The Approach to Optimal Management Targets Under Climate Change and Challenges

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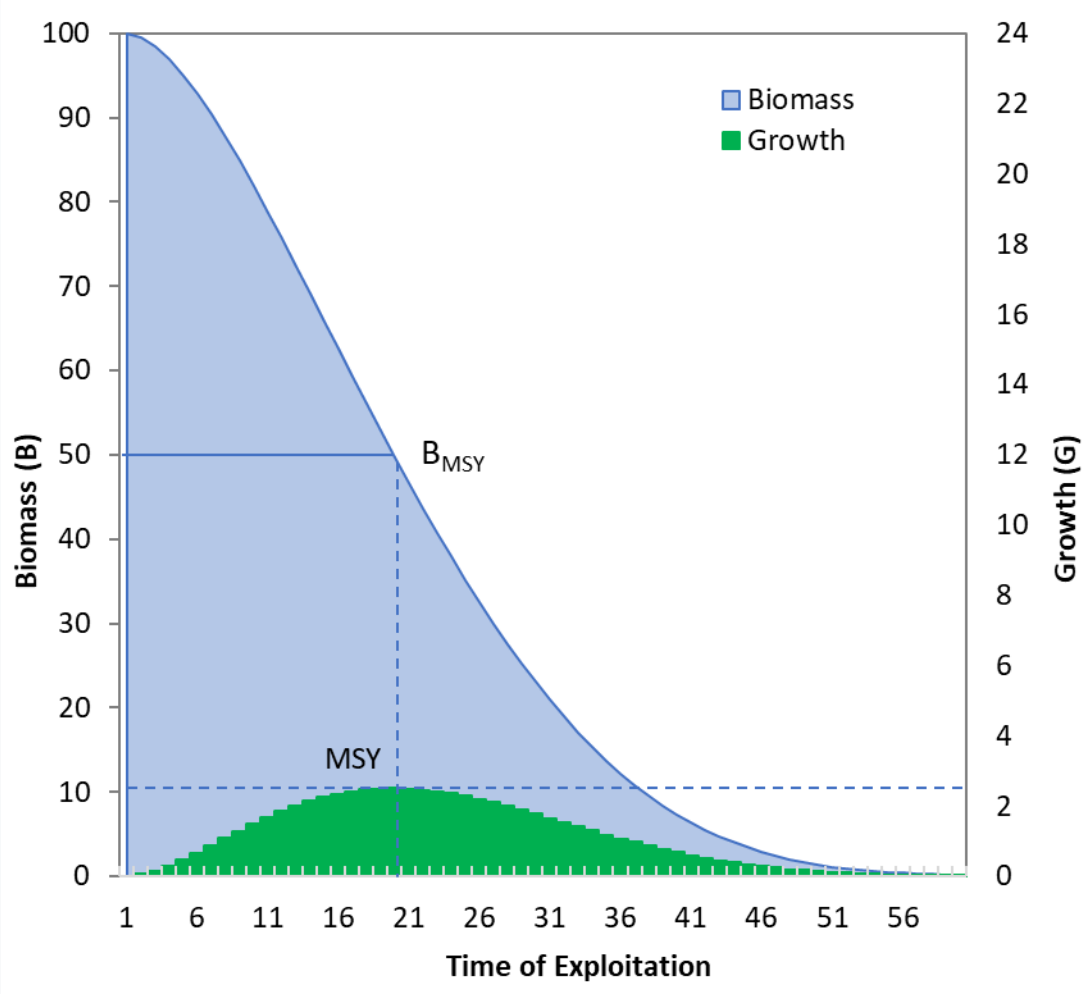
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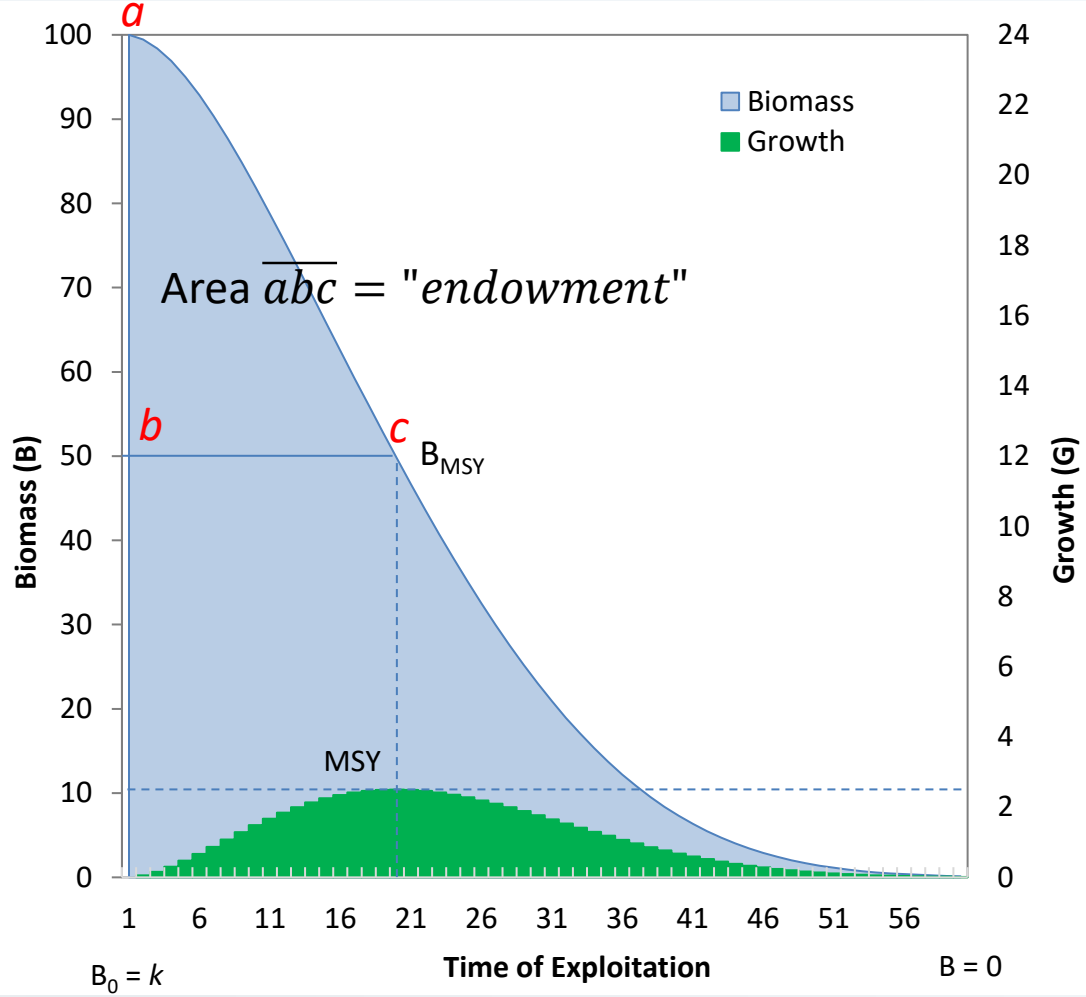
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Foundational Concepts



