Non-Linear Catchability and Optimal Fisheries Management Target

Dr. Minling Pan

NOAA/Pacific Islands Fisheries Science Center

PICES 2024 Honolulu

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Research Background

- National Standard 1 (U.S.) requires Optimal Yield (OY)
  - Biologists: MSY = OY
  - Economists: MEY = OY (MEY < MSY)
    (MEY: Maximum Sustainable Economic Yield)

- How far away is MEY from MSY?
  - Global fishery profits would be 29% higher under MEY than under MSY (Costello et al. 2016)

- However, MEY is hardly applied as a fishery management goal
  - Christensen (2010) “if operating at MEY level would result in so much higher profit for the fishery sector, why don’t they (managements and industry)”?
  - He looked for the answers from outside the fishery sector (e.g. processing & supply sectors)

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Research Questions

- A recent study reviewed the literature related to MEY (Dalton et al. 2018).
  - Confirmed the traditional definition of MEY exists considering benefits only within the fishery sector due to "**stock effect**"
  - Indicated challenges in MEY measure

- Questions remain: how to make MEY more useful?
  - What assumptions in Schaefer's bio-economic model could be relaxed?
  - What are the most important elements were missed in Schaefer's model?

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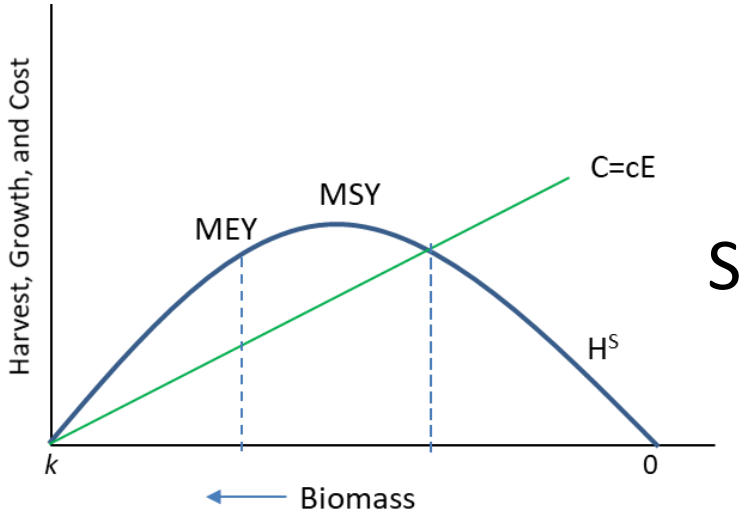
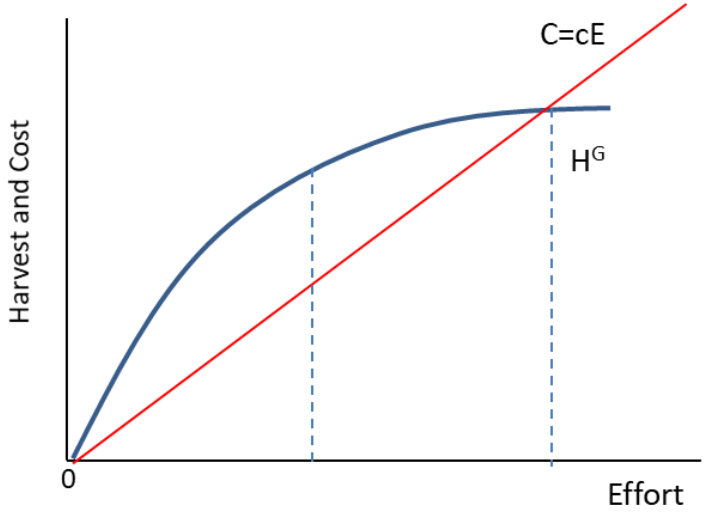
Schaefer Bio-Economic Model (1957)



Schaefer's optimal



Gordon's optimal

- Gordon-Schaefer's MEY (1957)
  - **H**arvest = **G**rowth
  - Effort is restricted by **C**atch = **G**rowth
  - ***q*** is fixed

- Gordon's MEY (1954)
  - No biomass characteristics included
  - Catchability ***q*** was a variable (not a fixed parameter)
  - **E**ffort was a choice variable

Research Objectives

- **In reality**
  - q (catchability) is not fixed;
  - Catchability changed due to technological changes, resulting different CPUE performances even under the same biomass condition;
  - Catch ≠ Growth (working paper)

- **The research objective:** allow non-linear catchability q into MEY determinations

