

# The Economic Benefit and Optimal Management of Marine Reserves

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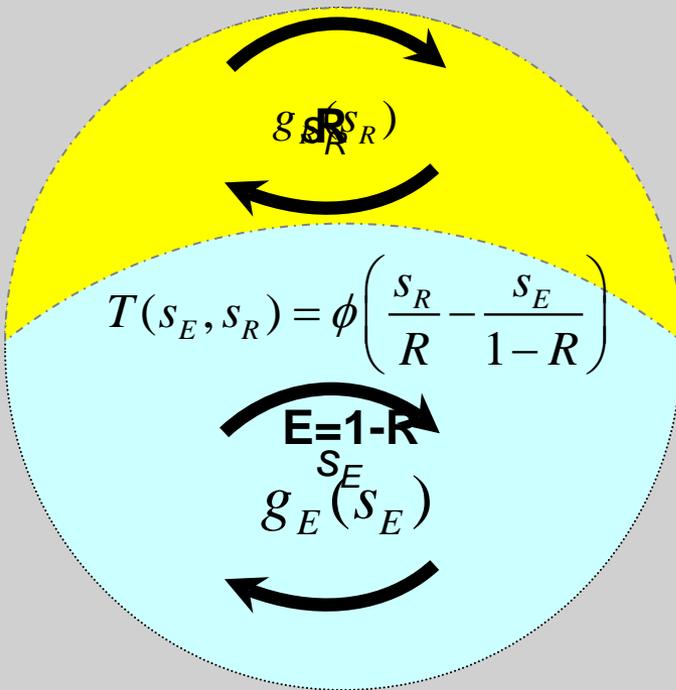
# Outline

- Classical perspective
- A recent approach
- Our new results

# Summary of Classical Perspective

- Marine reserves are known to be a measure to reduce ecological threats from fishing activities, but are also thought to be economically inefficient.
- Specifically, many would argue that optimally controlling harvest would suffice to guarantee economic efficiency, and sustainability, and setting a reserve just restricts fishing opportunities and profits.
- Thus, a no-take zone will increase stock abundance but reduce the harvest and the social surplus (profit of the fishing industry and consumer surplus).

# Technical Model of Marine Reserves



- The evolution of fish stocks are:

$$\dot{s}_E = g_E(s_E) + T - h$$

$$\dot{s}_R = g_R(s_R) - T$$

- Fishing return:

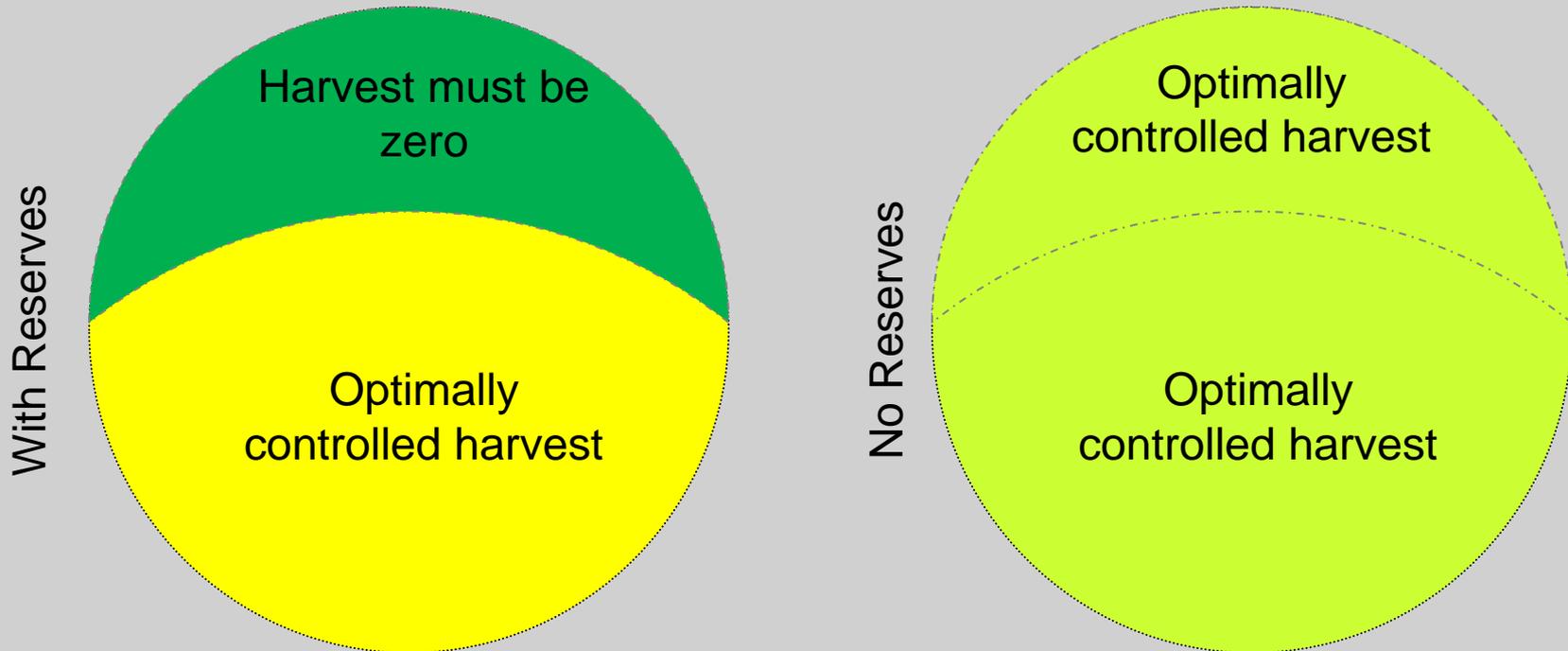
$$\pi(s_E, h) = p \times h - \frac{c}{s_E} \times h$$

- The authority controls harvest:

$$\text{Max}_{\langle h \rangle} \int_0^{\infty} e^{-\rho t} \pi(s_E, h) dt$$

- Solving this deterministic standard optimal control problem:
  - Reserves reduce the optimal harvest and efficiency.
  - Reserves increase overall stock abundance.
- We look at the intuition of each point.