Fisheries: Biomass, Growth, MSY, & MEY

Foundational Concepts



Fisheries: Biomass, Growth, MSY, & MEY

Stock Drawdown

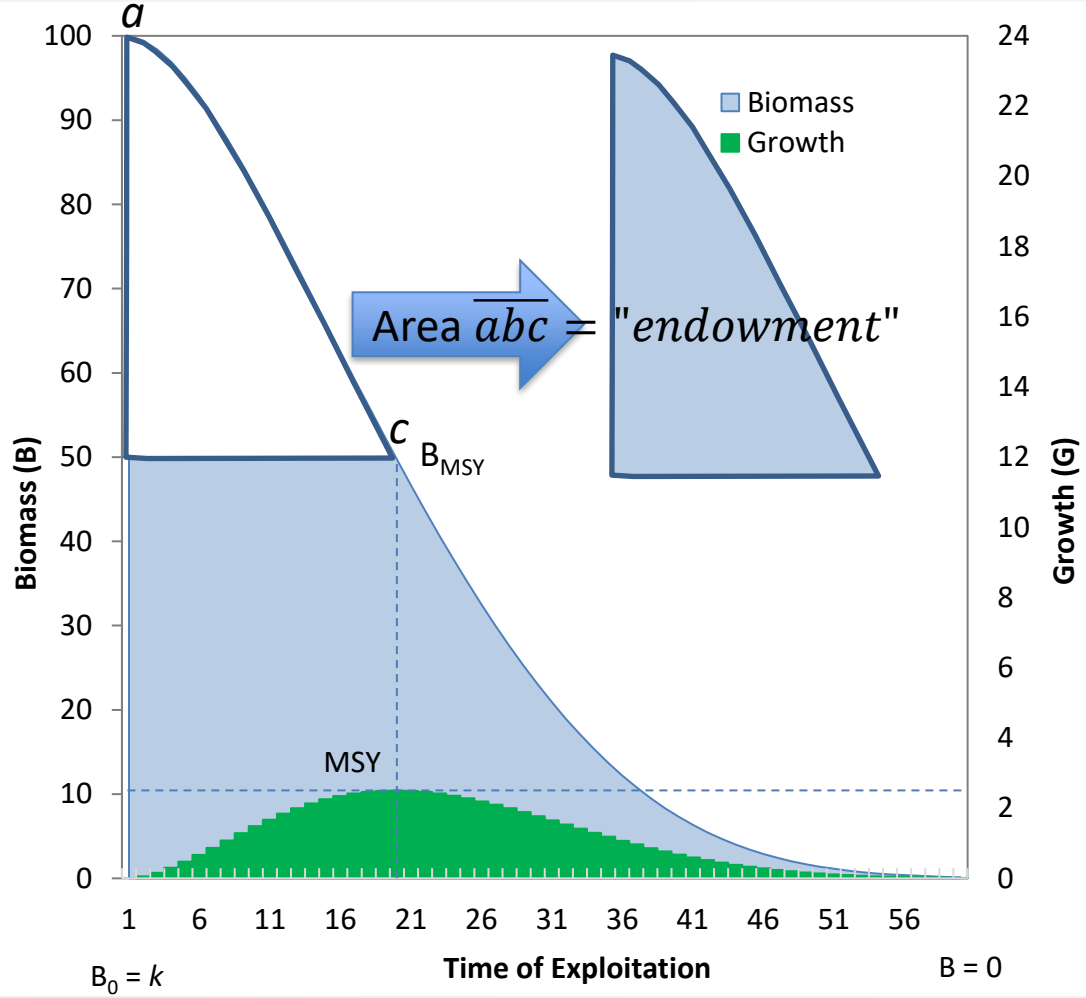
- Fisheries often start with a high initial biomass and then go through stock drawdown to reach to the long-term optimal
- MSY is only small % of B_{MSY} (e.g. bluefin 4%, bigeye 15%)