Volume 41, Issue 5

Pages: 1227-1615

October 2021

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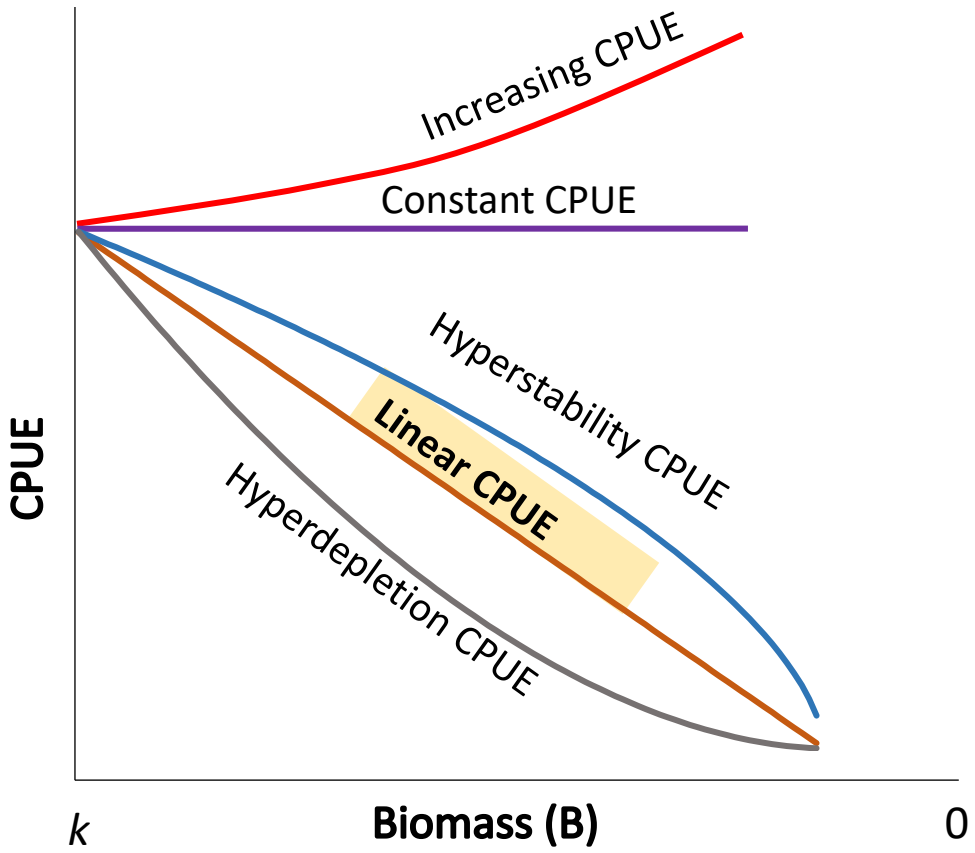
Maximum Economic Yield and Nonlinear Catchability

Minling Pan

https://afspubs.onlinelibrary.wiley.com/doi/full/10.1002/nafm.10661

Why Does Catchability (*q*) Matter?

-- CPUE is not always linear to biomass changes



- Three CPUE relationships in responses to biomass changes suggested by Hilborn & Walters (1992)
- Burgess et al. (2017) studied 39 fisheries
  - **82%** were CPUE hyperstable
  - **36%** were severe hyperstable (CPUE constant or increasing with decreasing biomass)
- Biologists pointed out technological improvements, schooling behaviors, or combinations of the two, greatly increased catchability & high CPUE performances
- Implications to economists: **stock effect** varied by fisheries

