ECN 275/375 Environmental and natural resource economics 15: Renewables - fisheries (Perman *et al.* Ch 17)

Reading guide

Read sec, 17.1-17.11 an overview (rest of chapter in session 16). Focus on sec. 17.1 (biological growth), sec. 17.2 (steady-state harvests), sec. 17.3 (open access fisheries), 17.4 (dynamics) and. 17.8 (maximizing present value of rents). As before, solving Hamiltonians not part of the curriculum for ECN 275.

Remark on notation:

Private interest (discount) rate: Book uses *i* or *r*. This note: consistently *r*

Public interest (discount) rate: Book uses *i* or *r*. This note: consistently δ

Fisheries – repetition

Key concepts:

- S – stock size
- Biological growth as a function of stock size, $G(S)$
- Maximum sustainable yield (MSY and the corresponding stock size S_{MSY})
- Stability in a model + impacts of uncertainty
- Open access and open access equilibrium

Stock size, growth, and harvesting

Static model

Growth a function of stock size (density dependent growth): $G(S)$

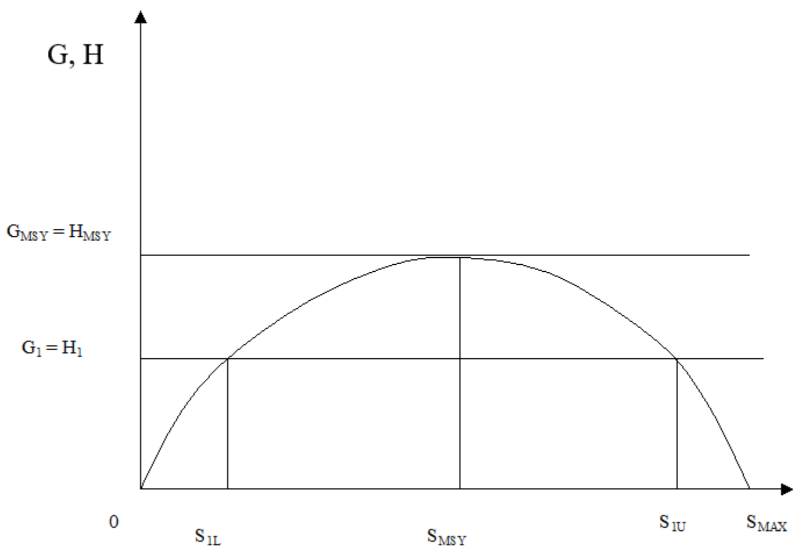
H : harvest rate

Fig 17.2: steady state harvest (H constant over some time period)

Stable equilibrium: S1U

Unstable equilibrium: S1L

H_{MSY} stable or unstable?



Open access model next page

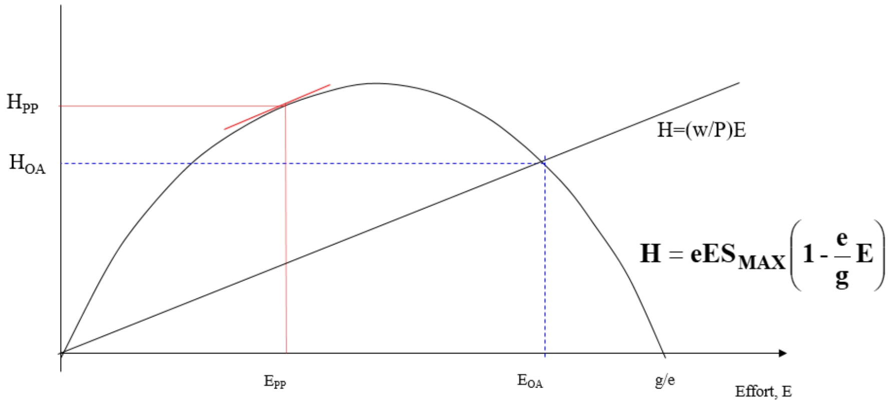
Open access fisheries

Static model:

p = per unit price on harvest
H = quantity harvested
E = effort (can be viewed as work hours with wage rate w)

Objective: maximize the rents form the fishery with effort as the decision variable:

$$\begin{Bmatrix} MAX \\ E \end{Bmatrix} \pi(E) = \begin{Bmatrix} MAX \\ E \end{Bmatrix} (pH(E) - wE)$$



FOC:

$$\frac{\partial \pi}{\partial E} = pH'(E) - w = 0 \Rightarrow H'(E) = \frac{w}{p}$$

But: in open access there is free entry (here; new fishermen can join the fishery → fishing continues until rents are zero → $\pi(E_{OA}) = 0$

Fig 17.4: growth of the fish stock set at the steady state for various effort levels, E

E_{OA}: open acces effort

→ zero rents

→ harvest level H_{OA}

E_{PP}: max rents (private property)

→ effort given by FOC → optimum effort: where slope of cost/price curve equals slope of steady state growth function

Biological growth (17.1)

Logistic growth function: $G(S) = g\left(1 - \frac{S}{S_{MAX}}\right)S$ where g is the growth rate at a given stock, S

Flexible functional form that yields the bell shaped curve in fig. 17.1 (in box 17.1 worth a read)

Open access fisheries (17.3)

A more formal approach than what we did in the repetition.

