

Renewable Resources/Fisheries
Based on Hackett chapter 5 and Perman et al.,
chapters 17

March 9, 2005

Biological growth processes

$$G = G(S)$$

An example: (simple) logistic growth:

$$G(S) = gS \left[1 - \frac{S}{S_{MAX}} \right]$$

Where g is the intrinsic growth rate (birth rate minus mortality rate) of the population.

Figure 4.3 Sustainable harvests.

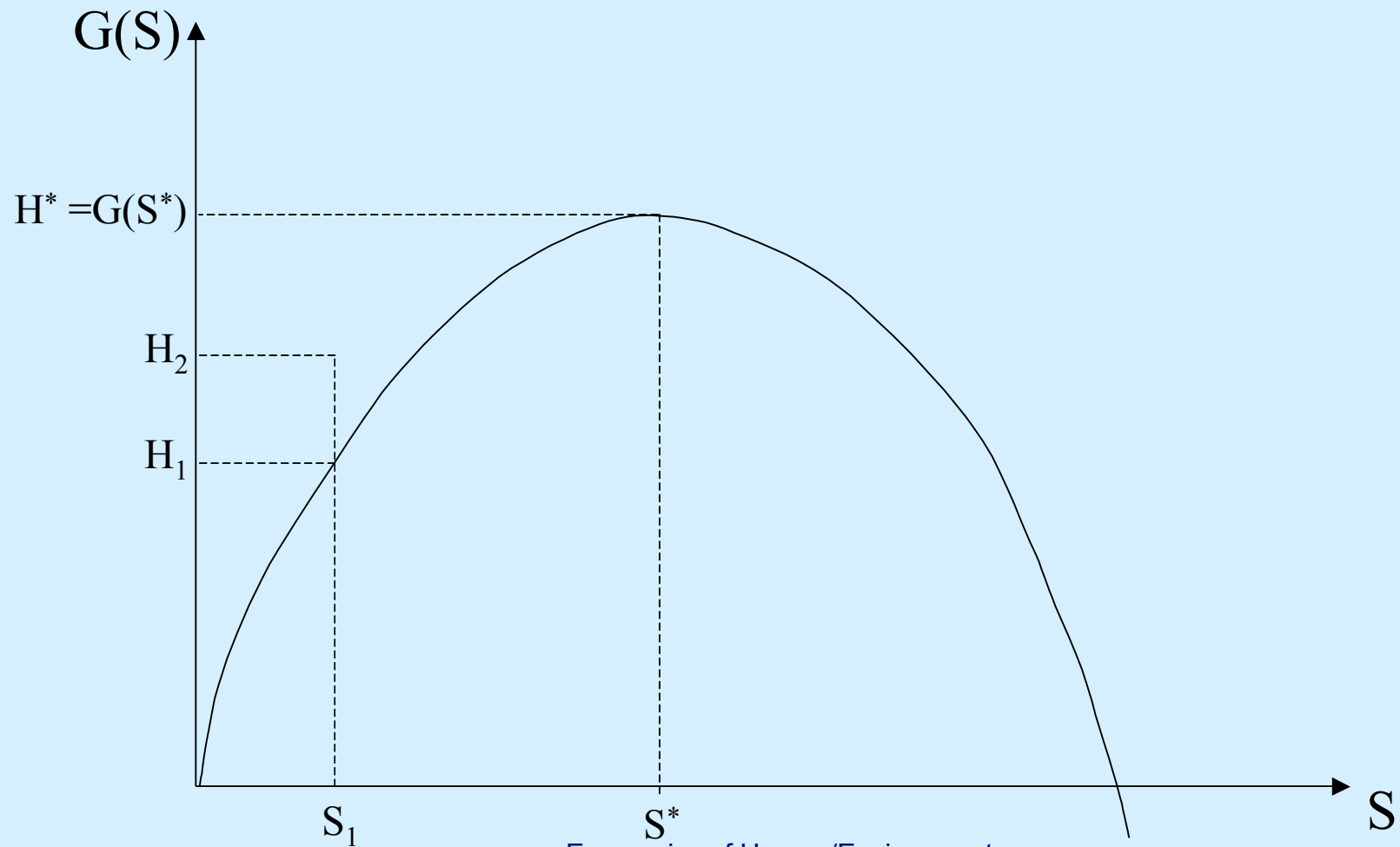
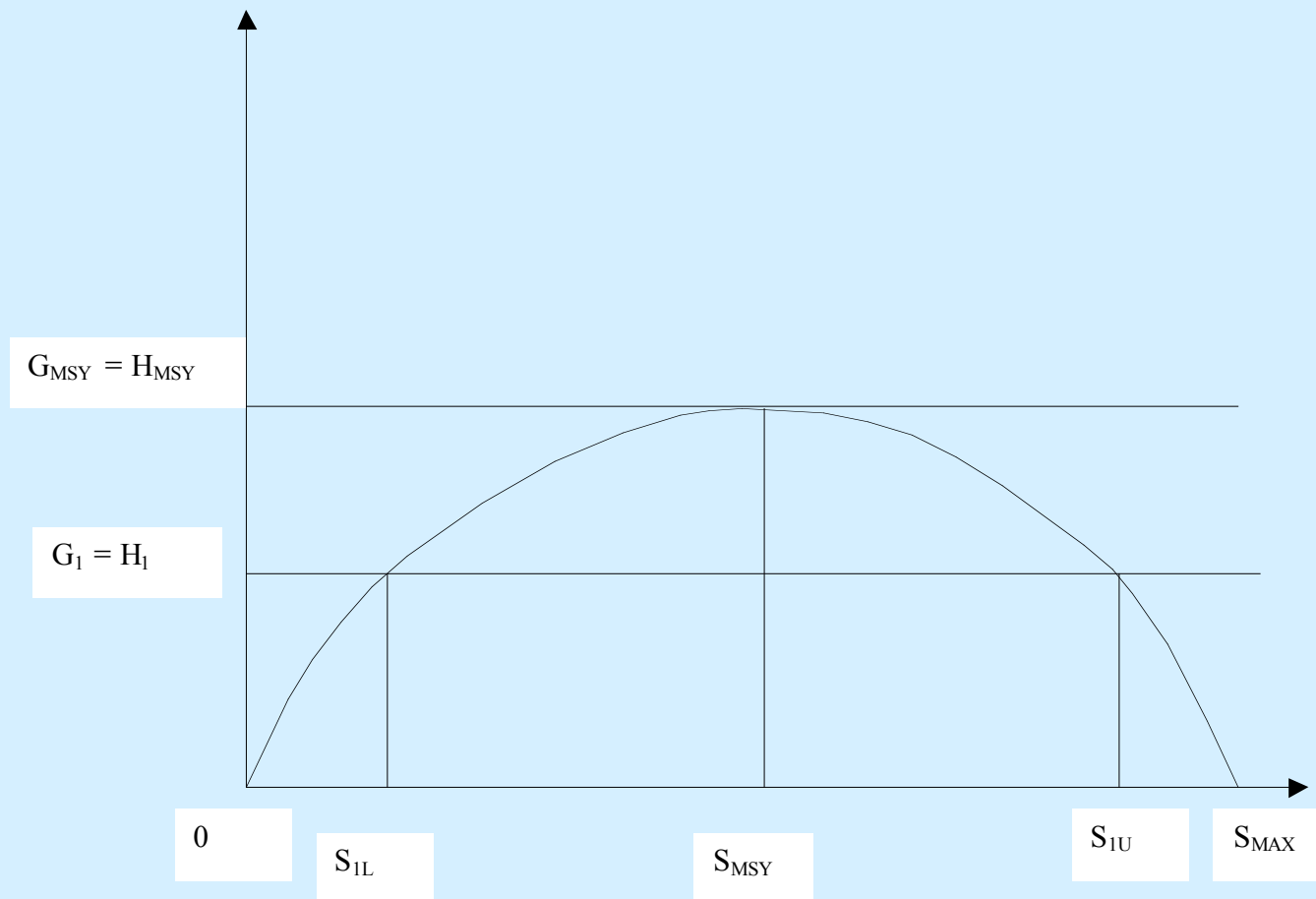


Figure 17.2 Steady-state harvests.