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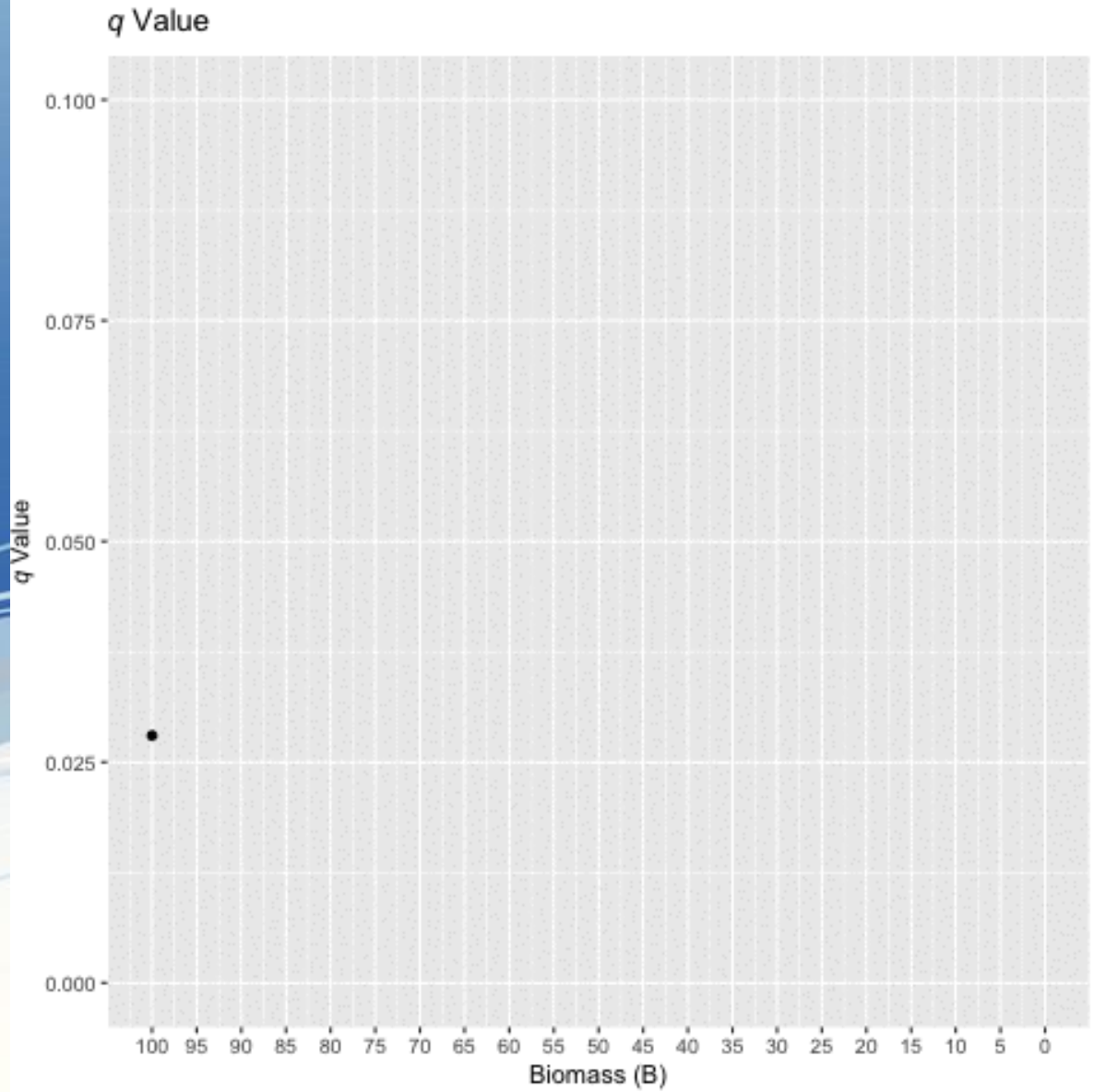