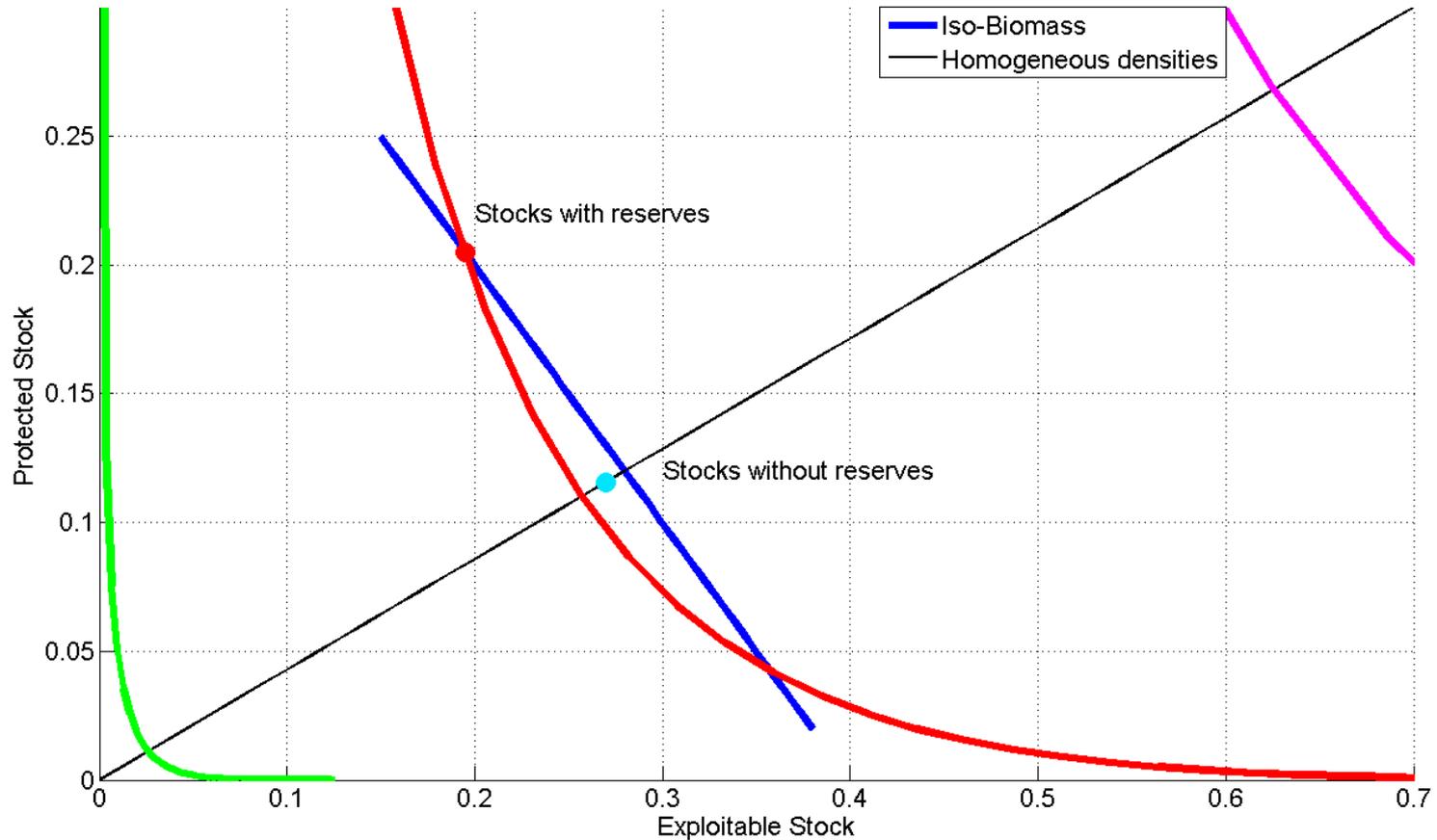
# Restricted Fishing Opportunities



- In both cases, harvest is optimally controlled in area(s) that are open for fishing.
- An imaginative reserve boundary makes clear that the reserve (if any) restricts fishing opportunities, reduces the flexibility of decision makers and the total return.

