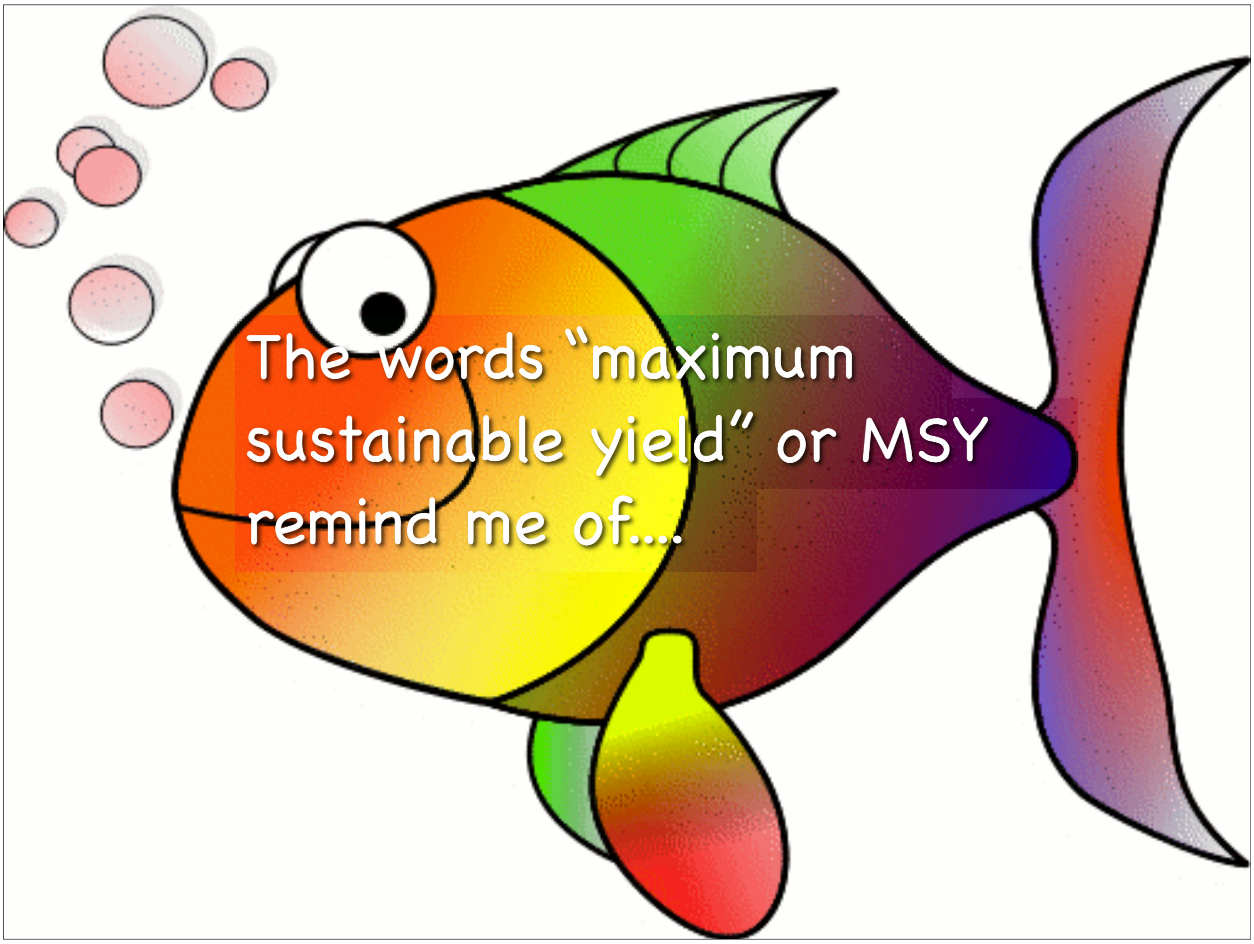

The Concept of Maximum Sustainable Yield...
...and its limitations


The words "maximum sustainable yield" or MSY remind me of....

The Johannesburg commitment

Plan of implementation (Pt 31):

- maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015

Objective

All models are wrong, (but) some are useful

So, how usefull is the concept of MSY for fisheries management in SEA?

Example of a simple food web, representing the oceanic part of the South China Sea
(based on Pauly 1999)

Why do we need MSY?