Endowment

- The surplus biomass above the long-term optimum (B_{MSY} or B_{MEY}) can be viewed as an "endowment", a start-up treasure given to a new fishery

Area $\overline{abc}$ = "endowment"

Endowment & Externality



Surplus harvests/productions is feasible when endowment > 0

Harvest **>** Growth

Endowment will be used up (endowment > 0) while arriving at long term optimal (B_{MSY} or B_{MEY})

Harvest **=** Growth

At the transition, Management "Cliff" exists

- **Excess** catch
- **Excess** capacity

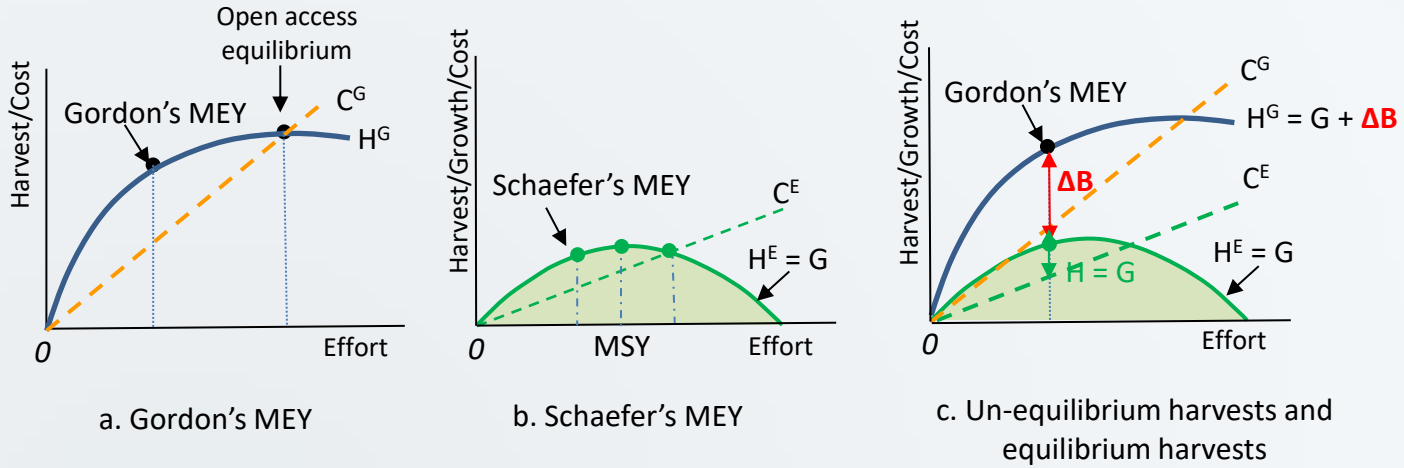
<u>Research Questions of this study</u>

- When does the ***Transition*** occur?
- How large is the "***cliff***"?

Limitations of Traditional Literature

CONCEPTUAL GAP

ΔB: Difference between total harvest (Gordon) vs. equilibrium harvest (Schaefer)



a. Gordon's MEY

b. Schaefer's MEY

c. Un-equilibrium harvests and equilibrium harvests

H^G: Gordon's harvest curve
C^G: Gordon's cost curve

H^E&G: Schaefer's harvest curve = Growth
C^E: Cost curve for equilibrium harvests
H = Revenue (Assuming unit price fish price)

Gordon (1954) Framework

Total harvest function – stock drawdown harvests are not constrained to biological growth

Schaefer (1957) Framework

Biological equilibrium perspective –

- Harvest equals to growth at every biomass level (H = G)
- Omits the dynamic stock drawdown required to reach B_{MSY}

Clark et al., 1979 Dynamic Model

"**Bang-bang" approach** – the most rapid trajectory to harvest endowment as the ***optimal path***

- Perfect malleability of fleet capital
- Zero scrap value for excess capacity
- In really -- the "***cliff***" can be very real

Discrete-Time Bioeconomic Model

Surplus Harvest Function

$$\boldsymbol{\pi_t} = \boldsymbol{E_t}[p_t CPUE(B_t) - c_t]$$

$\boldsymbol{E_t}$: fishing effort is an **exogenous** variable chosen by industry/managers