# Stock Abundance and Efficiency

Points along this curve generate the same return



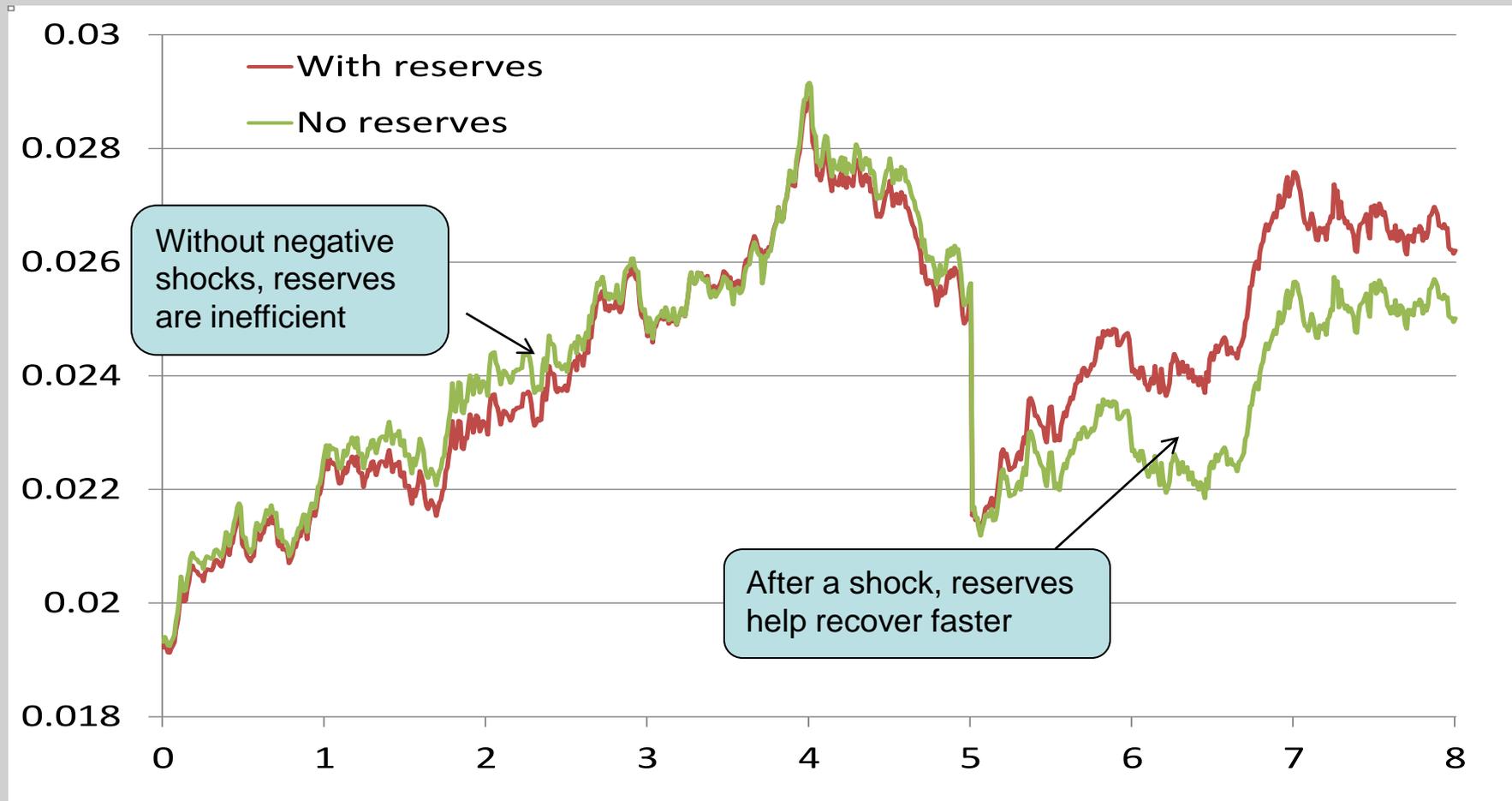
Value function for Pacific halibut fishery with 30% reserve approximated by perturbation