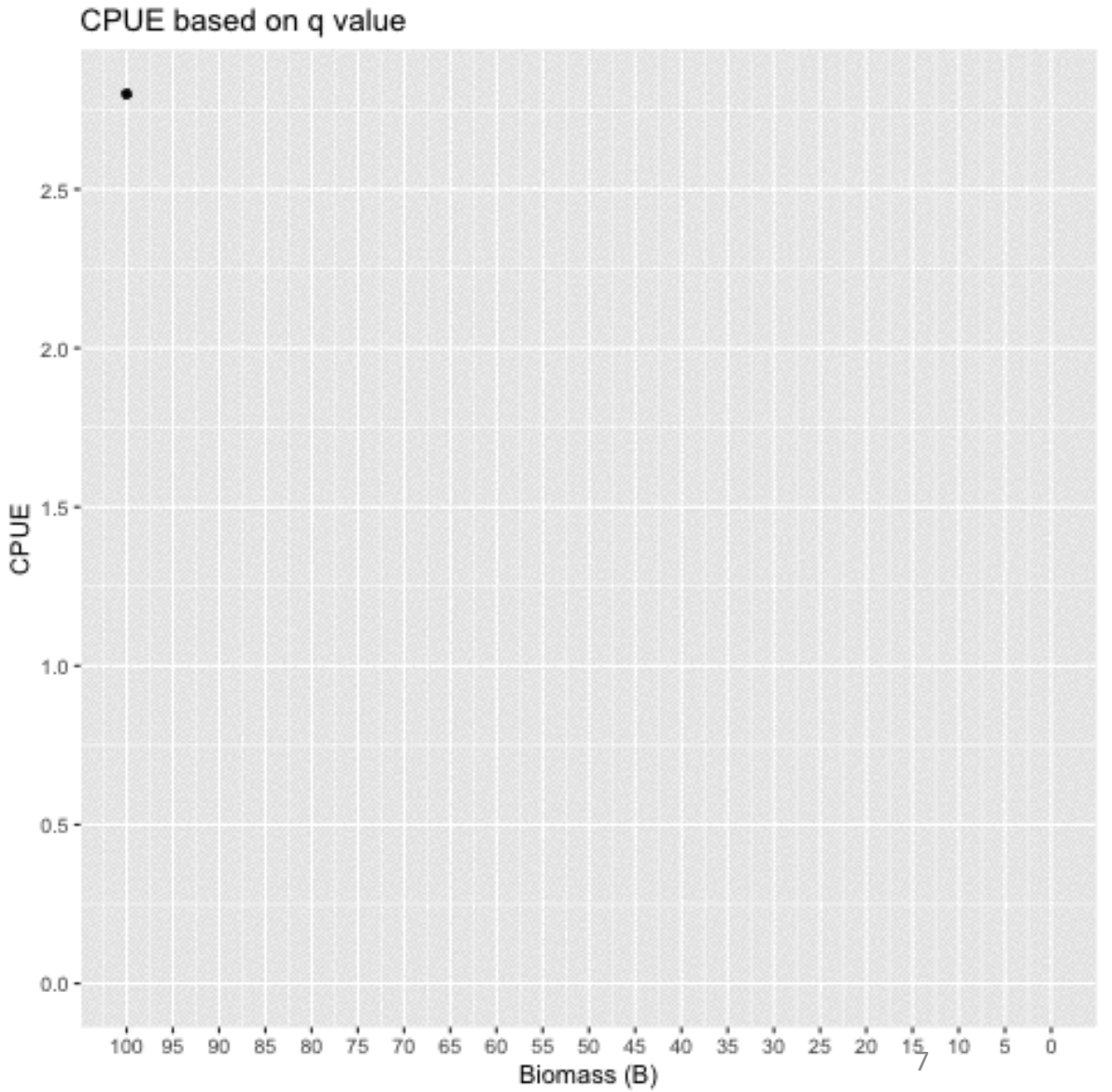
Catchability (q) & CPUE Performances





