Optimum Extraction of Renewable Resources - Fishery

Natural Resource Economics

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Outline

Introduction

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- Renewable resources like fisheries regenerate naturally.
- Management balances current use with future availability for sustainable yields.
- Key issues: optimal use rates, biological growth, property rights, economic vs. biological optima.

Biological Growth and Resource Dynamics

Biological Growth and Resource Dynamics

- Renewable resources regenerate, modeled as:

$$\frac{dX}{dt} = G(X) - H(t)$$

- $G(X)$: natural growth, often logistic.
- $H(t)$: harvest rate at time t.

Typical Growth Curve

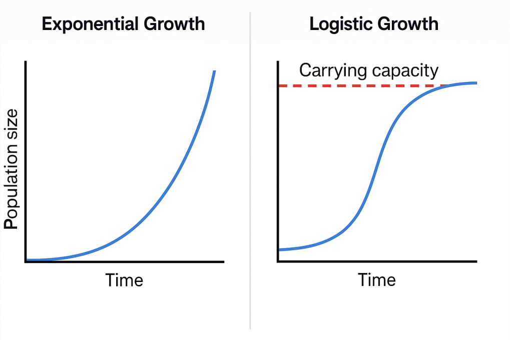

Figure:

Biological growth law: $G(X)$ vs. stock size X.

- Growth slow at low and high stock sizes.
- Maximum growth at intermediate size.
- Slows near carrying capacity K.

Logistic Growth Model

- Common model for growth:

$$G(X) = rX\left(1 - \frac{X}{K}\right)$$

- r: intrinsic growth rate.
- K: carrying capacity, max stock size.

A Model of Optimal Use

A Model of Optimal Use

- Goal: maximize present value of net benefits over time.
- Logistic growth model:

$$G(X) = rX\left(1 - \frac{X}{K}\right)$$

Derivation of Maximum Sustainable Yield (MSY) - Part 1

- Find stock X for maximum growth rate (MSY).
- Differentiate $G(X)$:

$$\frac{dG(X)}{dX} = r\left(1 - \frac{X}{K}\right) + rX\left(-\frac{1}{K}\right)$$

Derivation of MSY - Part 2

- Simplify the derivative:

$$\frac{dG(X)}{dX} = r - \frac{rX}{K} - \frac{rX}{K} = r - \frac{2rX}{K}$$

- Set derivative to zero:

$$r - \frac{2rX}{K} = 0$$

Derivation of MSY - Part 3

- Solve for X:

$$r = \frac{2rX}{K}$$
$$K = 2X$$
$$X = \frac{K}{2}$$

- MSY occurs at $X = \frac{K}{2}$.

Harvest Rates and MSY

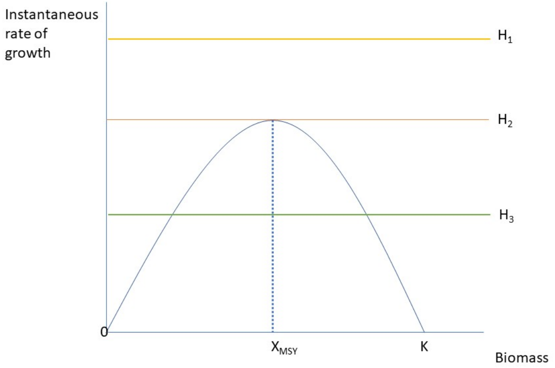

Figure 1: Harvest rates and Maximum Sustainable Yield

Harvest Rate Scenarios

- H_1: Harvest exceeds growth, leads to extinction.
- H_2: Harvest equals MSY at $X = \frac{K}{2}$, stock maintained.
- H_3: Harvest intersects growth at two points, right of MSY indicates overexploitation.

MSY and Biological Optimum

MSY and Biological Optimum

- MSY: largest constant harvest sustainable indefinitely.
- For logistic growth, $X_{MSY} = \frac{K}{2}$, $MSY = \frac{rK}{4}$.

Biological vs Economic Optimum

- MSY is purely biological, ignores costs, prices, discounting.
- Economic optimum maintains higher stock, harvests less than MSY to cut costs.

Some concepts Harvest Function and Fishing Effort

- Harvest function:

$$H = qEX$$

- q: catchability coefficient.
- E: fishing effort (boats, hours).
- X: stock biomass.

Harvest Cost

- Cost of harvest:

$$C(E, X) = cE$$

- c: cost per unit effort. Also referred to as TC in generic terms

Effort at MSY

- Effort at MSY:

$$H = qE_{MSY}X_{MSY} = MSY$$

$$E_{MSY} = \frac{MSY}{qX_{MSY}} = \frac{rK/4}{q(K/2)} = \frac{r}{2q}$$

Economic Optimum Effort

- Economic optimum at effort where marginal revenue equals marginal cost.
- Often assumes constant average cost.
- Harvest less than MSY, stock higher than X_{MSY}.

