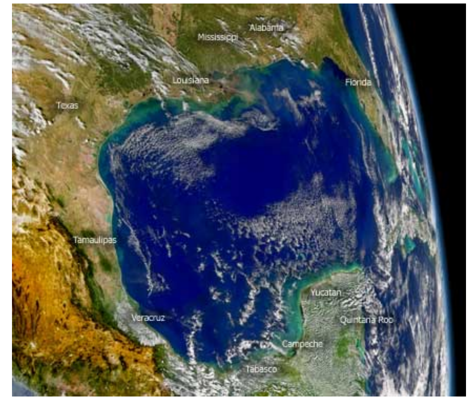

Modelling the effects of density-dependent mortality in juvenile red snapper caught as bycatch in Gulf of Mexico shrimp fisheries: Implications for management

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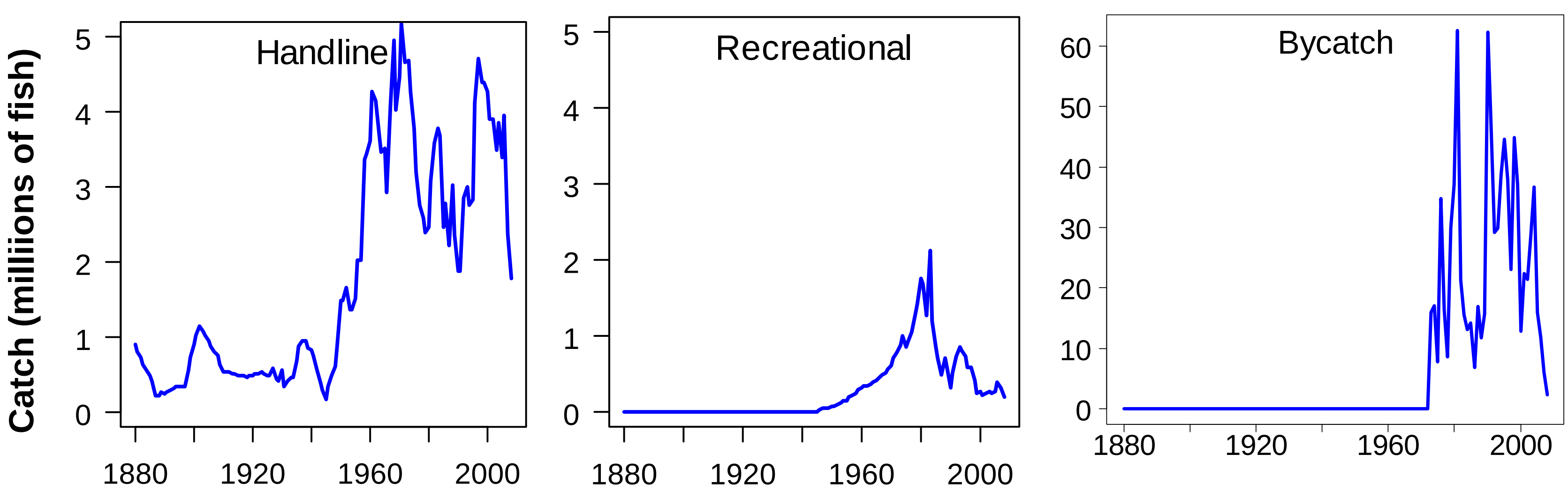
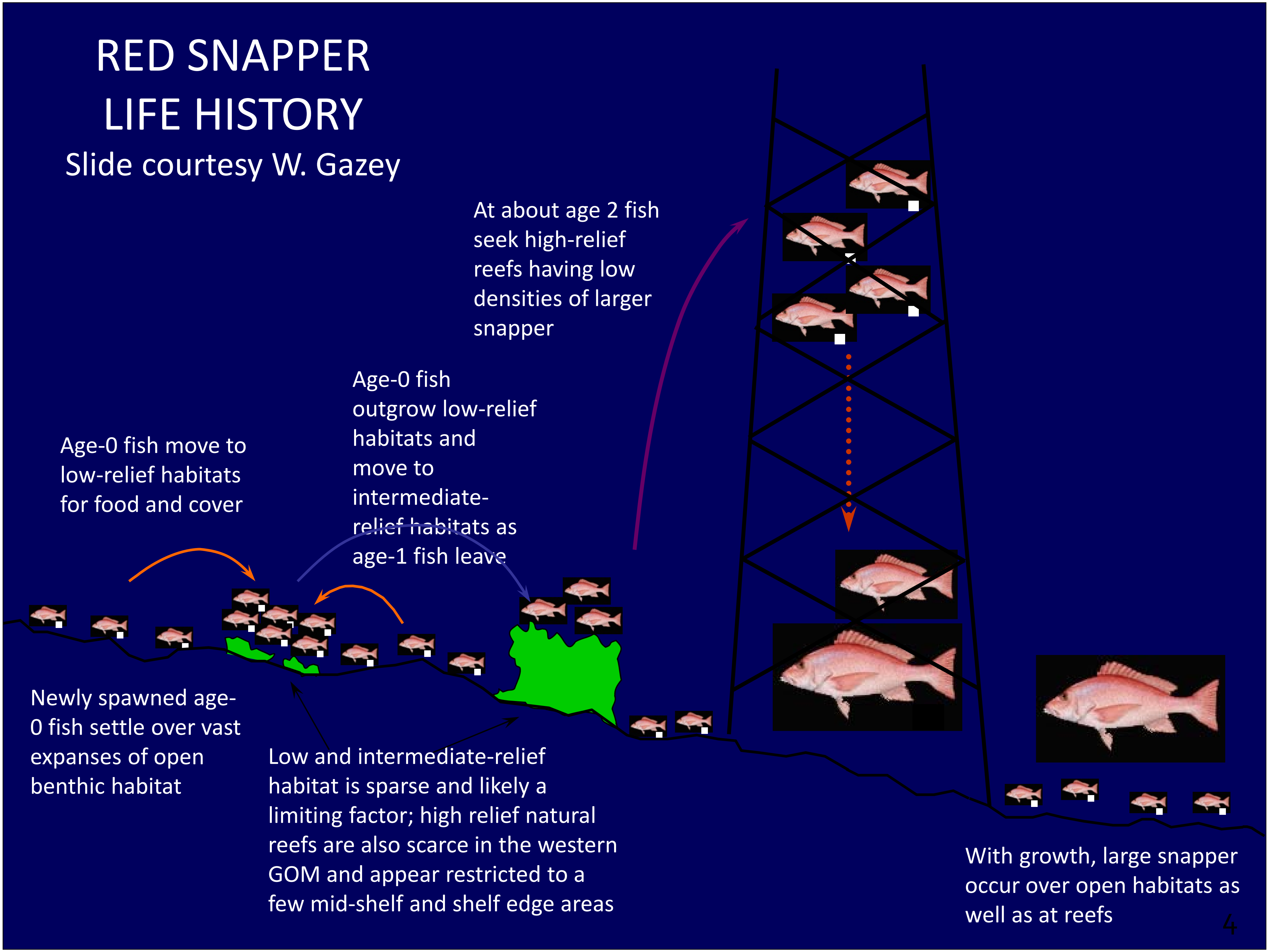
What do we need to know to assess status of a fish stock and predict its response to fishing?