Stable and unstable equilibria

- The maximum stock level is a stable equilibrium, as if stock were somewhat below or above, stock levels would naturally return to that point
- The minimum viable population is an unstable equilibrium
- See Perman box 17.1 d for critical depensation, in which extinction is more likely.
- Harvest according to any sustainable yield represents a steady-state
- Today we are only looking at steady-state harvest levels.

Tietenburg: What is the economically efficient harvest level?

- Will the MSY be the economically efficient level? No, because of:
 1. Harvest costs
 2. Discounting

Assumptions

- Constant price of fish
- Constant marginal cost of effort
- Declining catch per unit effort as stock decreases
- See figure 13.1.
- Note locations of $MB=MC$ vs. $TB=TC$

Effects of discounting

- A dynamic (temporal) problem means we are also weighing the value of harvests in the future
- As we already know, the higher the discount rate, the more we consume now
- So what do we think will happen?
- The simplified analysis here can be confusing because the optimal harvest level is probably not constant.

Allocating Common Pool Resources

As we learned in the marine capture fisheries case study in Hackett, many natural resource systems are not partitioned by private property rights. These resources may be held as state property or common property (among a defined user group), or they may simply be open-access.

This ownership status may be based on tradition or culture, or because certain resource stocks such as air, groundwater, or open-ocean fisheries are fugitive resources that cannot effectively be partitioned and privately owned.

Allocating Common Pool Resources

When a resource stock is not partitioned by private property rights, there is potential for rivalry among those who appropriate (harvest resource units) from the resource stock. In the fishery case study in the section above we developed the idea of the rule of capture externality. The *rule of capture externality* is more generally known as an appropriation externality, which occurs because resource units appropriated by one subtract from what is available for others.

Tietenburg and externalities ...

- He also points out that users impose and intergenerational externality, as also discussed in Pezzey.
- And thinking about dynamic efficiency, realize that in an open-access environment, users can't appropriate asset values, so scarcity rents are depleted.

Thus we say that a common-pool resource (CPR) has the following general characteristics:

- It is difficult to exclude multiple individuals from appropriating from the resource stock, such as is the case when the resource stock is not partitioned by a well-defined and enforced private property rights regime.
- The resource features rivalry in consumption, or subtractability, meaning that resource units appropriated by one party subtract from what is available to others.

How is a common pool resource different than common property?

- A common pool resource is a resource that multiple people can use, and that is subject to subtractability. It may be private property, government property, common property, or open access.
- Common property is an ownership regime. A “common property resource” is a resource owned as common property by some group of appropriators.

Allocating Common Pool Resources

A pure *public good* differs from a CPR in that it lacks rivalry in consumption. For example, public television and radio broadcasts do not feature rivalry in consumption because one person's reception does not usually impair the ability of someone else to receive the same broadcast.

Allocating Common Pool Resources

As Scott Gordon and others since then have shown, in the absence of effective institutions (rule structures) that limit appropriation from a CPR, people will over-appropriate from the CPR relative to the level of appropriation that would be efficient for the group as a whole.

Gordon Model for a Common Pool Resource

The Gordon model of a CPR uses the example of a fishery. Fishermen apply effort (deployment of labor and capital) to harvest fish from a fishery CPR.

The model captures dynamic effects such as fishery depletion in a single static diagram, which makes it a bit tricky.

