RENEWABLE RESOURCES:
Economics of the Fisheries (Lecture note by Arief Anshory Yusuf)

Static vs dynamic model of fisheries

STATIC

<u>Growth function</u>

Simplest case: proporsional or constant "growth rate" $\frac{d}{dt}x\cdot\frac{1}{x}=b-m$ where x = stock, b = birth, m = death rate

$\gamma := .02$ or $\frac{d}{dt}x=\gamma\cdot x$ or $x(t)=x_0\cdot e^{\gamma\cdot t}$ which is too simple

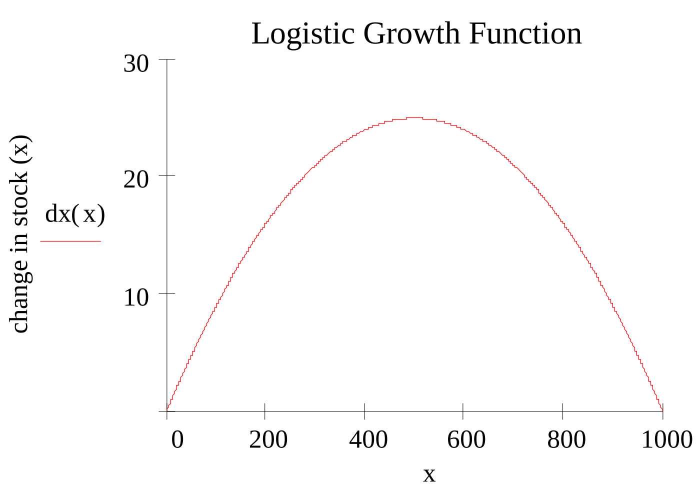
Generally, growth function depend on stock, or $\left(\frac{d}{dt}x\right)\cdot\frac{1}{x}=\gamma(x)$

for example $\gamma(x)=r\cdot\left(1-\frac{x}{K}\right)$ where r = natural initial growth, and K = carrying capacity

π

or change in x overtime or biomass rate of increase $dx=r\cdot x\cdot\left(1-\frac{x}{K}\right)$ logistic function

for example $r := 0.1$ $K := 1000$ $dx(x) := r\cdot x\cdot\left(1-\frac{x}{K}\right)$ for $x := 0..K$

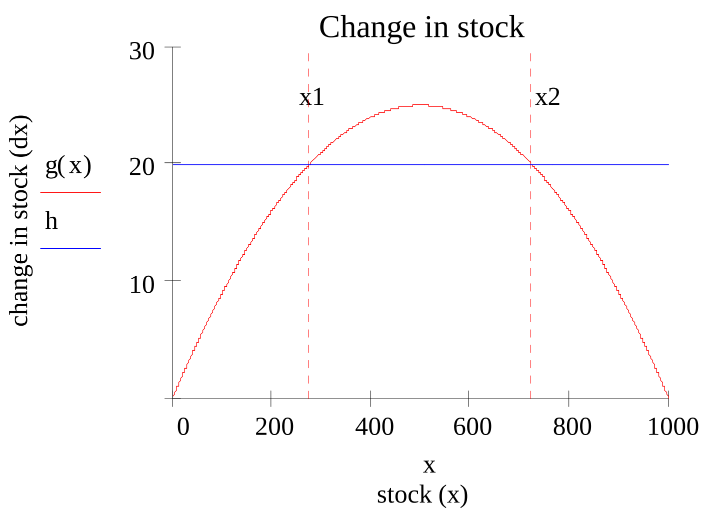


There could be another form of growth function, see Pearce lecture note and your text book for the case of critical depensation and compensation!!