- Life history
  - Longevity, Natural mortality, Maturity, Growth …
- Selectivity
  - What age do fish become vulnerable to fishery? Dome-shaped, asymptotic …
- Population scale (carrying capacity)
  - How big can the population get?
- **Productivity (rates)**
  - How fast does the population grow?
  - How does population growth rate change with respect to population size?
  - Understanding productivity key for determining resilience to fishing.
  - Unfortunately, productivity difficult to measure / estimate.
  - Simulation studies help characterise uncertainty and show potential implications for management

Red snapper (*Lutjanus campechanus)*

- Directed commercial and recreational fisheries (2+ yrs)
- Overfished/Undergoing overfishing
- Bycatch in shrimp fishery (age 0 and 1 years)
- Reducing bycatch a key component of the management plan
- Since 2005, large reductions in shrimping effort (Hurricane Katrina, increased fuel prices, decreased shrimp prices …)
- Job done?




RED SNAPPER
LIFE HISTORY
Slide courtesy W. Gazey
At about age 2 fish seek high-relief reefs having low densities of larger snapper
Age-0 fish outgrow low-relief habitats and move to intermediate-relief habitats as age-1 fish leave
Age-0 fish move to low-relief habitats for food and cover
Newly spawned age-0 fish settle over vast expanses of open benthic habitat
Low and intermediate-relief habitat is sparse and likely a limiting factor; high relief natural reefs are also scarce in the western GOM and appear restricted to a few mid-shelf and shelf edge areas
With growth, large snapper occur over open habitats as well as at reefs

Density-dependent survival and fishing

- Density dependent processes almost always assumed to be complete when fish recruit to fishery
- Assumption violated if fish caught before density-dependent dynamics complete
- Bycatch mortality and natural mortality interact:
  - Bycatch mortality increases (juvenile density reduced), juvenile survival improves
  - Bycatch mortality decreases (juvenile density increased), juvenile survival decreases
- Compensatory feedback mechanism

Key uncertainties for managing the snapper fishery

- Q*: Will reductions in bycatch be effective for rebuilding?
- Q*: How are fishery reference points affected by assumptions about timing of density-dependent natural mortality?

- Approach: Develop age-structured model containing density dependent age-0 survival simultaneous with bycatch and compare with conventional age-structured model

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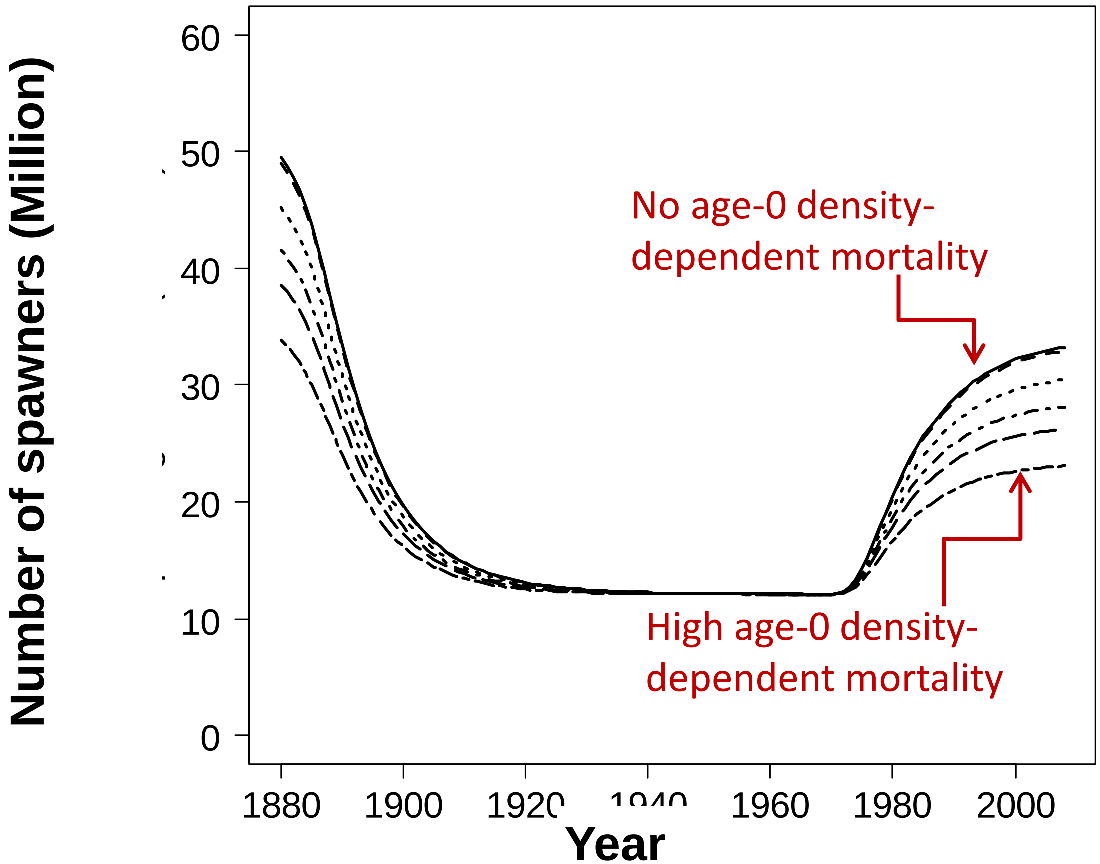
Model comparison

	Density-dependence model	**Conventional model**
Age-0 *N*	Beverton-Holt function	Beverton-Holt function
Age-1 *N*	Beverton-Holt function with *F*	$e^{-(F+M)} N$
Age-0 Catch	Density-dependent catch eqn	Baranov equation
Key estimated parameters	R_0, CR, M_{d0}	R_0, CR