ΔB

Equilibrium Harvest Function

$$\boldsymbol{\pi_t^E} = \boldsymbol{E_t^E}[p_t CPUE(B_t) - c_t]$$

$\boldsymbol{E_t^E}$: equilibrium fishing effort in **Schaefer**

$$\boldsymbol{E_t^E} = \frac{r}{q_t}\left(1 - \frac{B_t}{B_0}\right)$$

Bridging non-equilibrium vs. equilibrium harvests

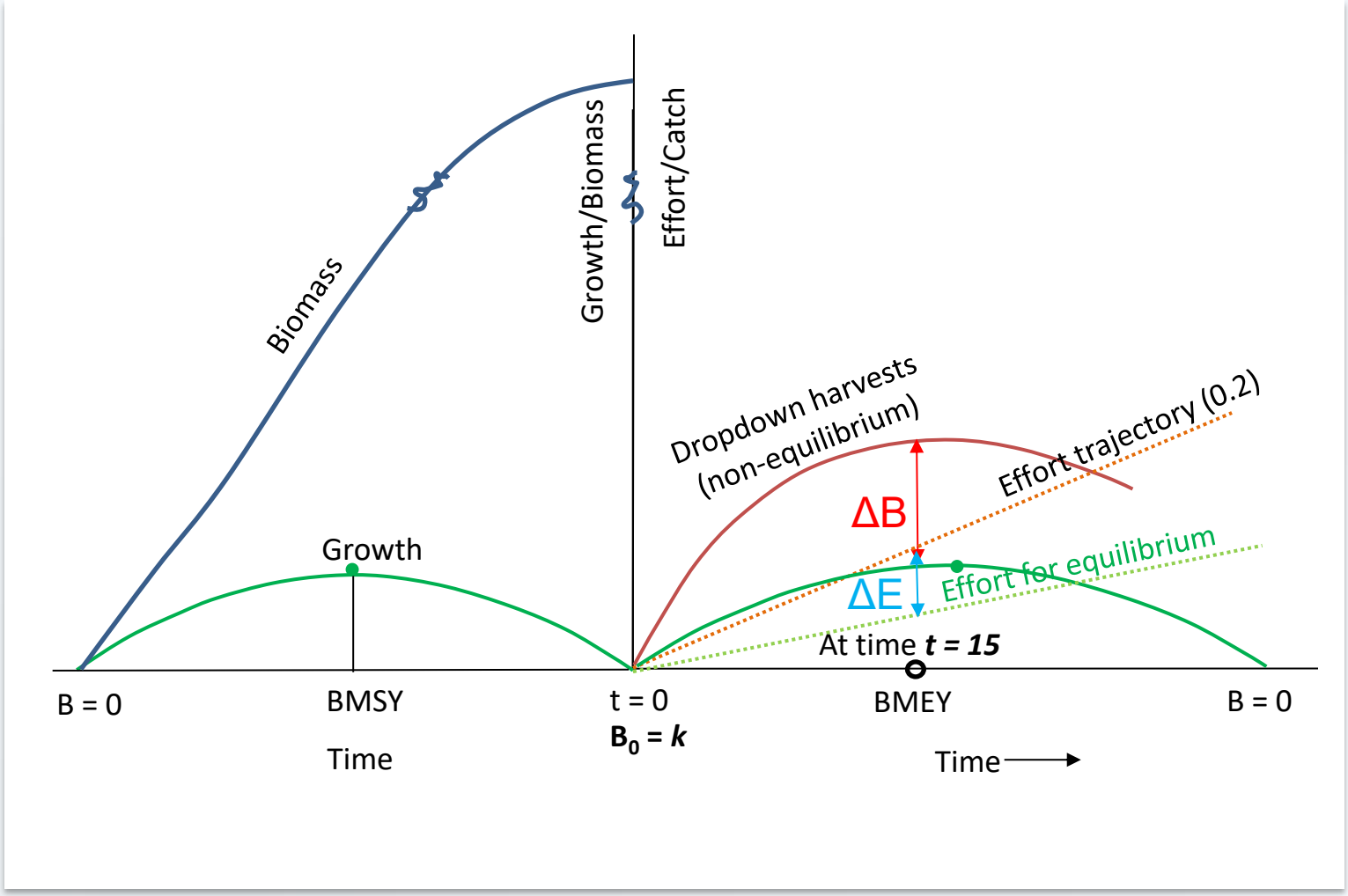
Transition cliff at each discrete time

Excess catch

Excess capacity

The time it takes to reach the optimal

Time It Takes to the Optimal Target



Simulation Framework

- Pitcher (1995) (r = 0.1; q = 0.28)
- Effort increasing at slope of 0.2

Results from Simulation

- Reach BMEY at 15 years (66%)
- Reach BMSY at 20 years (50%)
- Open Access: at 26 years (33%) from initial stock

Excess Capacity: The Transition “Cliff”