With harvest (h), change at some point in time became $dx = g(x) - h$

where now, $g(x) := r \cdot x \cdot \left(1 - \frac{x}{K}\right)$

where g(x) = change over time (growth)
(not growth rate!, growth rate is (dx/x), so for example with $h := 20$ (constant)



if g(x) > h, stock will increase
if g(x) < h, stock will decrase
or if x < x1 or x > x2, stock will decrease
if x1 < x < x2, stock will increase,
See Power Point Slide!

h_m is maximum sustainable yield, which is maximized at K/2!

in our example $h_m := g\left(\frac{K}{2}\right)$

at $\frac{K}{2} = 500$ $h_m = 25$

Fishing Effort (E)

$h_i = h_i(b_i, l_i, x)$ where, h is harvest, b is number of boats, l is labor, x is stock
Note: x does not have subscript i (individual fisherman)

Aggregate harvest (total harvest of the industry) then become $h = \sum_i h_i$ or $h = h(B, L, x)$

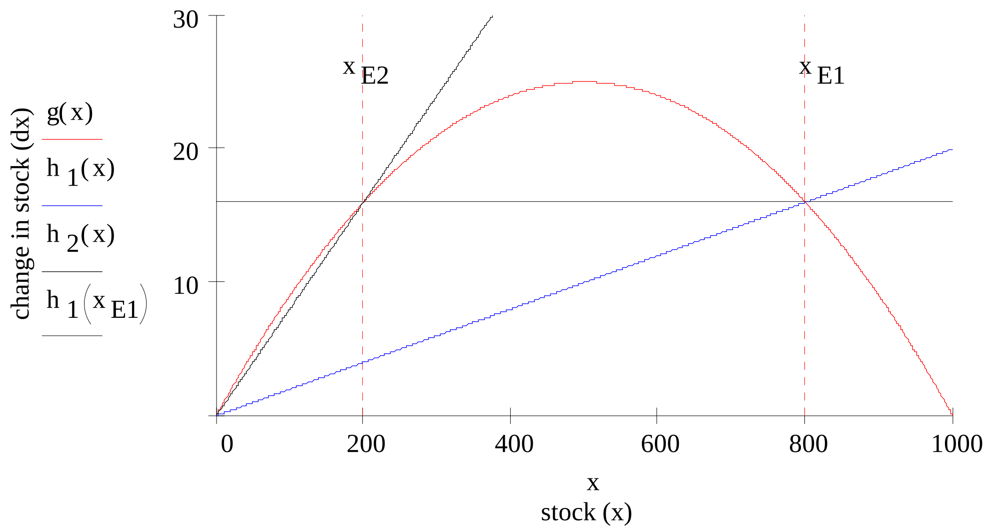
Schafer (1954) suggests $\frac{h}{E} = \theta \cdot x$ or $h = \theta \cdot E \cdot x$ where θ is constant

for any given effort (E) we can determine "bioeconomic equilibrium" with harvest

for example, with $\theta := 0.01$ $E_1 := 2$ $h_1(x) := \theta \cdot E_1 \cdot x$