Iso-Return curves

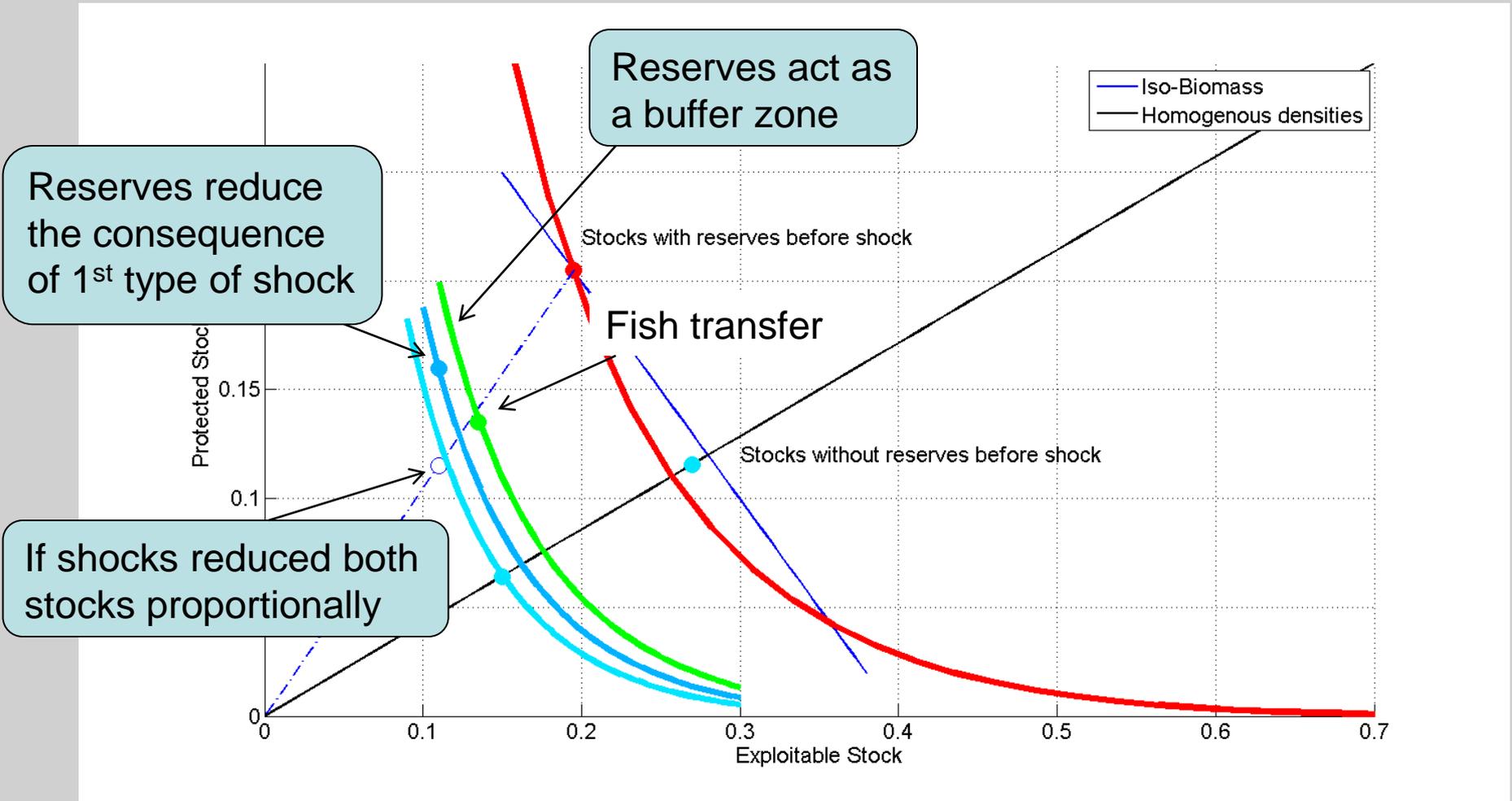
## Recent Approach

- The classical perspective is appropriate only when fish stock does not suffer from negative shocks.
- In practice, there are two types of negative shocks:
  - Shocks caused by fishing activities (e.g. discarding, bottom trawling), affecting the exploitable stock.
  - Natural shocks (e.g. caused by a disaster) affecting both the exploitable and protected stocks.
- Then, marine reserves have 2 economic roles:
  - Reducing the consequence of the 1<sup>st</sup> type of shocks.
  - Acting as a buffer zone, helping the exploitable stock recover faster and improve fishing return (Grafton, Kompas and Pham 2006).

