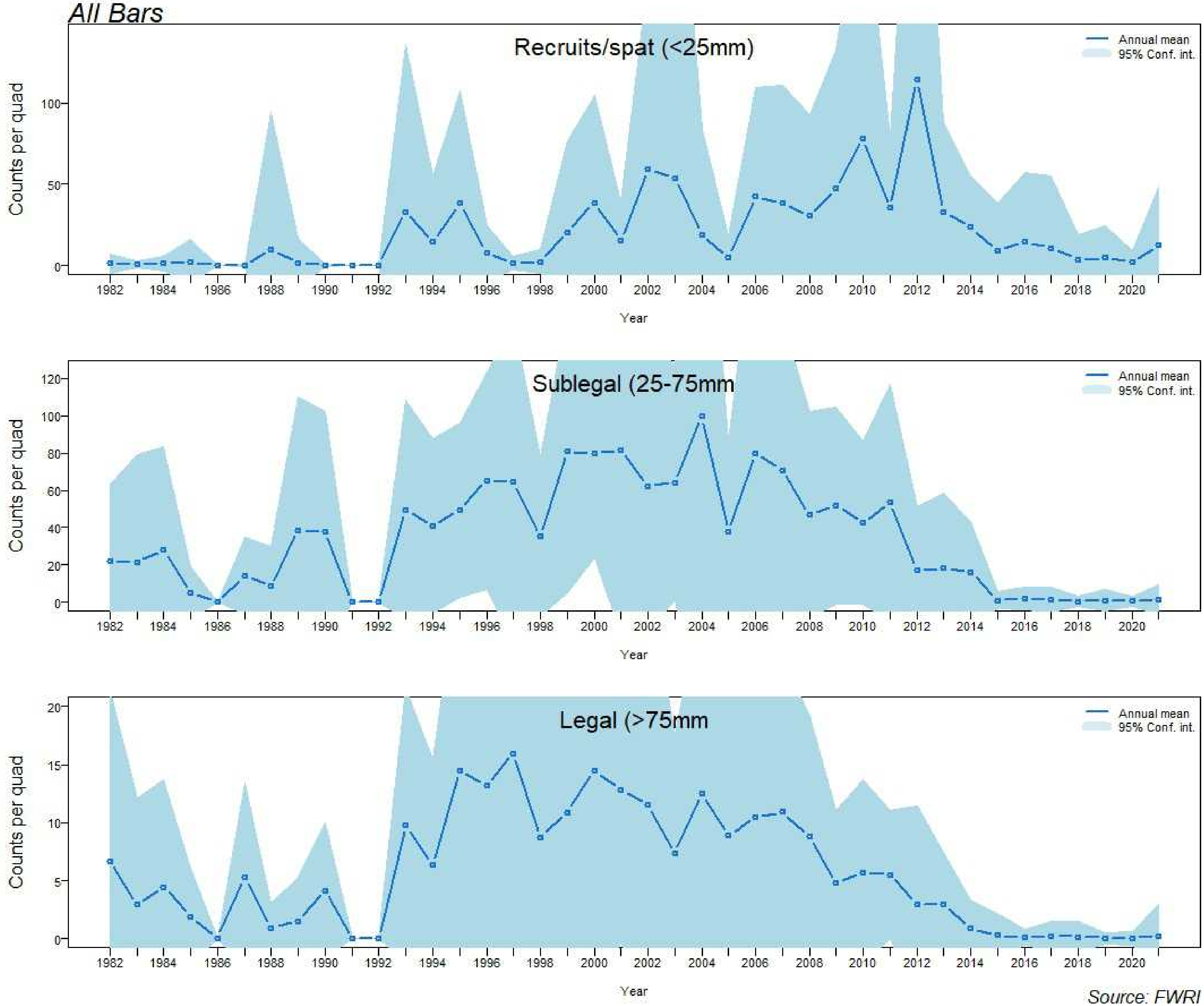
Were trips high before collapse?