Gordon Model for a Common Pool Resource

Gordon model:

- **A unit of effort generates additional cost (marginal effort cost), such as from operating a vessel and paying a crew for an hour.**
- **A unit of effort generates additional revenues (marginal revenue product) from selling fish.**

Gordon Model for a Common Pool Resource

We can simplify the analysis by having *marginal effort cost* be **constant**.

Note that *marginal revenue product* **declines** as more and more fishing effort is applied because the fish become less and less abundant and thus fewer are harvested with a given unit of effort.

Gordon Model for a Common Pool Resource

Average revenue product is total revenue divided by total effort.

The average/marginal relationship tells us that average revenue product will be pulled down by falling marginal revenue product.

(ARP is like your cumulative GPA, while MRP is like your semester GPA. If your semester GPA falls, it pulls down your cumulative GPA, but not by as much.) 😊

Gordon Model for a Common Pool Resource

Case 1: Group Optimum Harvest:

Recall from Chapter 4 that a profit-maximizing firm seeks to produce output where marginal revenue equals marginal cost. Likewise Hotelling rent is maximized to the group of fishermen if they can set the group's total fishing effort where marginal effort cost equals marginal revenue product.

Gordon Model for a Common Pool Resource

In fact, this management system would result in less than the maximum sustainable yield being harvested from the CPR. Why?

Since at MSY output is maximized, thus total revenue is maximized, thus marginal revenue equals zero. Unless marginal effort cost is zero, MSY leads to higher exploitation of the resource than is optimal from an economic point of view.

Gordon Model for a Common Pool Resource

Case 2: Full Rent Dissipation:

Under open-access conditions, however, the fishermen are unable to limit harvest to the level of effort where marginal effort cost equals marginal revenue product. In fact, entry occurs until profit is zero and there is no additional incentive for adding more effort to the fishery.

Zero profit → Total Revenue Product = Total Effort Cost

Divide both sides by effort → Average revenue product = average effort cost.

Gordon Model for a Common Pool Resource

Effort	TEC	MEC or AEC	MRP	ARP	TRP	Group Profit
1	250	250	600	600	600	350
2	500	250	550	575	1150	650
3	750	250	500	550	1650	900
4	1000	250	450	525	2100	1100
5	1250	250	400	500	2500	1250
6	1500	250	350	475	2850	1350
7	1750	250	300	450	3150	1400
8	2000	250	250	425	3400	1400
9	2250	250	200	400	3600	1350
10	2500	250	150	375	3750	1250
11	2750	250	100	350	3850	1100
12	3000	250	50	325	3900	900
13	3250	250	0	300	3900	650
14	3500	250	-50	275	3850	350
15	3750	250	-100	250	3750	0
16	4000	250	-150	225	3600	-400
17	4250	250	-200	200	3400	-850

← **Group optimum**
where
MRP = MEC

← **Full Rent Dissip.**
where
ARP = AEC

Figure 17.3 Steady state equilibrium fish harvests and stocks at various effort levels.