Drawdown harvest arrived at BMEY

Catch = 5.5 units

Effort = 3.0 units

Equilibrium harvest at BMEY

MEY = 2.3

Effort = 1.2

ΔB

The Transition Cliff

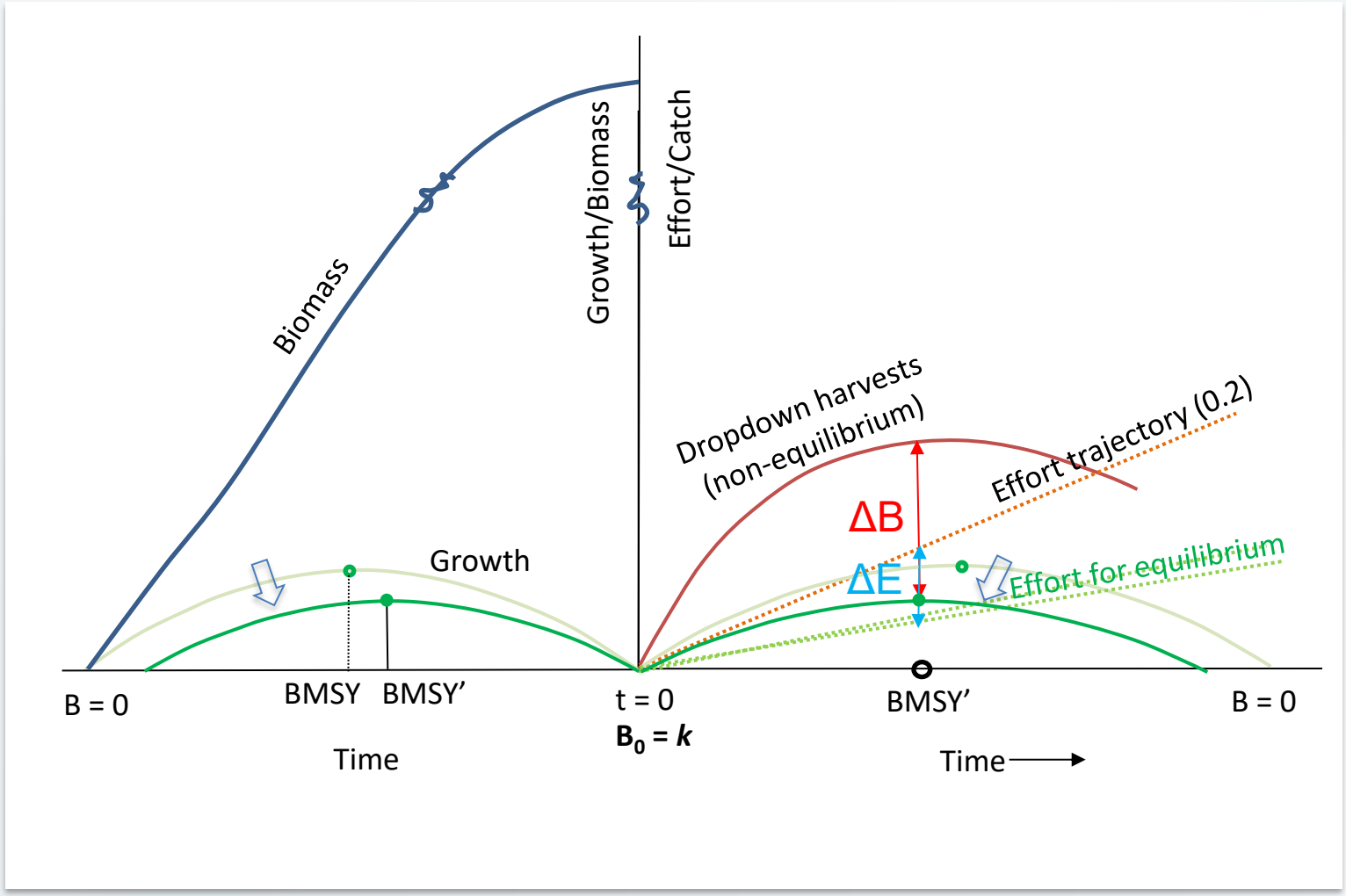
240% catch

250% capacity

Take Home Message

Common property is not the only cause for overfishing/overfished/over-capacity. Therefore, privatized ownership may not be the sole solution