Age-1 *N* $\rightarrow$ $$N_{t+1} = \frac{\alpha N_t}{1 + \beta N_t}$$ *where* $$\alpha = e^{-(M_{i0}+F)}$$ $$\beta = \frac{M_{d0}}{(M_{i0}+F)}\left(1 - e^{-(M_{i0}+F)}\right)$$

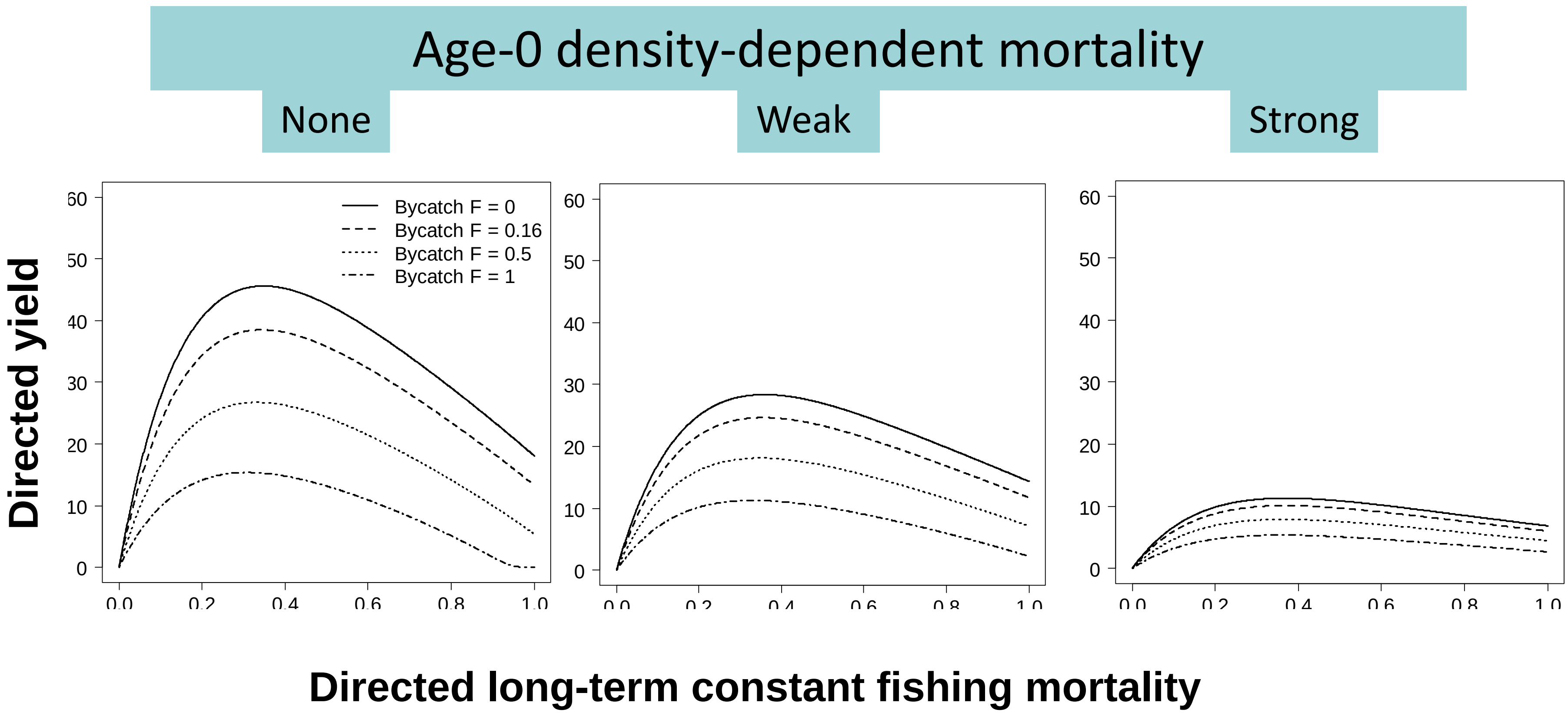
Fixed *F* scenarios:
Rebound potential when bycatch removed

Fixed historical shrimp bycatch rate *Fs = 1.0* y^{-1}



- **In the presence of strong density dependent Age-0 mortality rebound is reduced**