Fisheries Management: Without first addressing the biological bottom line, there may soon be no resource to pursue"

Need to know, how much can be taken out of the system, without causing it to collapse:
=> determine the level at which fisheries resources can be exploited without exhausting them, or:

To determine the Maximum Sustainable Yield

Graham-Schaefer Model: Discrete Time Surplus Production (1)

Catch (Y) can be written as the product of fishing mortality F and stock size B or more generally as a function of stock biomass, fishing effort E, and a constant, known as the "catchability coefficient" q

Catch (Y) = Fishing Effort in time (E_t) X Catchability (q) X Abundance of stock (X_t)

$$Y_t = E_t\, q\, X_t$$

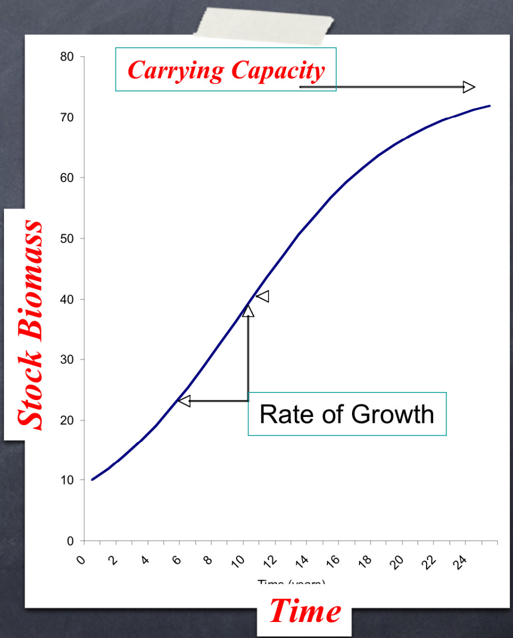
or

$$X_t = Y_t / (E_t\, q)$$

Surplus Production Models

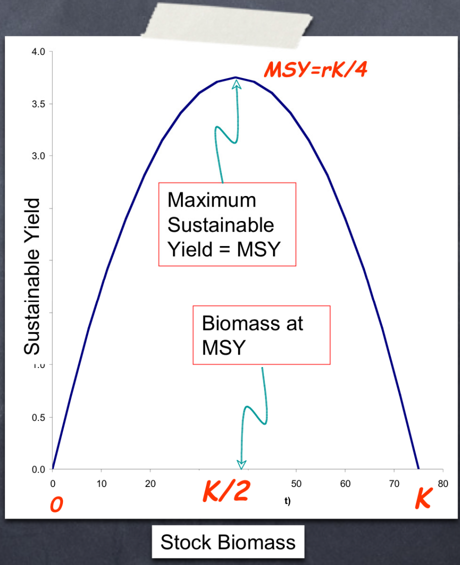
Limited Population Growth

- Logistic growth: populations increase proportional to their biomass, but the rate of increase slows as the population approaches its carrying capacity.
- Rate of change (production) is maximum when the population is at half of its carrying capacity.



Graham's Theory of Sustainable Fishing (1935):

- If removals can be replaced by stock production each year, the fishery is sustainable.
- If stock size is maintained at half its carrying capacity, the population growth rate is fastest, and sustainable yield is greatest (Maximum Sustainable Yield).



K = unfished stock biomass at carrying capacity
r = intrinsic rate of stock growth.

$$\frac{dX_t}{dt} = F(X_t) - Y_t$$

X_t denotes the resource stock in time t, $F(X_t)$ denotes growth of the resource stock in time t, and Y_t denotes yield from the resource stock in time t. Substitute into the Graham-Schaefer production function

$$Y_t = qE_tX_t$$

with q = catchability coefficient, and where Et denotes fishing effort in time t and Xt denotes the resource stock biomass in time t. Next, substitute in the logistic growth function,

$$F(X_t) = rX_t[1 - \frac{X_t}{K}]$$
$$= rX_t - \frac{r}{K}X_t^2$$

where r denotes the intrinsic growth rate of the resource stock and K denotes the environmental carrying capacity. This substitution gives

$$\frac{dX_t}{dt} = rX_t[1 - \frac{X_t}{K}] - qE_tX_t$$

To obtain steady-state equilibrium, $\frac{dX_t}{dt} = 0$ (so that $F(X) = Y$ or the addition to the resource stock F(X), is counterbalanced by the removals from the resource stock, Y), and note that and in steady-state. Solving for the steady-state level of X gives:

$$X^* = K[1 - \frac{qE}{r}] = K - \frac{qEK}{r}$$

The yield-effort curve for the logistic growth function, or Schaefer model, and simple form of the production function chosen is obtained by substituting in X* in Y = EX and solving for Y solely in terms of E, r, and K.

$$Y = qEX$$

$$= qKE[1 - \frac{qE}{r}] = qKE - \frac{q^2KE^2}{r}$$

This equation is quadratic in E. For sufficiently high levels of effort (E > r/q) the yield is zero, i.e. beyond the critical level of effort the yield is zero. Therefore, if the effort level E exceeds r/q, the population will be driven towards extinction.