# Reserves and Optimal Harvests



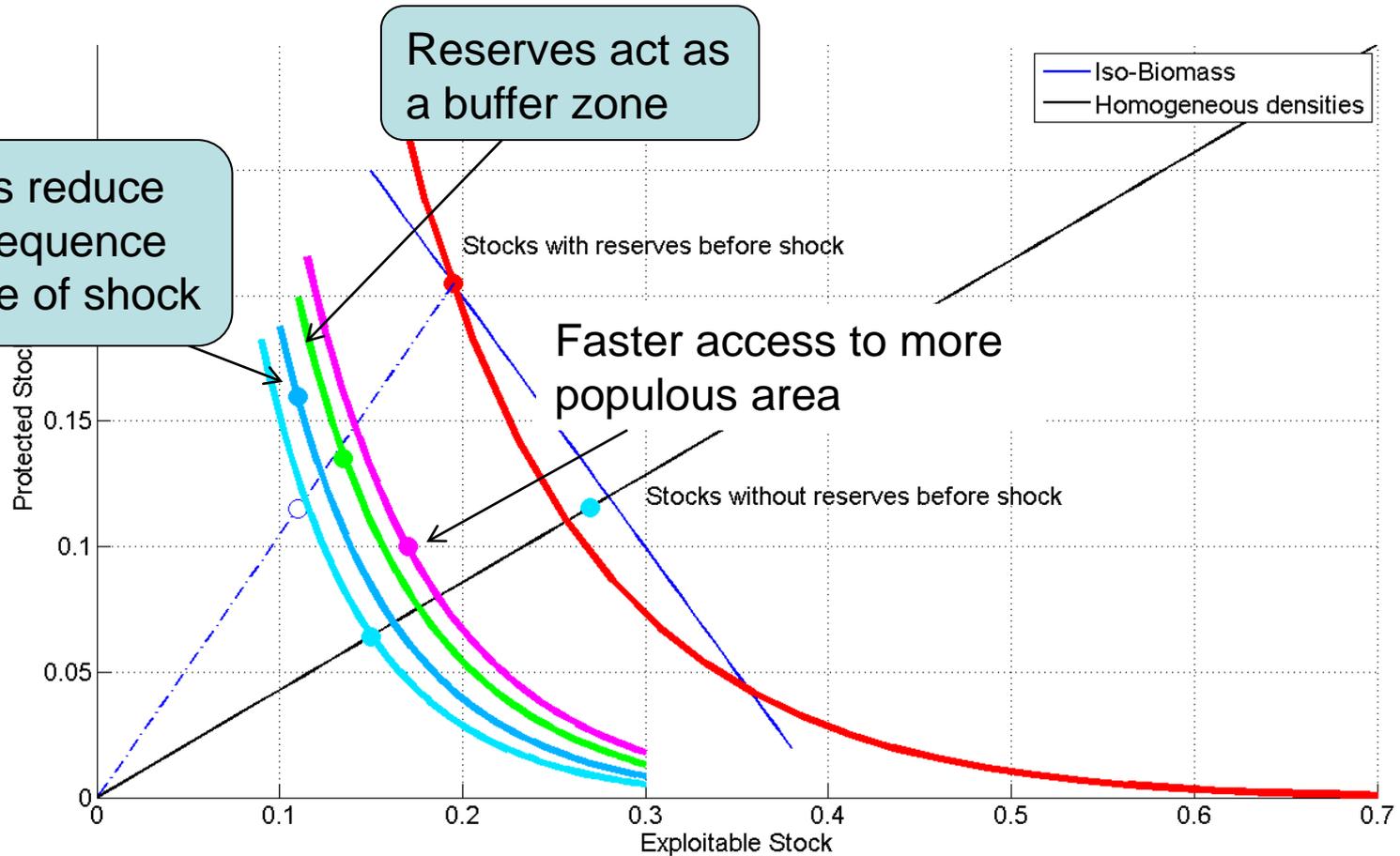
# Insight into Recent Approach



# What makes the buffer zone work

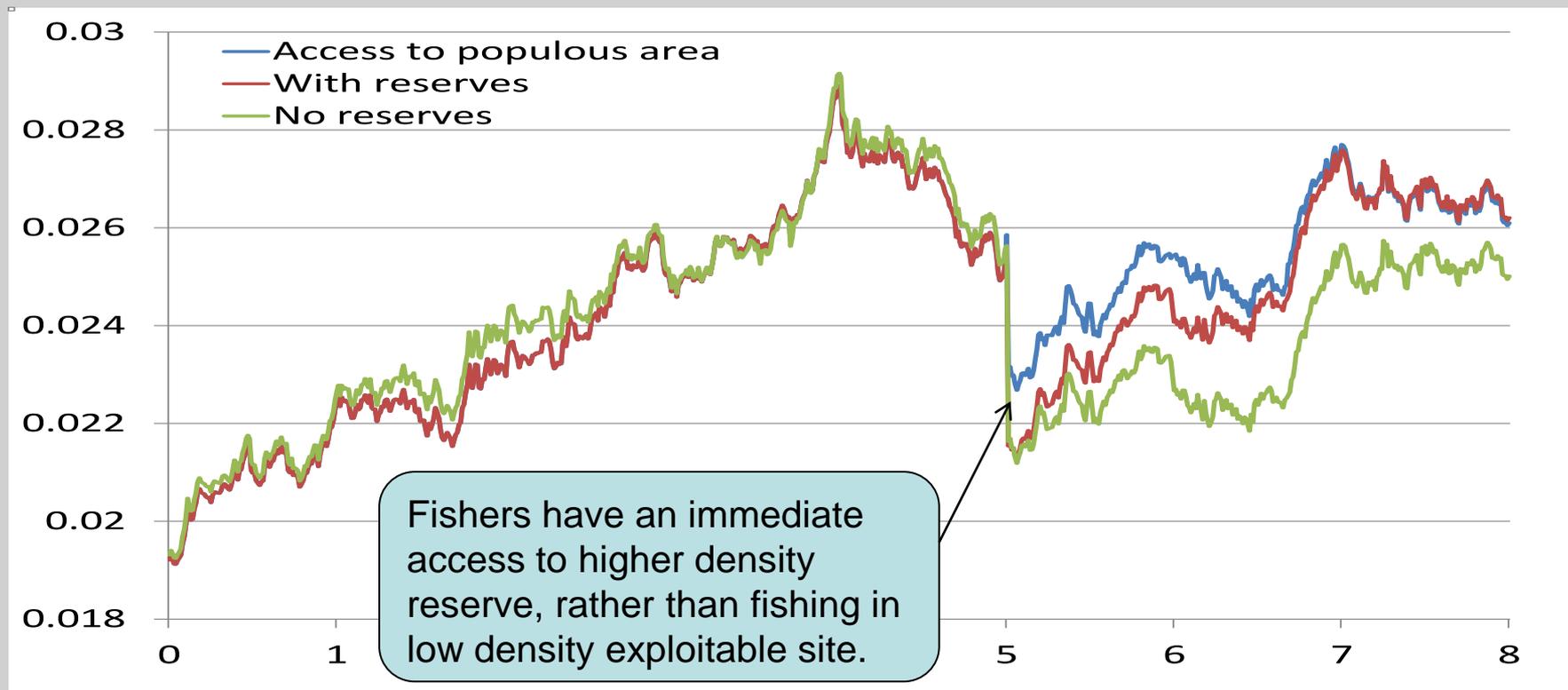
- The idea of a buffer zone depends on the assumption that fish migrates from high-density reserves to low density exploitable areas.
- This is a realistic assumption but it is difficult to measure migration speed.
- If the migration is slow, the gain from the buffer zone is small. Then the economic efficiency of marine reserves is again questionable?