Equilibrium reference points: MSY under four fixed bycatch scenarios

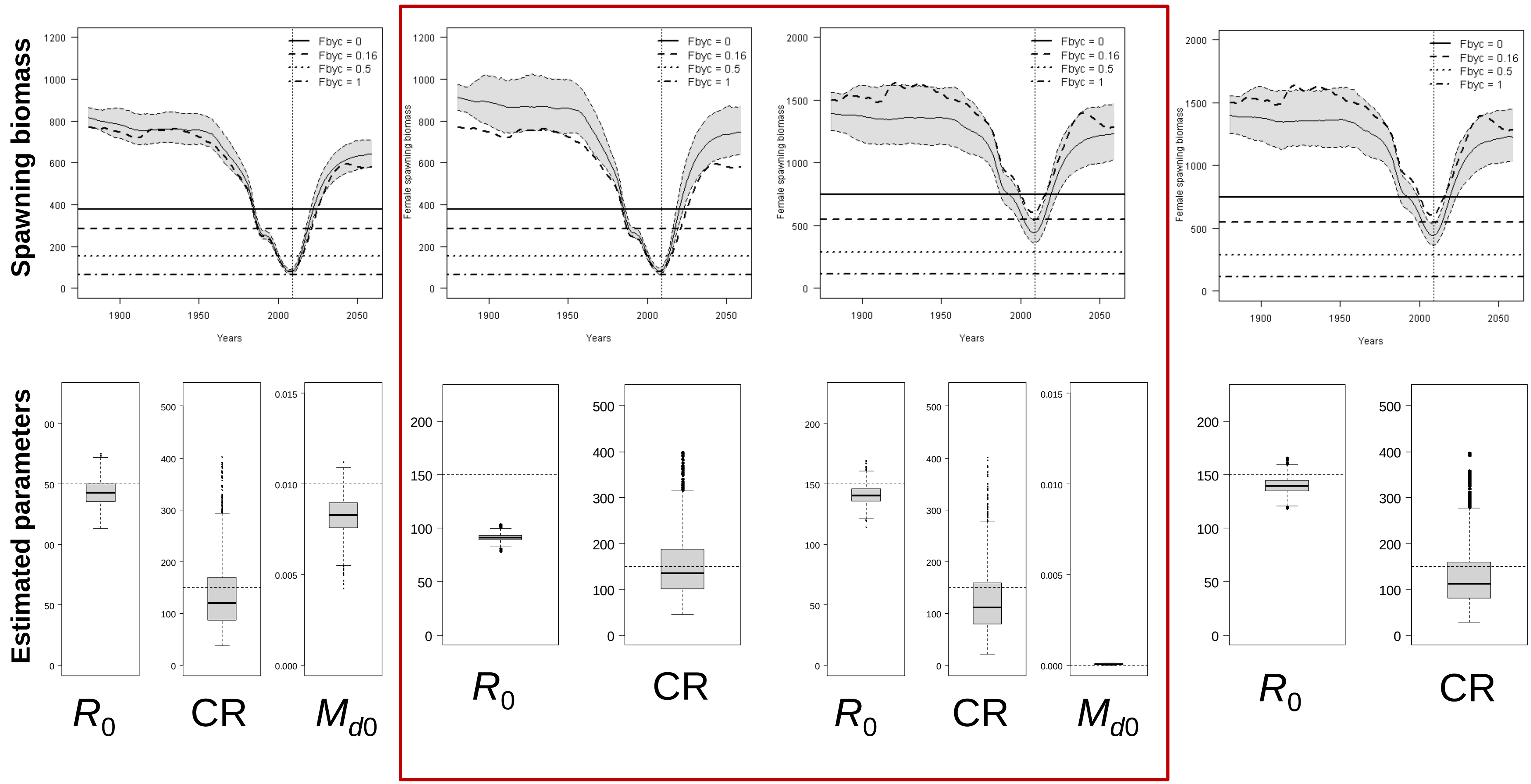


Structural uncertainty: Four-way simulation test

OPERATING MODEL / **ASSESSMENT MODEL**	M_{d0} **= 0.01** **True state of nature**: Age-0 density-dependence	M_{d0} **= 0** **True state of nature**: NO Age-0 density-dependence
M_{d0} **= 0.01** **Assessment model assumption**: Age-0 density-dependence	**C1. CORRECT ASSUMPTION**	**C3. INCORRECT ASSUMPTION** (TYPE I ERROR, FALSE POSITIVE)
M_{d0} **= 0** **Assessment model assumption**: NO Age-0 density-dependence	**C2. INCORRECT ASSUMPTION** (TYPE II ERROR, FALSE NEGATIVE)	**C4. CORRECT ASSUMPTION**