A common objective of renewable resource management has been to maintain standing stock $X_t \equiv X$ so as to give a maximum sustainable yield or MSY.

Mathematically, in terms of the continuous time model $\frac{dXt}{dt} = F(Xt) - Yt$ one seeks to maximize sustainable yield Y = F(X), which requires F′(X) = 0. For the logistic growth function

$$F'(X) = \frac{dF(X)}{dE} = 0$$ at $$X_{MSY} = \frac{K}{2}$$

and

$$Y_{MSY} = \frac{rK}{4}$$

Note that steady-state equilibrium means that corresponding to each biomass level X is a certain rate of harvest Y = F(X) that just balances the natural rate of growth and thus maintains an equilibrium. This rate of harvest, at which Y = F (X), is sustainable yield, and MSY is simply the maximum sustainable yield.

The resource stock level corresponding to maximum sustainable yield or MSY, X_{MSY}, is obtained from the logistic growth function as follows:

$$F(X) = rX[1 - \frac{X}{K}] = rX - \frac{r}{K}X^2.$$

From the first-order conditions for a maximum

$$F'(X) = r - 2\frac{r}{K}X = 0,$$

so that:

$$r = 2\frac{r}{K}X \quad \text{or} \quad 1 = \frac{2}{K}X$$

or

$$X_{MSY} = \frac{K}{2}.$$

In words, the resource stock at MSY is one-half of the environmental carrying capacity, K.

Y_{MSY} is obtained by substituting $X_{MSY} = \frac{K}{2}.$ in F(X) for the logistic growth function and solving as follows:

$$F(X_{MSY}) = Y_{MSY} = rX_{MSY}[1 - \frac{X_{MSY}}{K}]$$
$$= r\frac{K}{2}[1 - \frac{\frac{K}{2}}{K}] = r\frac{K}{2}[1 - \frac{1}{2}]$$
$$= \frac{rK}{4}.$$

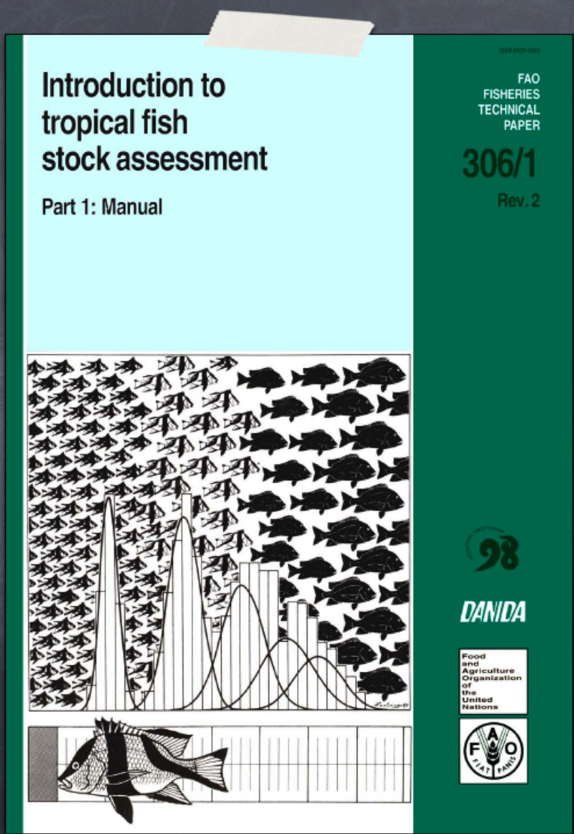
The level of effort corresponding to maximum sustainable yield, E_{MSY}, is obtained by taking the first derivative of the Schaefer yield-effort curve, Equation (6), with respect to E and solving for the corresponding level of E, E_{MSY}.

$$E_{MSY} = \frac{r}{2q}.$$

Note that the critical level of effort – the effort level which is sufficient to drive the population to extinction – is $\frac{r}{q}$ from above, which equals $2E_{MSY}$.