- In our most updated works, we find that even if the migration is slow, marine reserves can still improve the return if fishing firms have a faster access to more populous areas after a shock.

# Summary of New Results



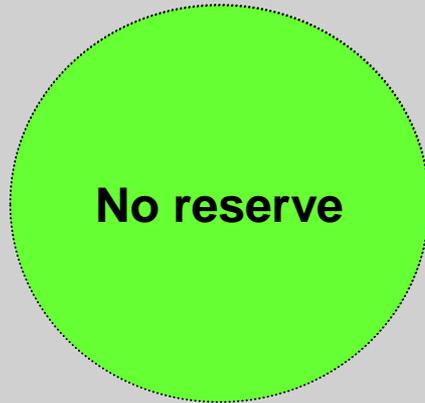
# Updated results

- After a shock, if we can provide fishing firms with access to more populous protected area, efficiency can be improved.

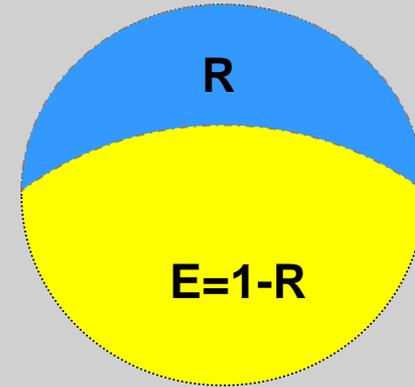


- Two ways to provide faster access: (i) Temporary Deregulation and (ii) Switching Reserves.