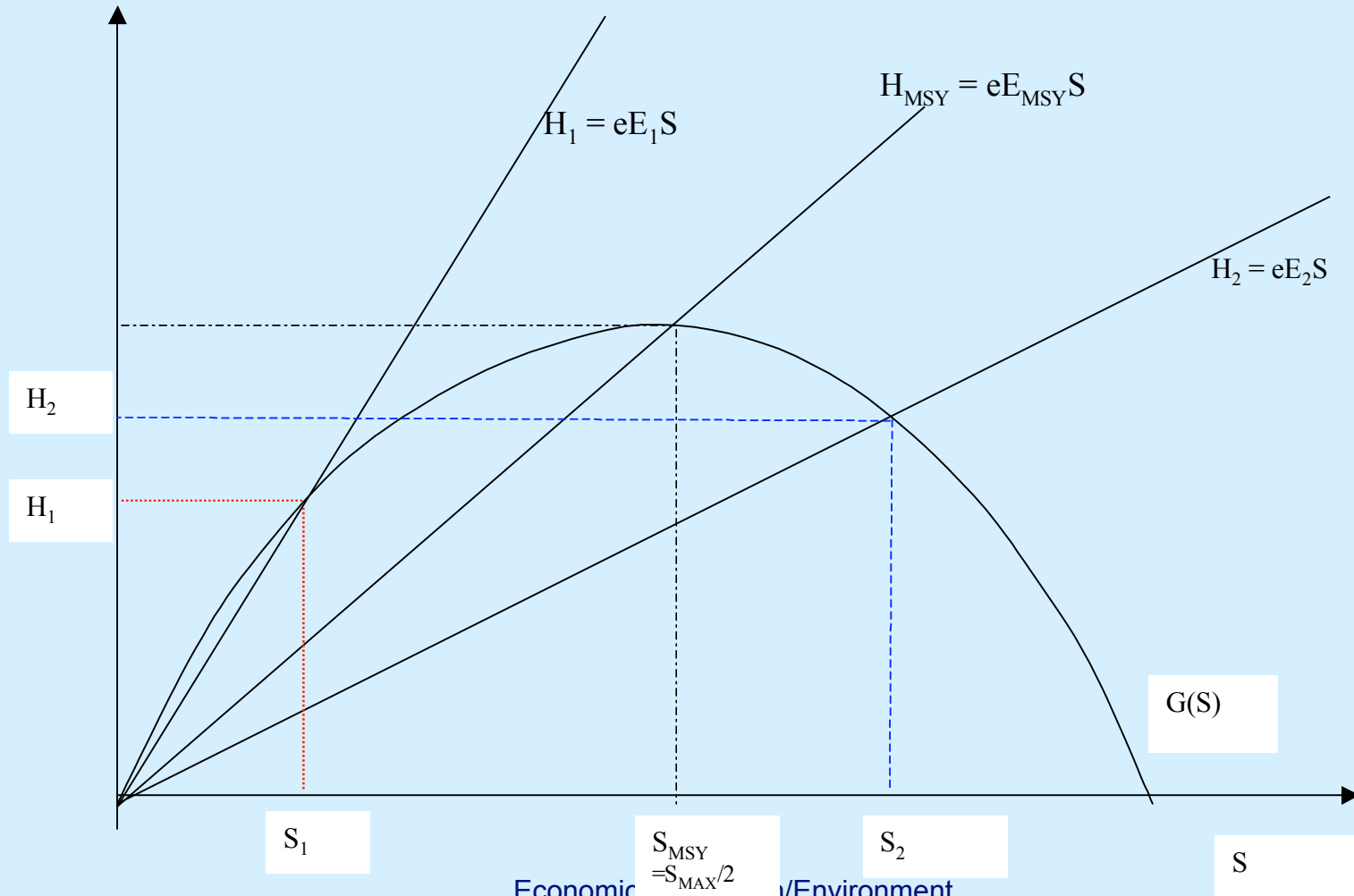