Four-way simulation test
True R_0 the same for all four scenarios

C1. True: DD Assumed: DD	C2. True: DD Assumed: no DD	C3. True: No DD Assumed: DD	C4. True: No DD Assumed: No DD



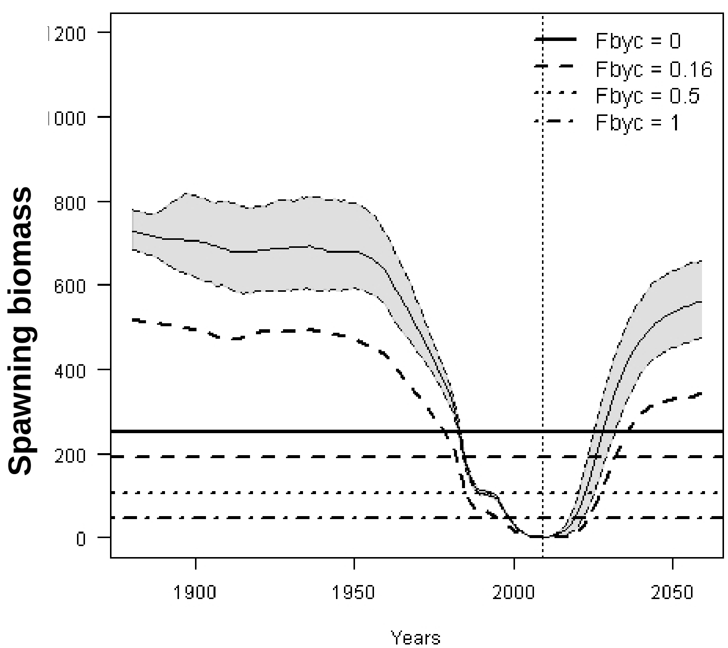
These simulations suggest that the incorrect DD model (C3) was better able to capture underlying dynamics than the incorrect No DD model (C2)

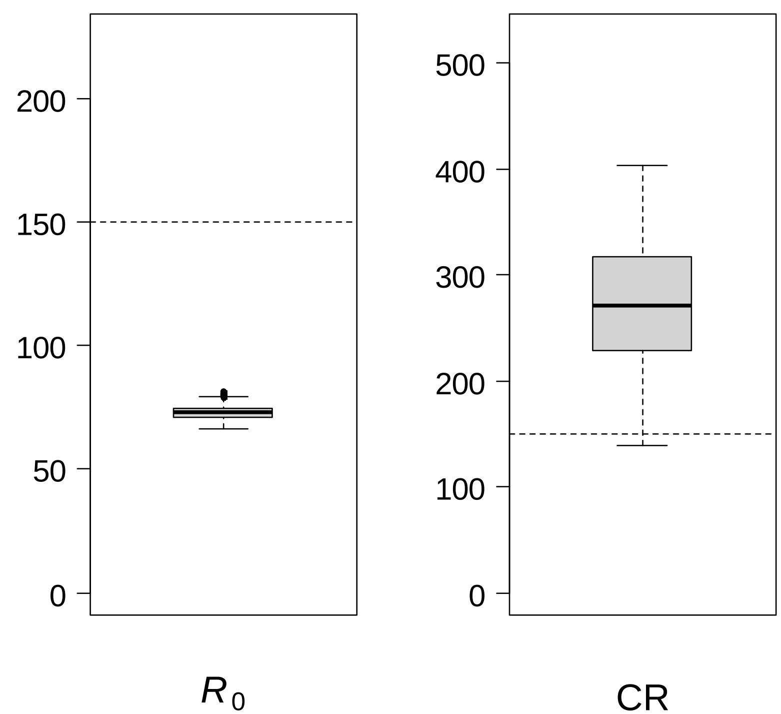
Effects of incorrect assumption of No DD (C2) worsen as true density dependence increases