Research Approach

— Modify Gordon-Schaefer's model using non-linear catchability

- In Schaefer's model, the production (harvest) function is written as

$$H = qB \cdot E = CPUE \cdot E$$

$$CPUE = qB$$

*When **q** is fixed, CPUE is linear (proportional) to biomass change*

H: Catch
G: Growth = $rB(1-B/k)$
q: Catchability
B: Biomass
E: Effort

- In the study, ***q*** is a non-linear variable to **B**iomass, then CPUE (average productivity) is also non-linear to **B**iomass

$$CPUE = q(B) \cdot B$$

$$H = CPUE \cdot E = q(B) \cdot B \cdot E$$

- *CPUE is defined by two elements **q(B)** and **B**, and these two elements could move at **opposite** directions*
- *We examine how productivity and MEY changes in relation to **q(B)** changes*

Extensions over Gordon-Schaefer's Model

- Allowed to reflect technological progress and schooling behavior of individual fisheries;
- The key parameters included into the model, such as **E**ffort and **CPUE,** are expressed in "***nominal terms***" which are commonly available in fisheries (of course assuming biomass data are also available).

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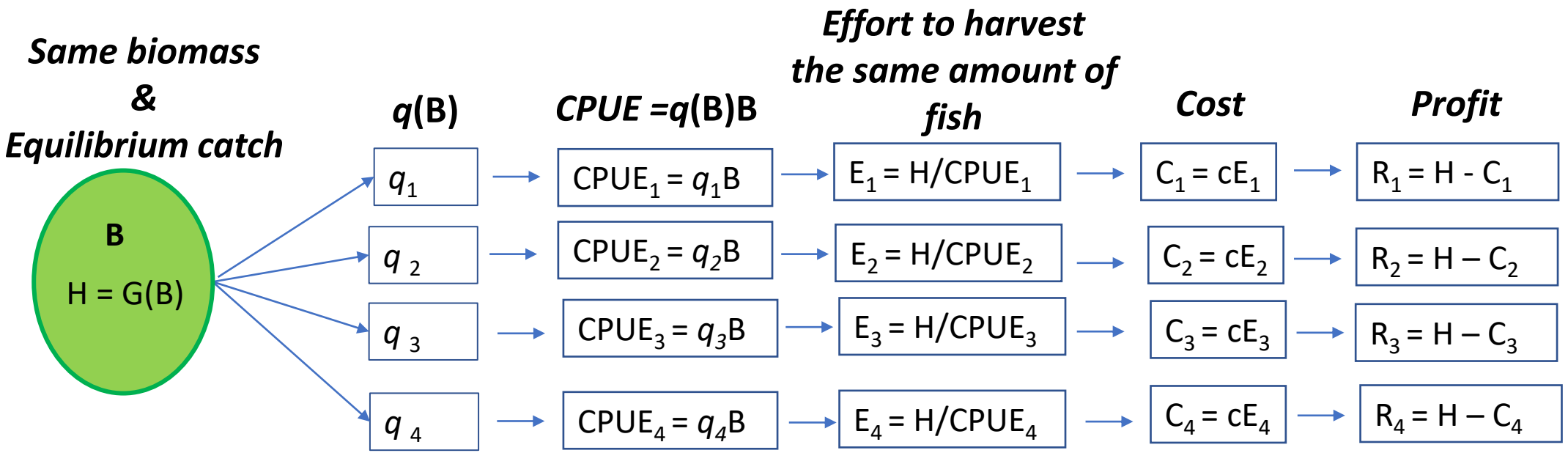
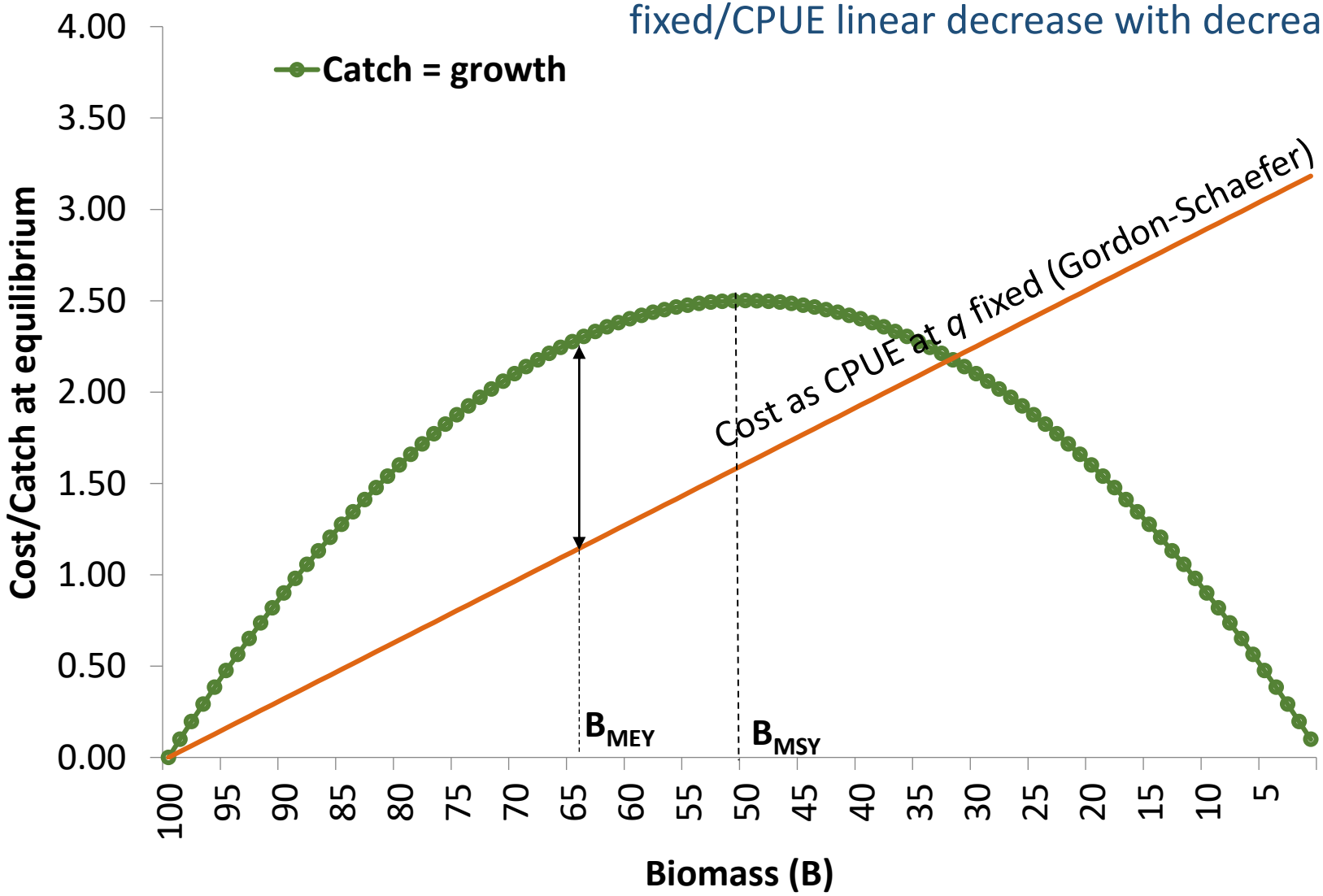
Simulation Analysis Framework

– How MEY changes under four different CPUE performances (Adopting parameters from Pitcher's 1995 study)