Total Cost and Fishing Effort

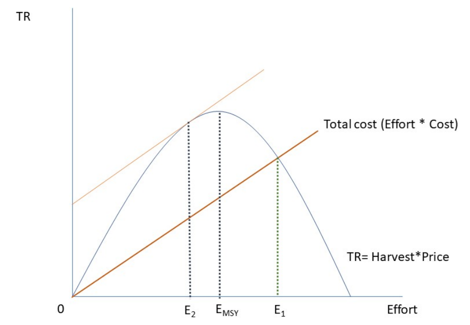

Figure 2: Total cost curve and fishing effort

Harvest under different efforts

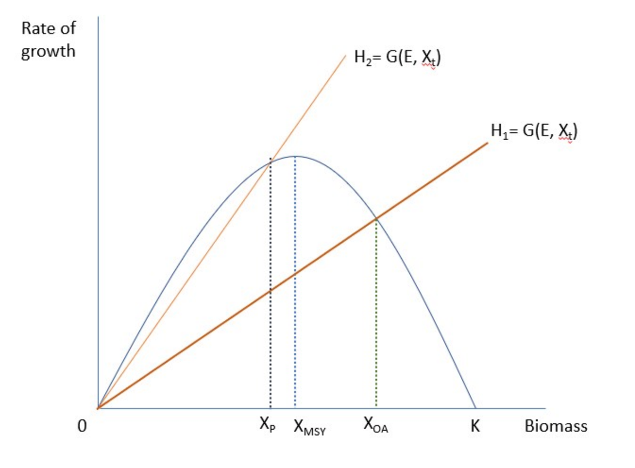

Figure 3: Total harvest, X_P as economic optimum

Economic Optimum vs. MSY

Table 1: MSY vs. MEY

	MSY	**MEY (Economic Optimum)**
Objective	Maximize sustainable yield	Maximize profit
Effort	E_{MSY}	$E_{MEY} < E_{MSY}$
Stock size	$K/2$	$> K/2$
Harvest	$rK/4$	$< rK/4$

The Common-Property Problem

The Common-Property Problem

- Open access causes overuse, depletion.
- Users ignore impact on stock, others.
- Known as "tragedy of the commons."

Economic Consequences

- Rent dissipation: profits drop to zero as more enter.
- Overexploitation: stock below economic optimum, often MSY.
- Depletion/extinction: harvest exceeds regeneration.

Equilibrium under Open Access

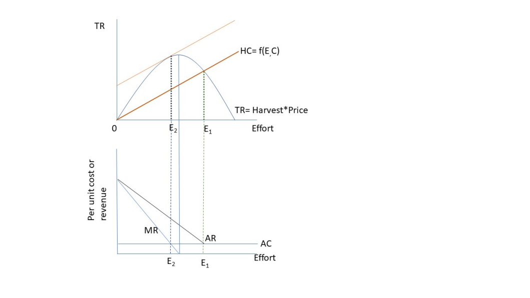

Figure 4: Equilibrium under Open Access

Open Access Over-exploitation

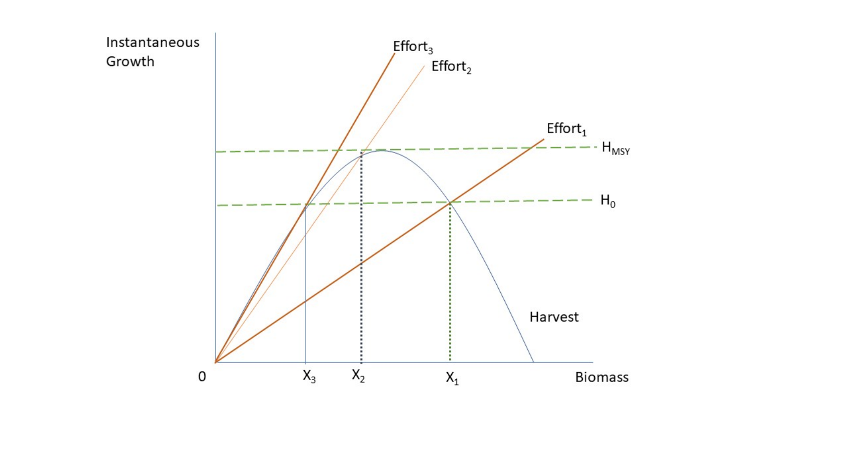

Figure 5: Under Open Access, less stock needs more effort - tragedy of commons

Open Access vs. Private Property

- Open access: AR=AC, harvest $<$ MSY, stock $<$ MSY, high effort.
- Private property: MR=MC, effort less, stock $>$ MSY, harvest $<$ MSY.
- Open access inefficient: more effort for smaller harvest.(Both private and open access harvest the same fish in the long run, but open access require greater effort (Cost!))

Policy Responses

Policy Responses

- Property rights: ITQs, TURFs.
- Regulation: licenses, quotas, closures.
- Economic tools: taxes, tradable permits, subsidies.

Concluding Remarks

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- Renewable resources need sustainable management.
- Biological (MSY) and economic optima differ.
- Open access causes overexploitation; governance vital.

Questions

Questions - Part 1

- Explain MSY and carrying capacity with a growth model.
- Prove MSY at half carrying capacity; derive effort at MSY.
- How does economic optimum differ from biological in fisheries?

Questions - Part 2

- Explain overexploitation under open access in fisheries.
- Show open access harvest inefficiency (more effort, less harvest).
- Discuss tragedy of commons in fisheries, policy options.