$E_2 := e_2$ $h_2(x) := \theta \cdot E_2 \cdot x$

however, harvest at E1 could be with only E = $e_2 = 8$



Connecting effort (E) with harvest or change in x at equilibrium

Remember that at equilibrium $h(x) = g(x)$

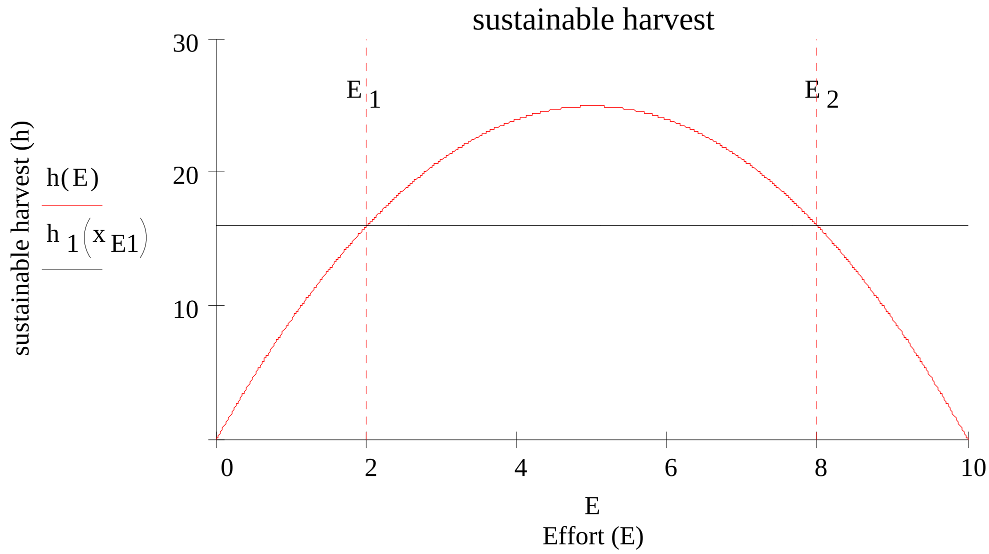
so $\theta \cdot E \cdot x = r \cdot x \cdot \left(1 - \frac{x}{K}\right)$ or $\theta \cdot E = r \cdot \left(1 - \frac{x}{K}\right)$ or $1 - \frac{x}{K} = \frac{\theta \cdot E}{r}$ or $\frac{x}{K} = 1 - \frac{\theta \cdot E}{r}$

thus $x = K \cdot \left(1 - \frac{\theta \cdot E}{r}\right)$ this is x at stock equilibrium

back to harvest function, which is $h = \theta \cdot E \cdot x$ and imputting equilibrium x, then we have

$h(E) := \theta \cdot E \cdot \left[K \cdot \left(1 - \frac{\theta \cdot E}{r}\right)\right]$ this is again, a quadratic function $h(E) \rightarrow .01 \cdot E \cdot (1000 - 100.0 \cdot E)$

for $E := 0, .01 .. \frac{r}{\theta}$ we can draw a sustainable harvest function



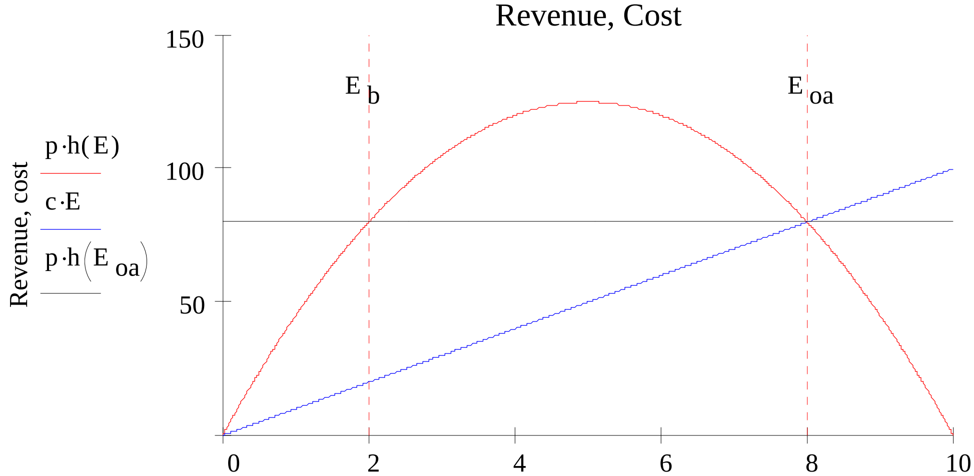
Note: untill now, what we have learnt are all mostly BIOLOGY, not ECONOMICS yet.