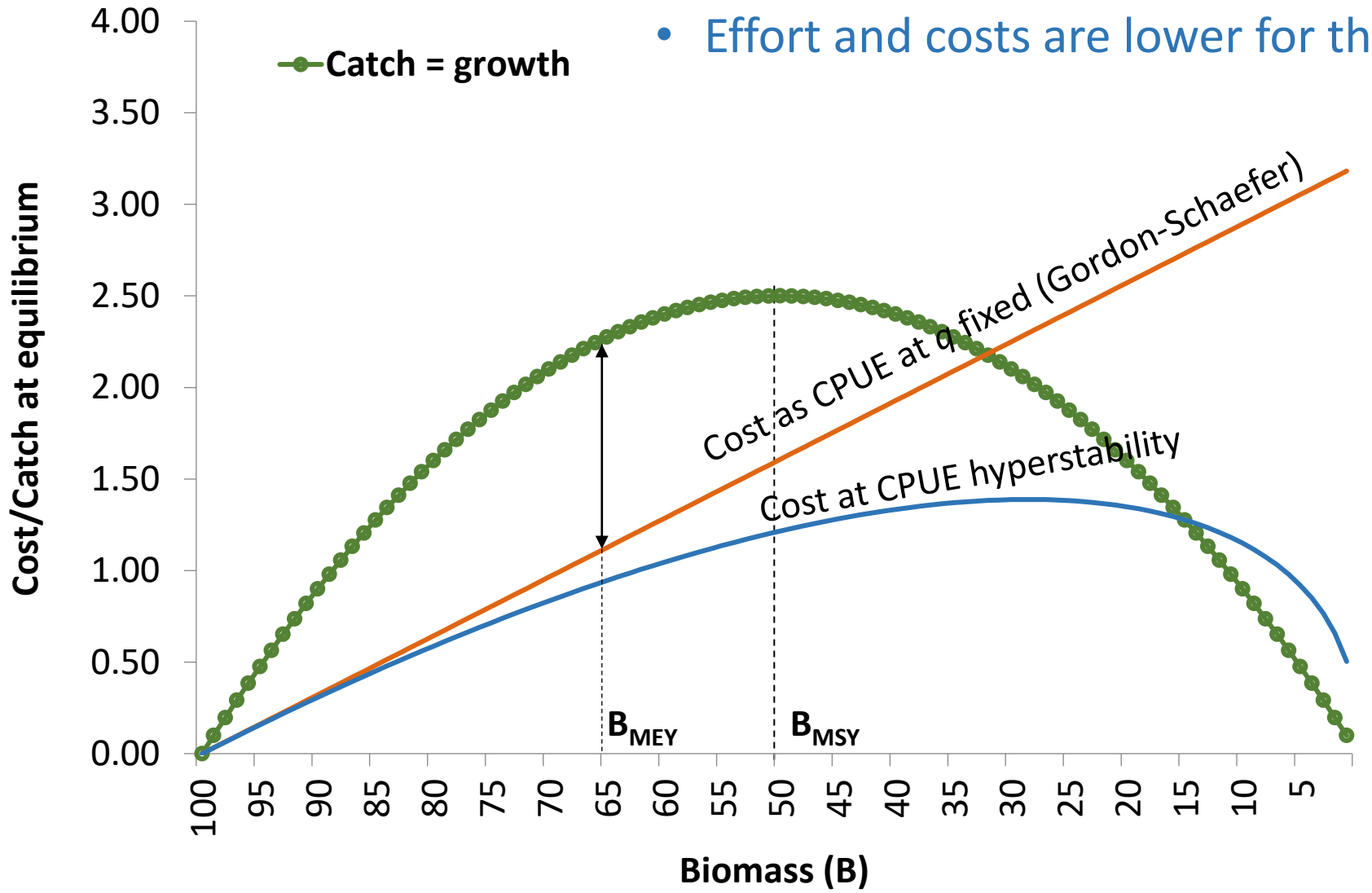
Simulation Results --

- CPUE linear -- Gordon-Schaefer's Model, q fixed/CPUE linear decrease with decreasing biomass