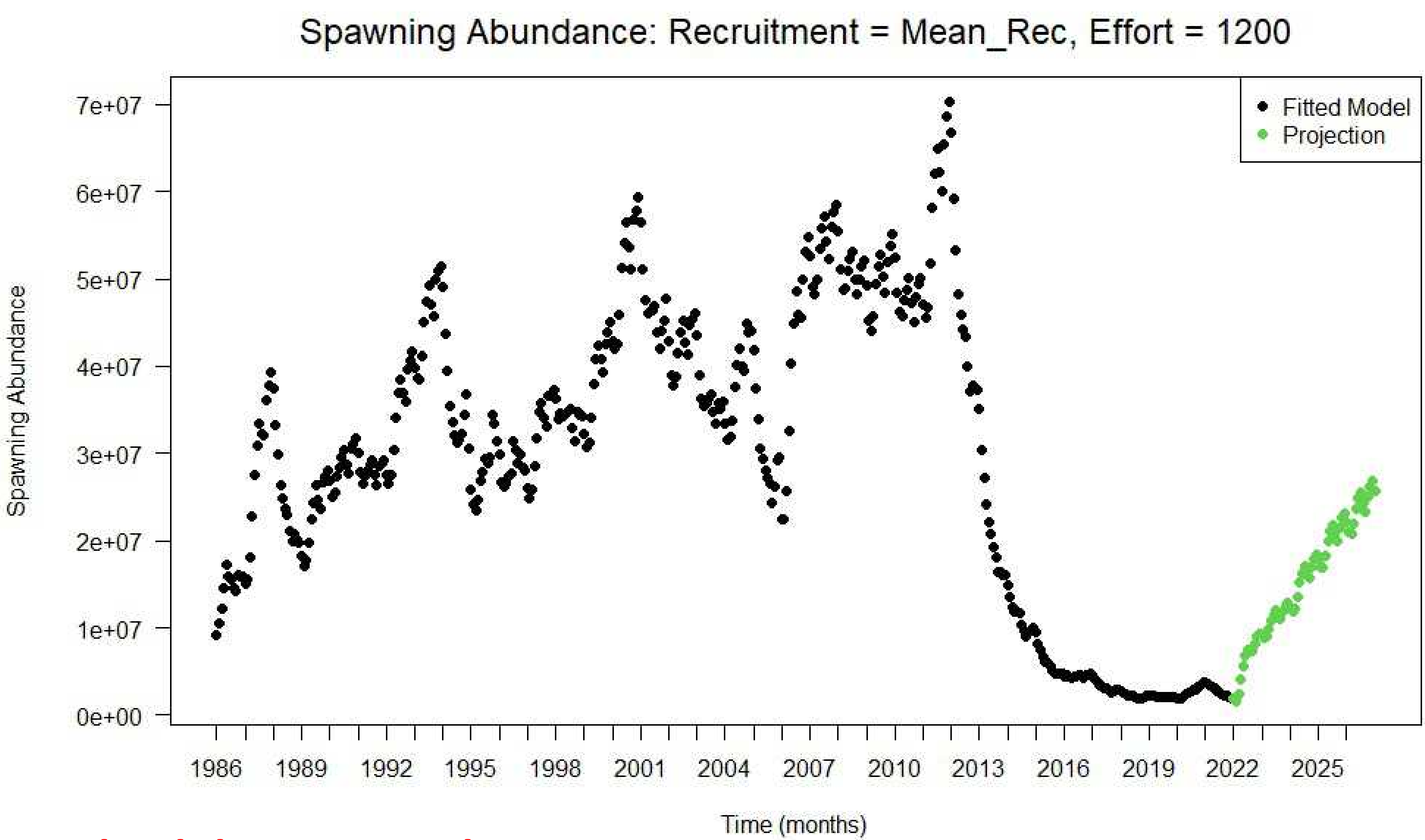
Were landings high before collapse?



Data: fisheries independent data: all bars



Med effort, avg. recruitment: Spawning abundance



Probably unrealistic