In other words: A stock is overfished, when

$$E > \frac{r_s}{2q_s}$$



MSY: Definition(s)

- The highest theoretical equilibrium yield that can be continuously taken (on average) from a stock under existing (average) environmental conditions without affecting significantly the reproduction process. Also referred to sometimes as Potential yield .
- (MSY or YS.): The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others.

Equilibrium yield

- For the equilibrium situation the production of biomass per time unit, equals the removal by fishing, the yield per time unit, plus the amount of fish dying of natural causes.
- Equilibrium yield: In theory, the yield or catch that could be taken every year by a fixed amount of fishing effort, maintaining the stock at a constant level, assuming a steady-state situation "at equilibrium" with the total fishing effort in the long term. The concept neglects inter-annual environmentally driven stock fluctuations and so is not useful for short term predictions. It is, however, useful for guidance on long term strategy formulation.

Group work

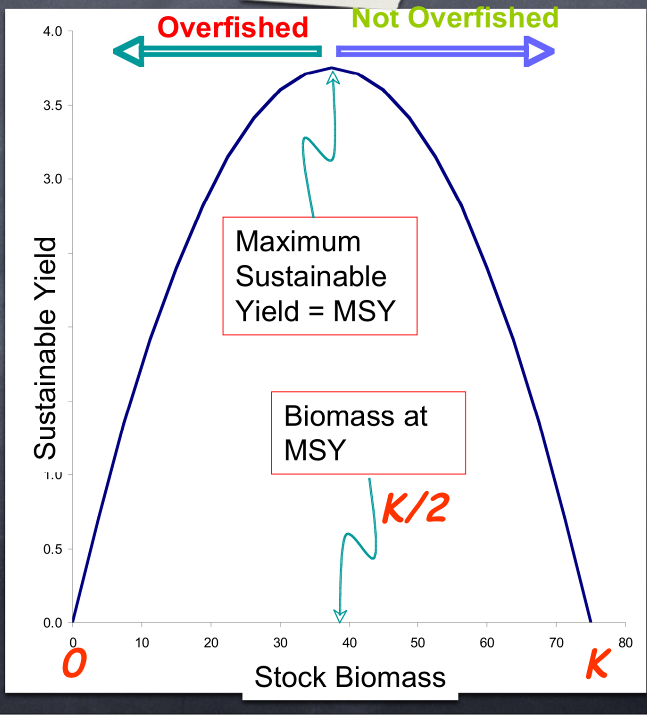
- Group 1: Requirements for determining MSY
- Group 2: MSY-based fishery management 1: Stock-focused management tools and approaches (aiming at BMSY) and their limitations
- Group 3: MSY-based fishery management 2: Effort-focused management tools and approaches (aiming at EMSY) and their limitations
- Group 4: Alternative or supplementary management tools and approaches?