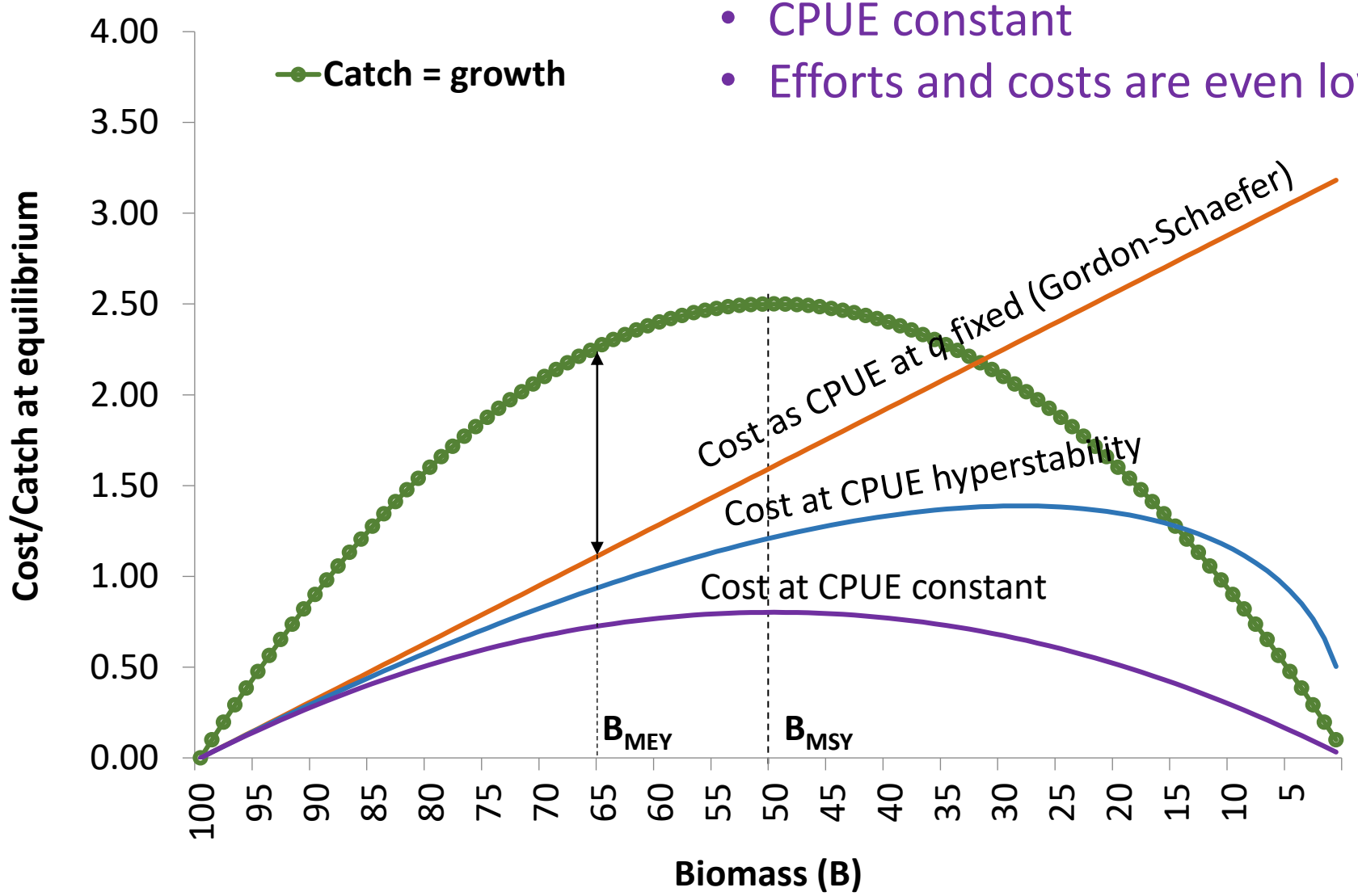
Simulation Results --

- CPUE decreasing in slower rate
- Effort and costs are lower for the same catch



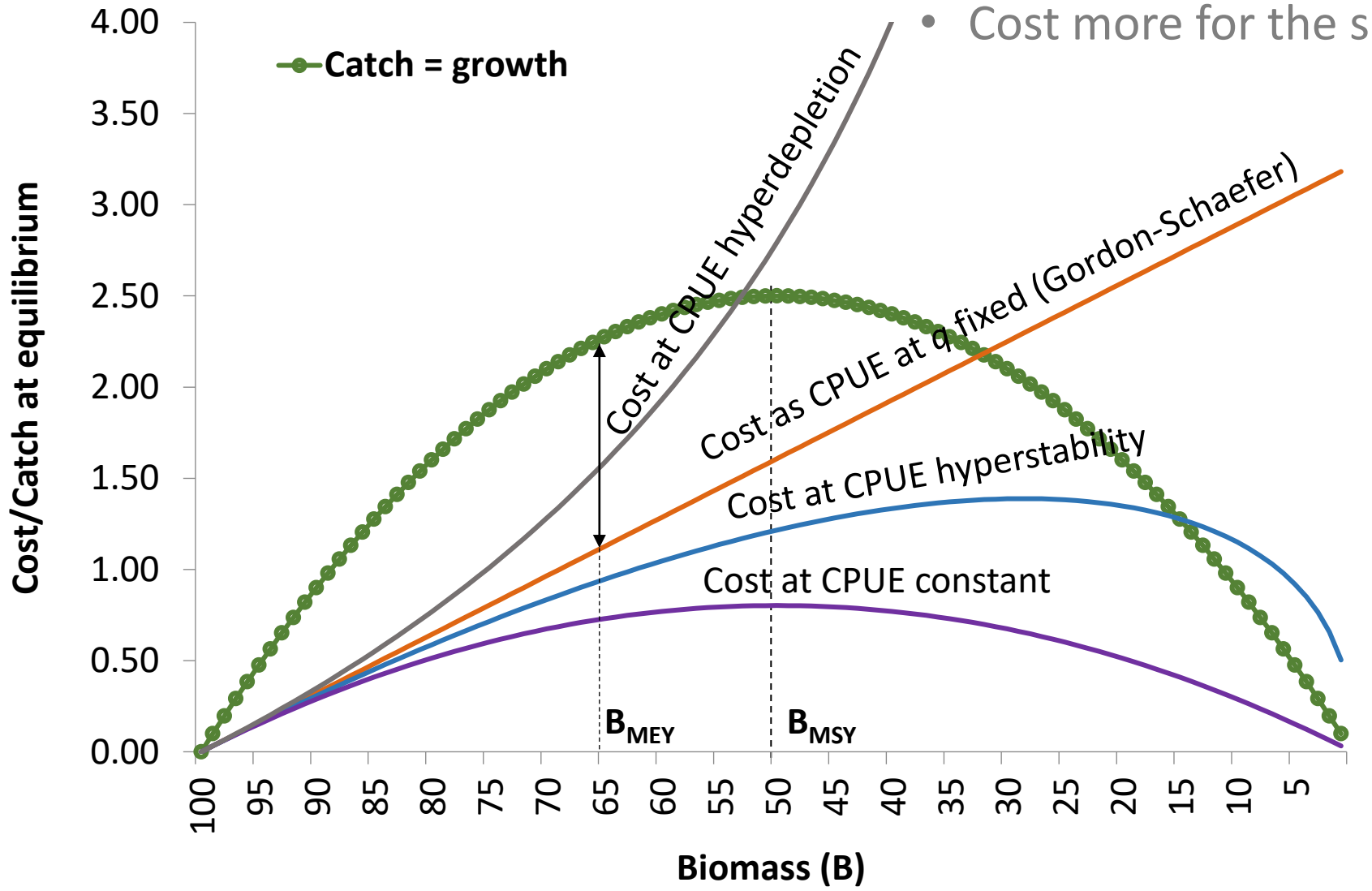
Simulation Results –

- CPUE constant
- Efforts and costs are even lower

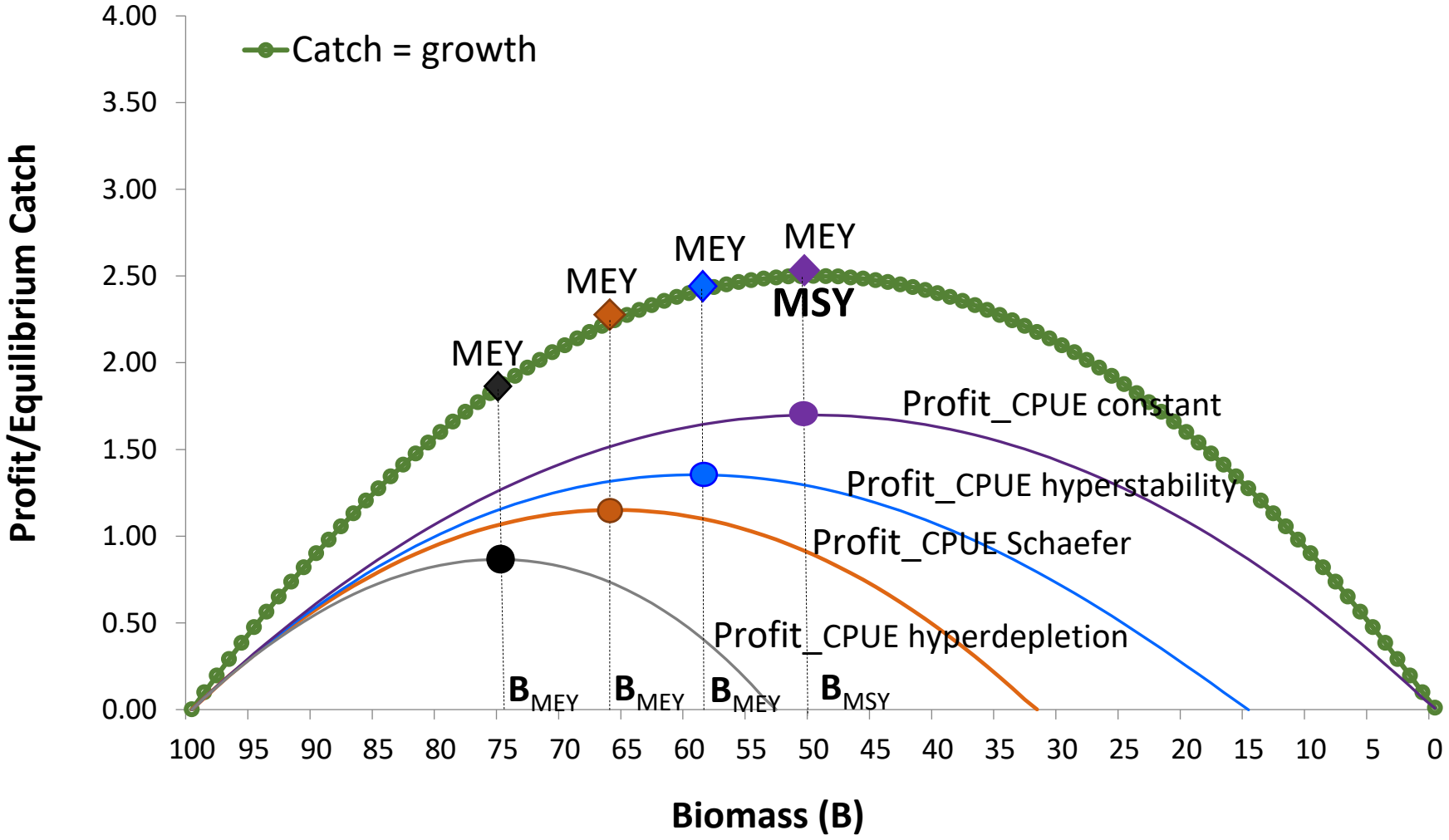


Simulation Results –

- CPUE decreasing quickly
- Cost more for the same catch



Simulation Results – Profit curves and MEY



Profit curves under different CPUE performances and MEY

Conclusions

- MEY can be different or equal to MSY. At constant CPUE is (or even increasing CPUE) with decreasing biomass. The less sensitive CPUE is in response to changes in biomass, the benefit of keeping higher biomass in water is less noticeable

  MSY = MEY

  BMEY = BMSY

- However, in a fishery where CPUE is highly sensitive to the biomass, MEY could be further away from MSY.

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Thank you