Impact of Climate-Driven Productivity Decline



Climate change in ocean productivity

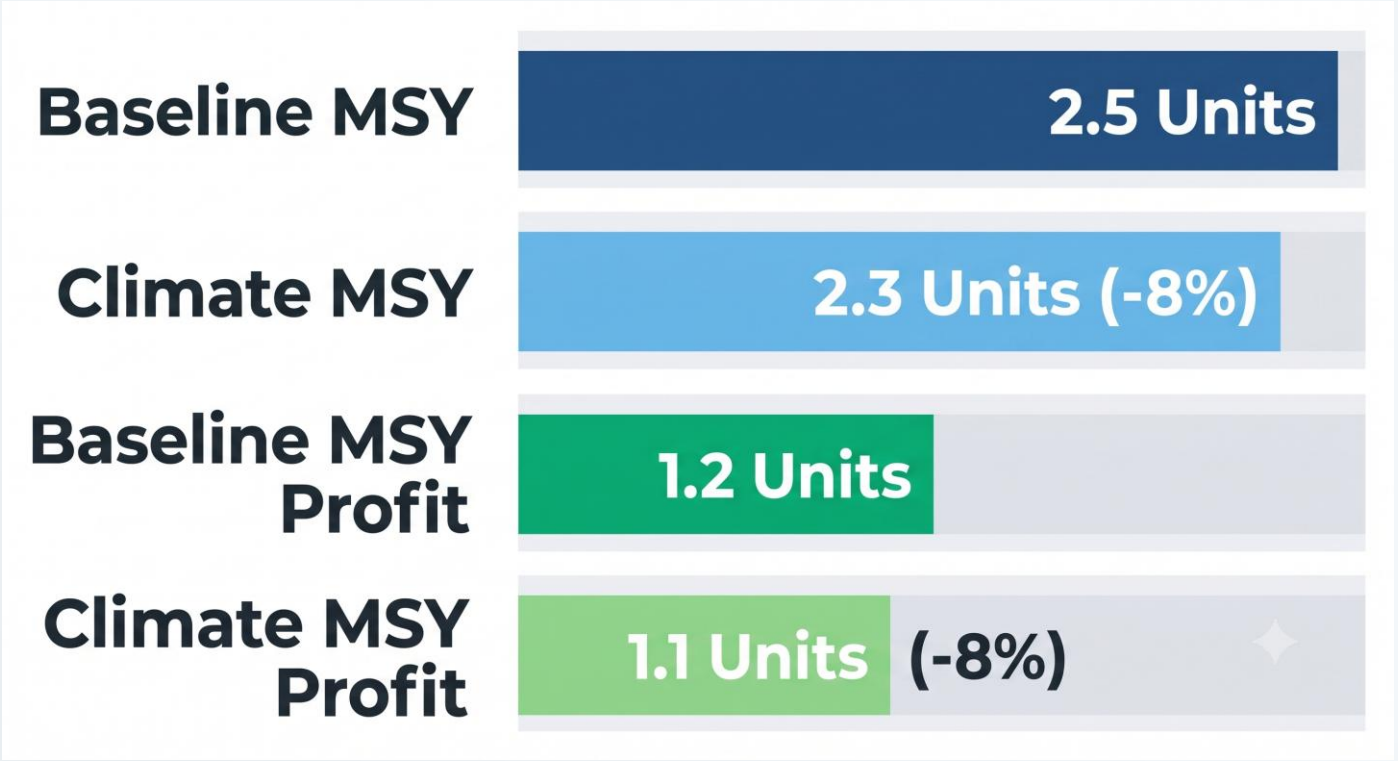
(Woodworth-Jefcoats et al., 2017)

- 2–5% per decade lower productivity of commercial fish
- Climate warming reduces intrinsic growth (0.35% annual decline)