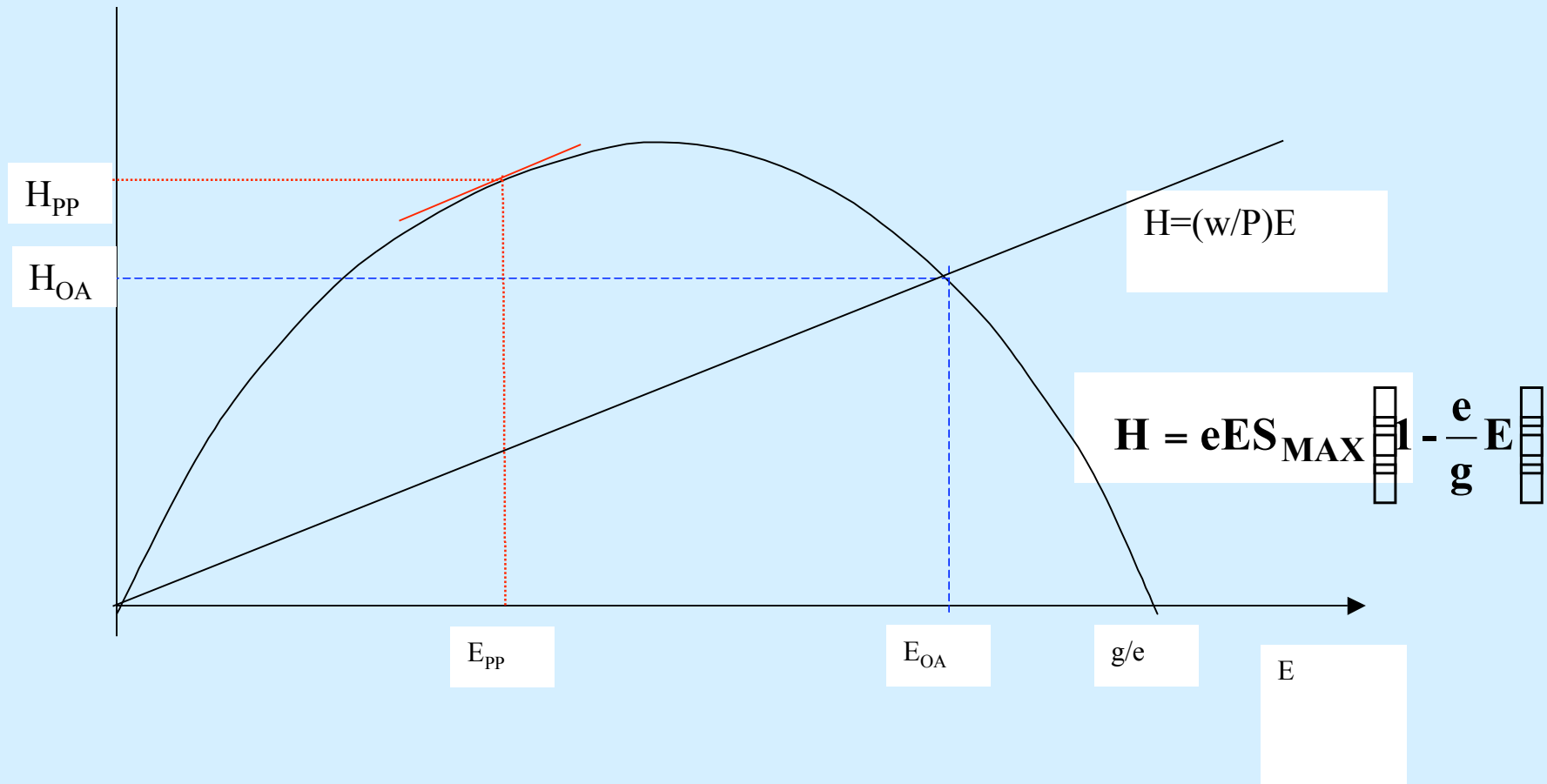