Lets define profit as $\Pi(E) = p \cdot h(E) - c \cdot E$

where Π is profit, p is price and c is unit cost per effort (constant)

for our example $p := 5$ $c := 10$

Open access nature of the resources lead to equilibrium when $\Pi(E) = 0$ or when Revenue is equal to cost, this is called rent dissipation



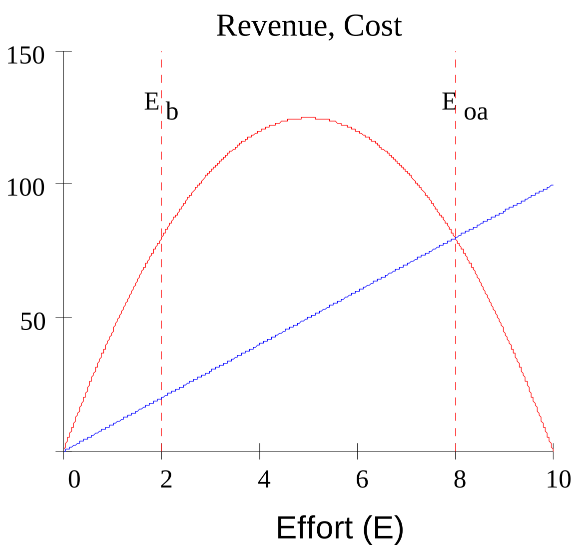
Revenue of $p \cdot h(E_{oa}) = 80$ is produced with $E_{oa} = 8$ however this could also be achieved with

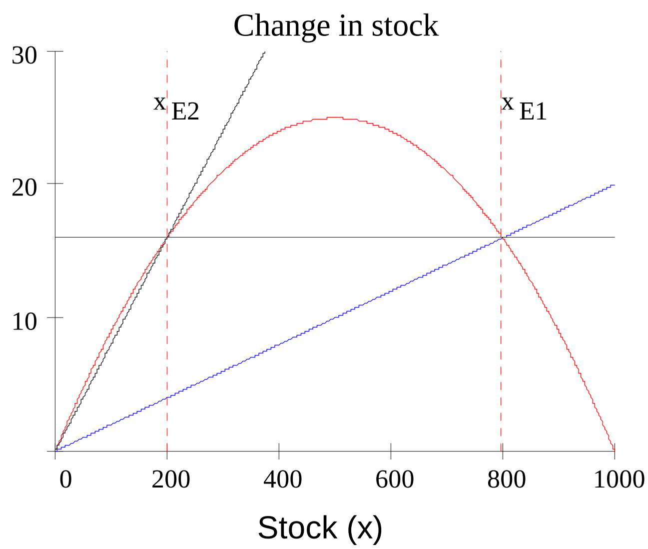
$E_b = 2$ which is much less

E
Effort (E)

This is the notion of economic inefficiency. Where harvest < MSY is the notion of biological inefficiency, together this is called bioeconomic inefficiency!! OPEN ACCESS SITUATION!

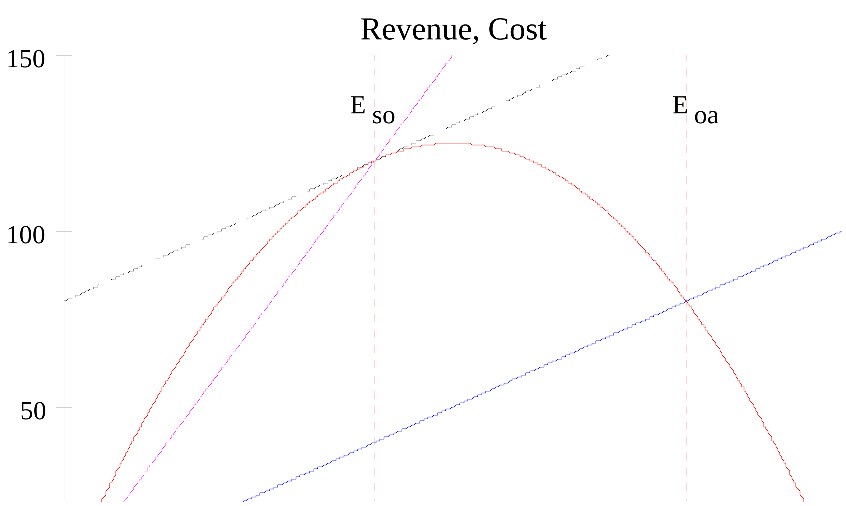
Keep in mind that large effort (E) means lower stock and vice versa!