Climate warming reduces optimal yields and profit

- MEY ⬇
- MSY ⬇
- Still with similar amount of excess capacity and catch

Climate Change Alters Optimal Targets

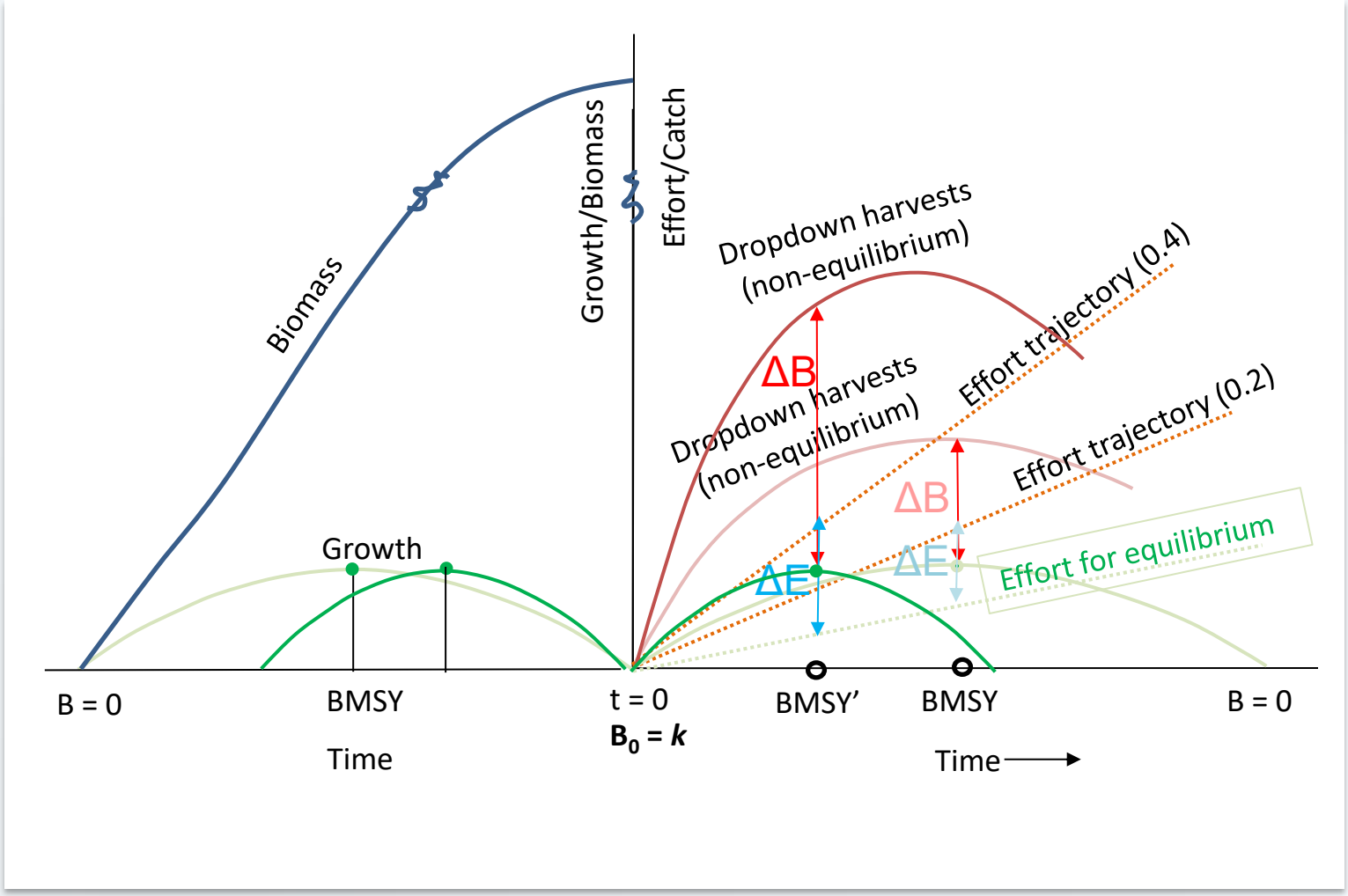


Arrived the optimal (BMSY & BMEY) year earlier

Climate Warming Impact at Profitability

- Reduced MSY 8%
- Reduced profit at MSY 8.3%

Rapid Effort Increase



IF effort increase in higher speed

Slope = 0.4 (vs. slop 0.2)

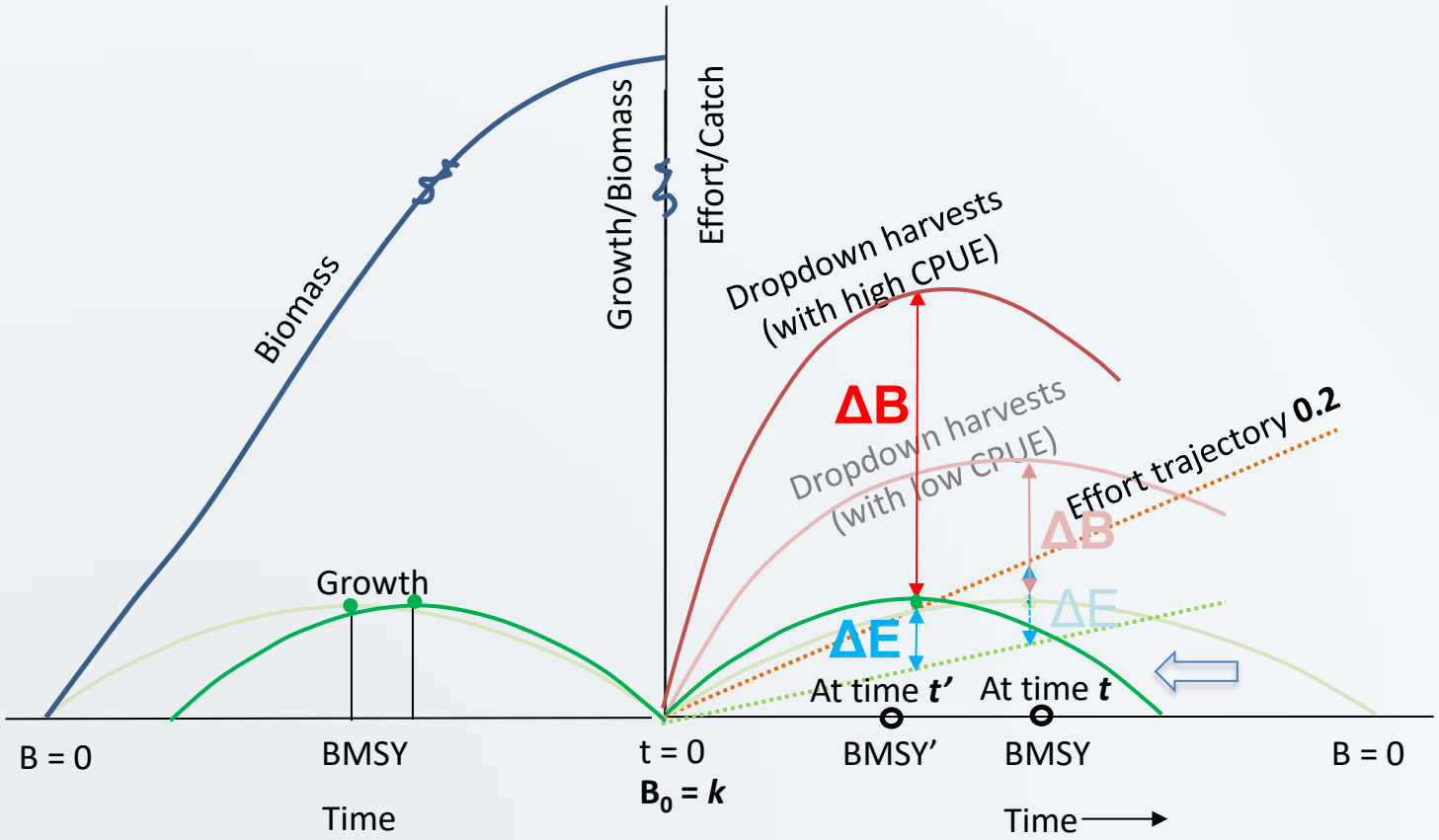
MSY or MEY does not change

- **10 years earlier** (vs. 20 years)
- **Higher** "cliff" at the transition

50% time
250% catch
290% capacity

"Bang-Bang" approach results severe excess effort and catch

Technological Improvements



Baseline model

- Linear CPUE
  (CPUE linear decrease as **B** decrease)