C2. True: DD

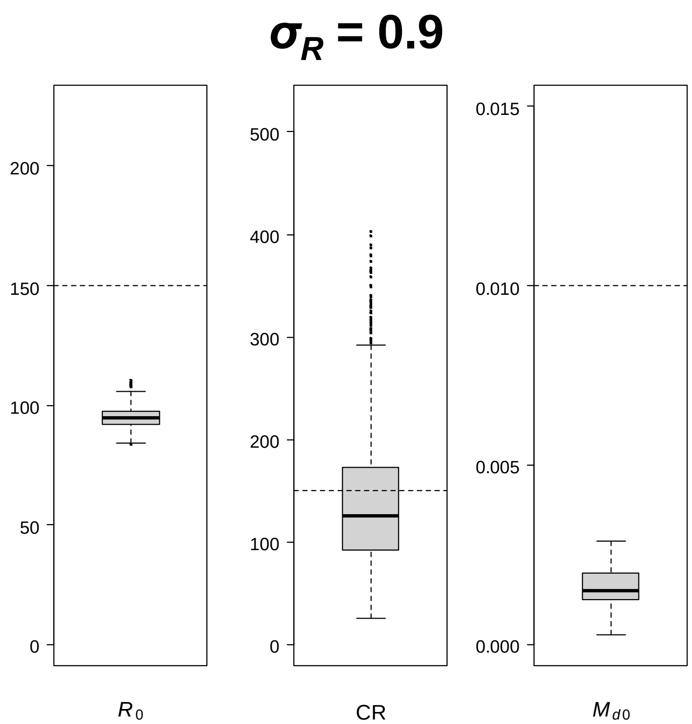
Assumed: no DD

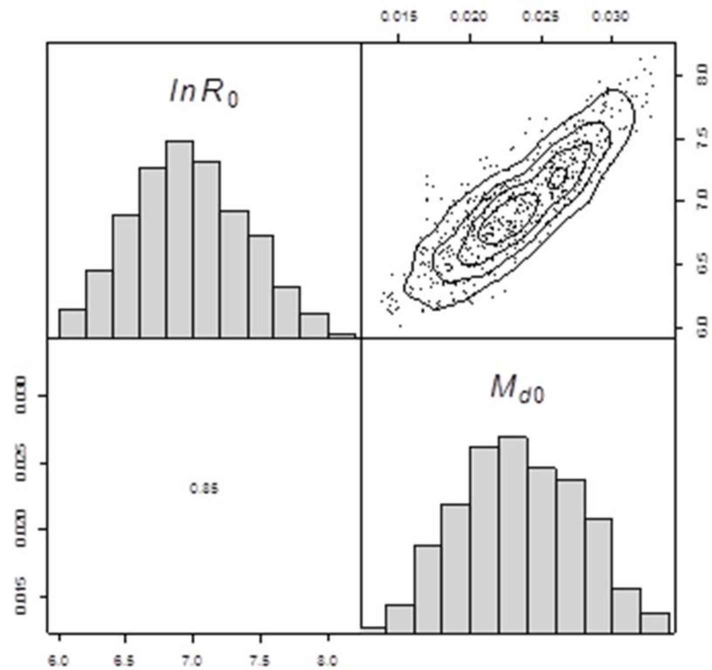
$M_{d0} = 0.02$





Estimability of density-dependent mortality parameter M_{d0}





- Ability to estimate M_{d0} deteriorates with increased process error
- R_0 and M_{d0} are highly confounded

Conclusions

- Failure to account for density-dependent mortality occurring simultaneously with bycatch can lead to:
  - Biased fishery reference points
  - Underestimation of impacts of directed fishery
  - Overestimation of impacts of bycatch
- Management plans cannot rely solely on bycatch reduction and should include directed fishery
- Definition of reference points is problematic in the presence of numerous sources of mortality affecting different demographic components of population.*

*__Powers__, J.E. 2005. N. Am. J. Fish. Manage. 25: 785 – 790.

Ways forward

Productivity parameters are frequently confounded and very difficult to estimate with most datasets

- **Simulation studies** a first step in characterising uncertainty
- Develop **decision tables** representing advice across a range of structural uncertainty – separate tables/columns or integrate across models (e.g., ensemble modelling)
- **Management Procedure Evaluation**: identify management procedures that meet objectives across range of structural uncertainties
- **Adaptive management** (large-scale management experiments)
  - Direct assessment of juvenile snapper survival responses to elimination of shrimp bycatch mortality (experimental closed areas)

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