Figure 17.4 Steady state equilibrium yield-effort relationship.



Tragedy of the Commons

Gordon (1954):

There appears, then, to be some truth in the conservative dictum that everybody's property is nobody's property. Wealth that is free for all [an open access resource] is valued by no one because he who is foolhardy enough to wait for its proper time of use will only find that it has been taken by another (p. 135).

Hardin (1968)

The rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing the commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons (p. 1244).

Tragedy of the Commons

Russell (1996):

For years, [Sam] Novello had made a decent living off the abundant groundfish—cod, haddock, yellowtail flounder—that he hauled up off the Atlantic ocean floor. He used nets with a large-enough mesh size to allow juvenile fish to pass through, and worked the best spots sparingly with his tows. ‘I didn’t know I was a conservationist until somebody told me,’ he says, ‘but I believed in only taking the interest out of the bank’ But Novello watched many of his competitors make three times as much money depleting vast areas and keeping thousands of pre-spawning-size fish. And he has never forgotten the disdainful words of a local dealer: ‘What are you, stupid? One boat is gonna save every fish in the sea?’ So, he adds sadly, ‘Finally I said, OK, I’ll fish like everybody else does’.

Tragedy of the Commons

Tragedy of the commons refers to the “race for resources” that happens in a CPR under conditions of open access, or any poorly designed or enforced property rights system. The race for resource depletes the resource. The “tragedy” is that good people feel compelled to act badly.

At the heart of tragedy of the commons is an appropriation externality. Can you explain why?

Solutions to Tragedy of the Commons

1. If the resource is open access, convert it to private, government, or common property (note that the first two are most common in the US).

2. If the resource is private, government, or common property, determine why withdrawal is not being properly managed.

See Chapter 15 for details on locally self-governed CPRs that are common property.

17.6.3 The present value maximising fishery model

$$\text{Max} \int_0^{\infty} (p_t H_t - C(H_t, S_t)) e^{-it} dt$$

subject to

$$\frac{dS}{dt} = G(S_t) - H_t$$

and initial stock level $S(0) = S_0$. The necessary conditions for maximum wealth include

$$p_t = p \frac{\partial C(H, S)}{\partial H_t} \tag{17.6.3}$$

$$\frac{dp_t}{dt} + ip_t = p_t \left(\frac{dG(S)}{dS_t} - \frac{\partial C(H, S)}{\partial S_t} \right) \tag{17.6.4}$$

p is the market, or landed, price of fish

C treated here as an exogenously given fixed

.....)

p_t is a shadow price, the net price of fish.
 Economics of Human/Environment
 Fisheries, Lecture 7
 Dawn Parker, George Mason University

17.6.3.1 Steady state equilibrium in the present value maximising fishery

We have $G(S) = H$ and the optimizing conditions 17.29 and 17.30 collapse to the simpler forms

$$p = P = \frac{\partial C(H, S)}{\partial H} \quad (17.32)$$

$$ip = p \frac{dG(S)}{dS} = \frac{\partial C(H, S)}{\partial S} \quad (17.33)$$

$$i = \frac{dG}{dS} - \frac{\partial C}{\partial S} \quad (17.33)$$

Equation 17.33 is one (steady -state) version of what is sometimes called the 'Fundamental Equation' of renewable resources.

Results from the PV max fisheries model

- If the interest rate is zero, the outcome is the same as the static private-management Gordon model
- If as well harvest costs don't depend on stock size, harvest = MSY
- As discount rates go up, optimal fishing stocks go down
- At infinite discount rate, results converge to the Gordon model
- If costs don't depend on stock size, at the steady-state, the rate of growth will equal the interest rate.
- In general, there is no set relationship between the steady-state and MSY

EXCESSIVE HARVESTING AND SPECIES EXTINCTION

There are many reasons why human behaviour may cause population levels to fall dramatically or, in extreme cases, cause species extinction. These include:

- Even under restricted private ownership, it may be ‘optimal’ to the owner to harvest a resource to extinction. Clark (1990) demonstrates, however, that this is highly improbable.
- Ignorance of or uncertainty about current and/or future conditions results in unintended collapse or extinction of the population.
- Shocks or disturbances to the system push populations below minimum threshold population survival levels.

WHATEVER THE REGIME, SPECIES EXTINCTION IS MORE LIKELY:

- the higher is the market (gross) resource price of the resource
- the lower is the cost of harvesting a given quantity of the resource
- the more that market price rises as the catch costs rise or as harvest quantities fall
- the lower the natural growth rate of the stock, and the lower the extent to which marginal extraction costs rise as the stock size diminishes
- the higher is the discount rate
- the larger is the critical minimum threshold population size relative to the maximum population size.