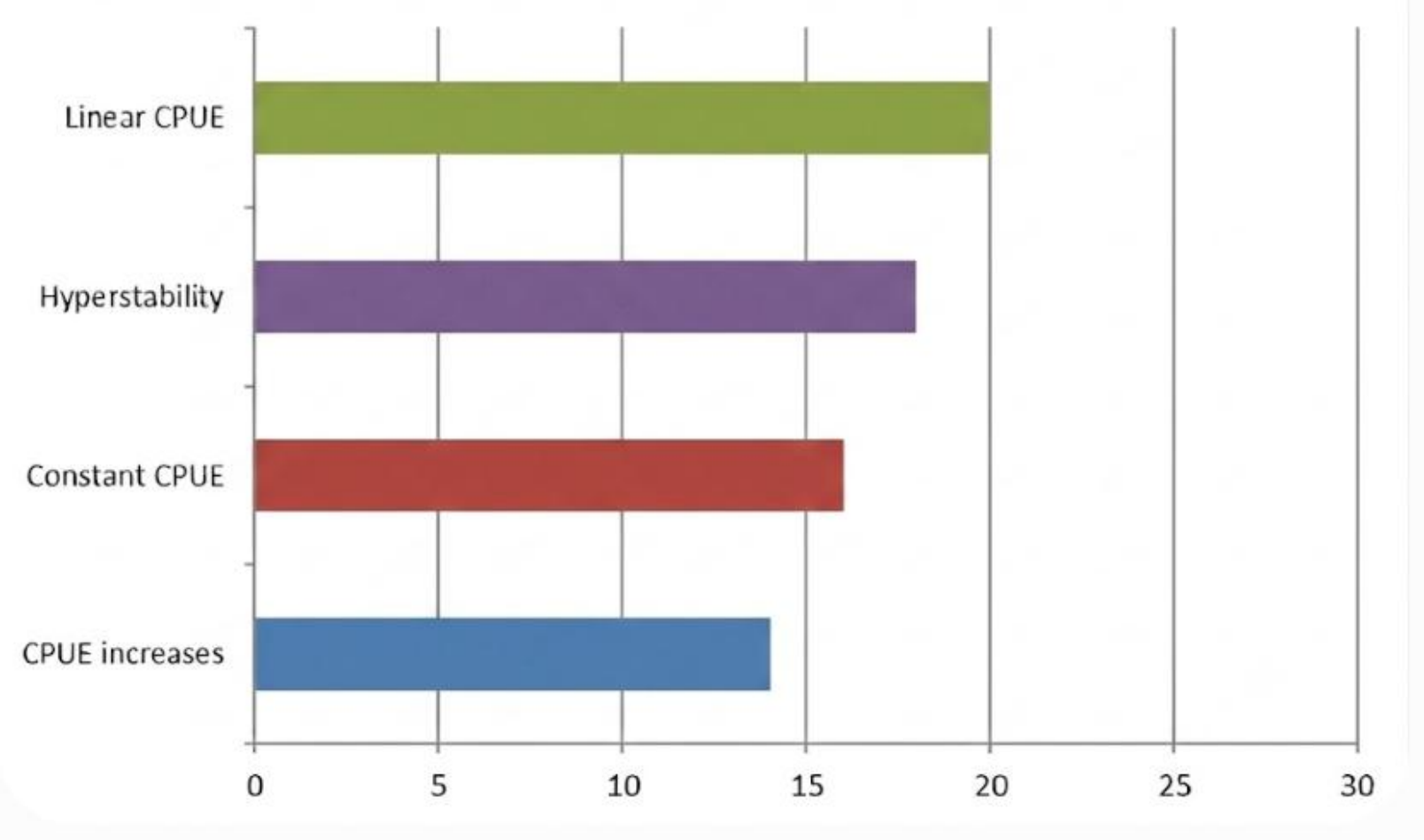
Improved CPUE, CPUE may increase even **B**iomass decreasing

- Hyperstable
- CPUE constant
- CPUE increasing

Same effort but catch more fish

- Arriving the optimal earlier
- Similar excess capacity (**ΔE**)
- **Much higher** excess catch (**ΔB**)
- Fishery may **collapse** within short period of time even no increase in nominal effort (# of vessels or trips)

Impacts of Various CPUE Performances



Higher CPUE performance shortens the time to reach the optimal Target

- Linear CPUE
  20 years
- Hyperstable CPUE
  18 years
- Constant CPUE
  16 years
- CPUE increasing
  14 years

Conclusions & Management Implications

- “Endowment harvests” generate externalities that are relevant to fisheries management
  - Excess capacity and excess capacity
- The discrete-time bioeconomic model developed in this study can quantify the impacts of “endowment”
  - Time it takes to optimal target
  - Magnitude of excess capacity and excess capacity at transition
  - Potential time to collapse if absent of management ***under open access***
- The simulation framework demonstrated how to assess the impacts of climate change, technological advancements, market conditions, and other key factors

More Information



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