Harvest function – general formulation: $H = H(E, S)$, frequently replaced by a catch efficiency formulation $H = eES$, where e is a harvesting efficiency (catch) coefficient.

Costs a function of effort – general formulation: $C = C(E)$. If effort is similar to labor (with an hourly wage), the special case is $C = wE$, were w is the wage rate.

Gross benefits of a fishery: $B = pH$ (price times harvested quantity)

Rents from a fishery: $\pi = B - C = pH(E) - wE$

In a biological equilibrium $H = G$.

Using the logistic growth function (17.3) and the catch efficiency formulation:

$$G=g\left(1-\frac{S}{S_{MAX}}\right)S=eES=H$$

Transform the colored parts to get $S=S_{MAX}\left(1-\frac{e}{g}E\right)$ (remark: $e < g$ for meaningful expression – if $e \geq g > 0$, the term $\frac{e}{g}E$ is greater than one, which implies the harvest is greater than the maximum stock size which it cannot be if the fishery is to be sustained over time).

Insert back into $H=eES$ to get $H=eES_{MAX}\left(1-\frac{e}{g}E\right)$, which solves the open access harvest → solve for the open access effort E_{OA} for which fishery rents are zero.

Maximizing present value of the rents (17.8)

Single owner of the fish resource who takes the market price P for given. Intitial fish population (stock) level: S_0

Harvesting costs: $C_t=C(H_t,S_t)$ where $C_H>0$ and $C_S<0$ (catching one unit of fish less costly when stocks are large – consistent with the catch efficiency formulation $H=eES$ used above.

$$\underset{\{H_t\}}{MAX}\,\pi(H_t)=\underset{\{H_t\}}{MAX}\left(P_tH_t-C(H_t,S_t)\right)e^{-rt}$$ where r (i in book) is fish owners' discount rate

s.t.

$\dot{S}_t=G(S_t)-H_t$ (resource stock change)

which gives the following current value Hamiltonian ($\mathcal{L}$) (λ_t replaces ρ_t used by the book):

$$\mathcal{L}= P_tH_t-C(H_t,S_t)+\lambda_t(G(S_t)-H_t)$$

with the following solutions:

$\lambda_t=P_t-\frac{\partial C(H_t,S_t)}{\partial H_t}$ (shadow price of resource constraint equal marg. revenues less marg costs)

$\dot{\lambda}_t=r\lambda_t-\lambda_t\frac{dG(S_t)}{dS_t}+\frac{\partial C(H_t,S_t)}{\partial S_t}$ (shadow price time change follows a Hotelling price path less the shadow price times marginal growth of stock plus marginal cost of stock change).

In steady state, there are no change in any of the variables over time, and the above equations simplifies (dropped time subscripts as the system is in a stable equilibrium) to:

(A) $\lambda_t=P-\frac{\partial C(H,S)}{\partial H}$ and (B) $r\lambda=\lambda\frac{dG(S)}{dS}-\frac{\partial C(H,S)}{\partial S}$

Interpretations:

1. Key issue here is to time the harvest of the fish ("the less one harvests today, the more there is to harvest tomorrow", but at a cost of sacrificing income today).
2. Choosing not to harvest is equivalent to a capital investment, where the fish stock (the capital) grows. The marginal costs of investing (second equation) breaks into the following decision rules:
    1. $r\lambda_t<\lambda_t\frac{dG(S_t)}{dS_t}-\frac{\partial C(H_t,S_t)}{\partial S_t}$ → harvest less (invest)
    2. $r\lambda_t>\lambda_t\frac{dG(S_t)}{dS_t}-\frac{\partial C(H_t,S_t)}{\partial S_t}$ → harvest more (invest not as profitable as cashing in)

Implication of 2.2: If for all stock sizes, the equation holds, liquidate the fish stock. This effect is reasonable if the second order derivatives of the growth is negative.

Exercises

See “exercises”

Discussion topics

1. Why would the result we have for resource owned by a single owner not hold if there are multiple owners?
2. What would it take for cooperation to take place (this is really simple :-))
3. If cooperation does not take place voluntarily, how could one make a cooperative outcome?
4. In the single owner case, suppose there is a virgin fishery (not fished before). What happens to the fish stock over time until a steady state is found? Explain.