# Temporary Deregulation



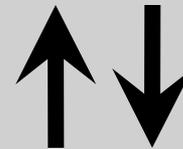
More populous  
area fished and  
fish transfer



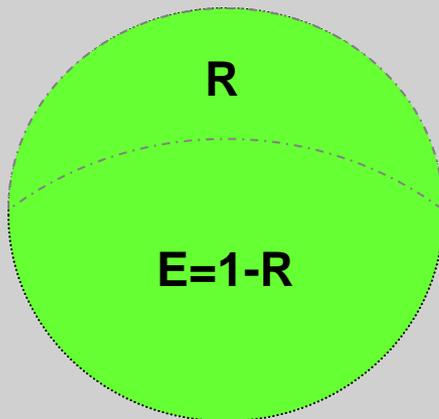
Setting a reserve  
in response to  
possible shocks



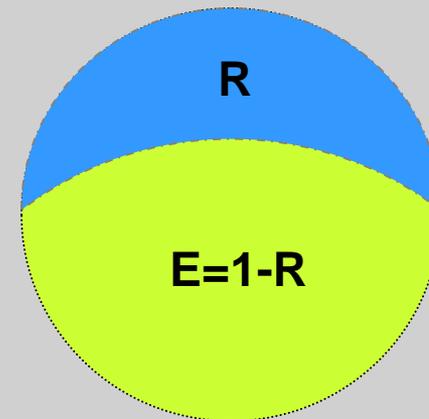
A shock  
occurs



~~Fishers wait  
for a recovery~~

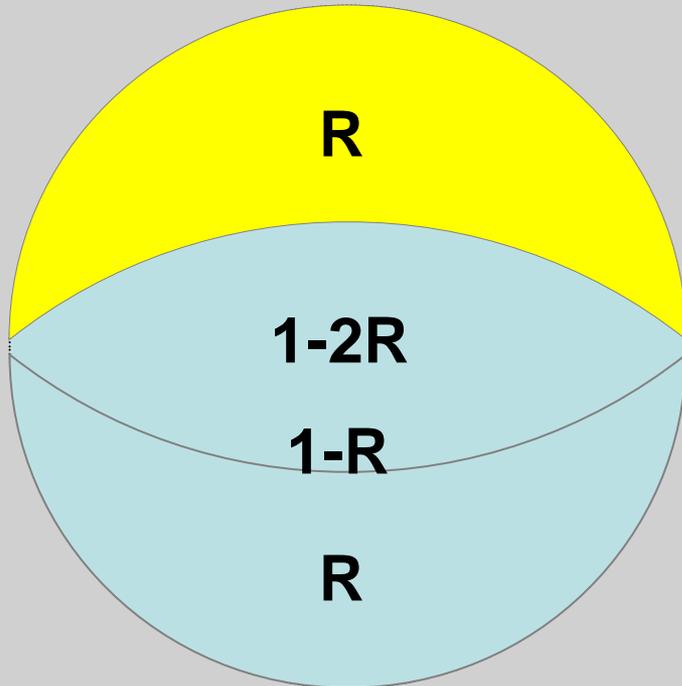


Regulated harvest



# Switching Reserves

A reserve will be changed from one location to another.



- High density protected area will be opened for fishing while a part of the exploitable area becomes protected.
- At this switching event, fish remain in their area, but the exploitable stock jumps while the protected stock drops.
- Fishing firms can fish in a more populous area and hence efficiency is improved.

# Solution Technique

- Both of the new approaches (temporary deregulation and switching) can be formally formulated in a dynamic programming framework with Bellman-like equations

$$\text{Value from today} = \max \{ \text{Current return} + \text{Value from tomorrow} \}$$

- However, they are hybrid, rather than standard optimal control problems (due to the change in the state space dimension and the jumps in fish stock) and cannot be solved using standard techniques.
- We solve the new formulations using parametric linear programming, a new technique that can be broadly applied to both standard and hybrid optimal control.

## Final Remarks

- Without shocks, marine reserves can increase the fish population but reduce the optimally extracted rent from the fishery resource.
- In a stochastic world, marine reserves can reduce the consequence of the shock and more importantly act as an ‘insurance’ buffer zone facilitating the recovery of the stock and harvest after a negative shock.
- After a shock, switching the reserves or temporarily opening the protected area for fishing may further improve the efficiency as fishers can have an access to more populous area without waiting for a slower recovery process.