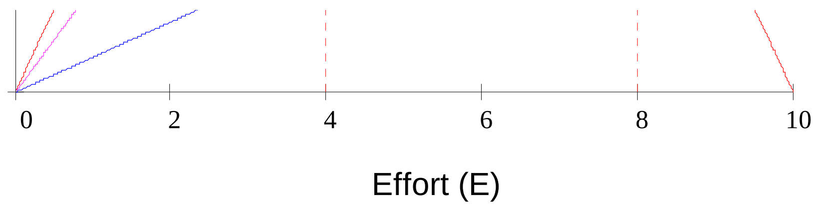




Social optimum harvest or Profit Maximizing harvest

when marginal revenue is equal to marginal cost, or when $\Pi'(E)=0$





Conclusion

Property right regime:

Open access (OA)

Sole ownership (profit maximization/social optimum/SO)

See the difference in Pearce's Text Book, page 284-249!!

$$xo := \begin{bmatrix} \frac{1}{(2\cdot r)}\cdot K\cdot\left[r + \sqrt{r\cdot\frac{(r\cdot K - 4\cdot h)}{K}}\right] \\ \frac{1}{(2\cdot r)}\cdot K\cdot\left[r - \sqrt{r\cdot\frac{(r\cdot K - 4\cdot h)}{K}}\right] \end{bmatrix} \qquad x1 := xo_1 \qquad x2 := xo_0 \qquad h_m := dx\left(\frac{K}{2}\right)$$

$$x_{E1} := \frac{-(\theta\cdot E_1 - r)}{r}\cdot K \qquad x_E := \begin{bmatrix} \frac{1}{(2\cdot r)}\cdot K\cdot\left[r + \sqrt{-r\cdot\frac{(-r\cdot K + 4\cdot h_1(x_{E1}))}{K}}\right] \\ \frac{1}{(2\cdot r)}\cdot K\cdot\left[r - \sqrt{-r\cdot\frac{(-r\cdot K + 4\cdot h_1(x_{E1}))}{K}}\right] \end{bmatrix} \qquad x_E = \begin{bmatrix} 800 \\ 200 \end{bmatrix} \qquad x_{E2} := \min(x_E)$$

$$E_{oa} := \frac{-(c - p\cdot\theta\cdot K)}{\left[p\cdot\left(\theta^2\cdot K\right)\right]}\cdot r \quad z := \begin{bmatrix} \frac{1}{\left[2\cdot\left[p\cdot\left(\theta^2\cdot K\right)\right]\right]}\cdot r\cdot\left[p\cdot\theta\cdot K + \theta\cdot\sqrt{p\cdot K\cdot\frac{\left(p\cdot K\cdot r - 4\cdot p\cdot h\left(E_{oa}\right)\right)}{r}}\right] \\ \frac{1}{\left[2\cdot\left[p\cdot\left(\theta^2\cdot K\right)\right]\right]}\cdot r\cdot\left[p\cdot\theta\cdot K - \theta\cdot\sqrt{p\cdot K\cdot\frac{\left[p\cdot K\cdot r - 4\cdot\left(p\cdot h\left(E_{oa}\right)\right)\right]}{r}}\right] \end{bmatrix} \quad E_b := \min(z)$$

$$E_{so} := \frac{-1}{2} \cdot \frac{(c - p \cdot \theta \cdot K)}{\left[p \cdot \left(\theta^2 \cdot K \right) \right]} \cdot r$$

$$e_2 := \frac{h_1\left(x_{E1}\right)}{\left(\theta \cdot x_{E2}\right)}$$