MSY based fisheries management approaches

- Input (effort) control
- Output (harvest) control

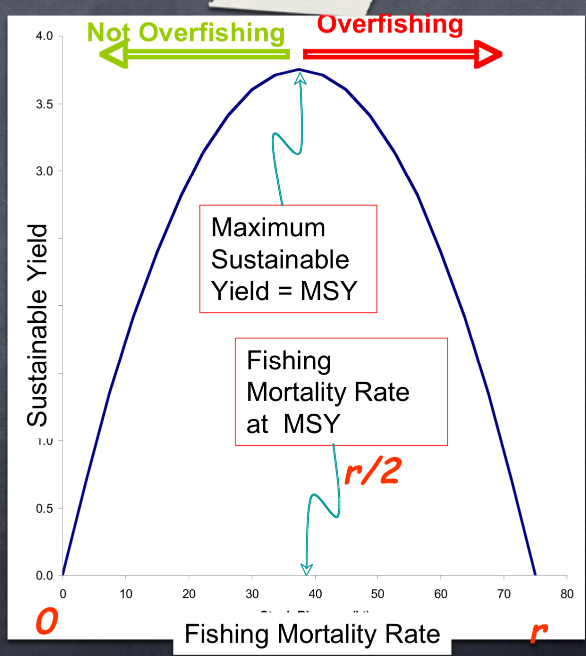
MSY and Fisheries Management

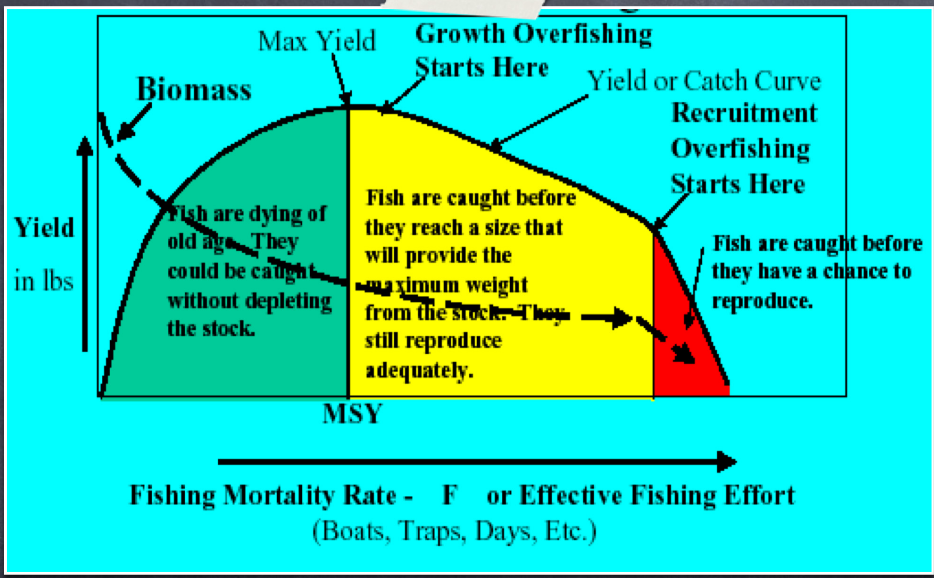
- Balancing a population at BMSY can be precarious
- Changes in stock size can occur due to many factors—many of which cannot be controlled.
- Targeting for a population size greater than BMSY creates a "reserve" that reduces yield slightly and protects against changes in stock status



MSY and Fisheries Management

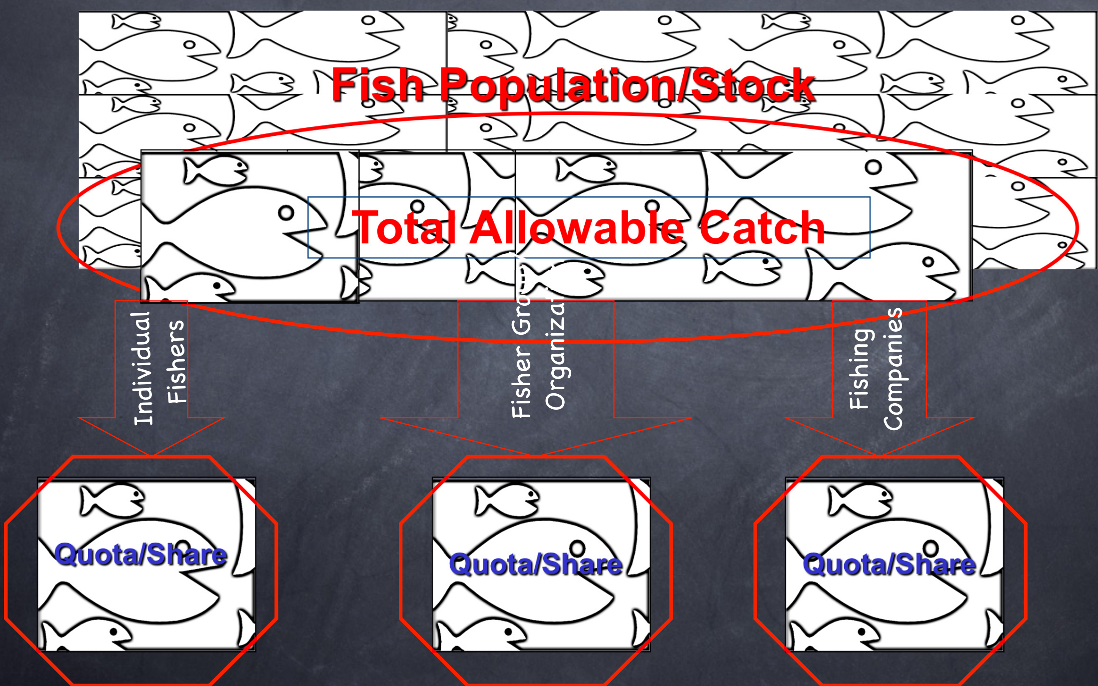
- Balancing a population at FMSY can be precarious also
- Changes in fishing mortality can arise form several sources
- Targeting for a fishing mortality rate LESS than FMSY leads to higher biomass, a slight reduction in yield and reduces the need for future reductions in effort.





2 types of overfishing and MSY

Catch Limitations and Quota

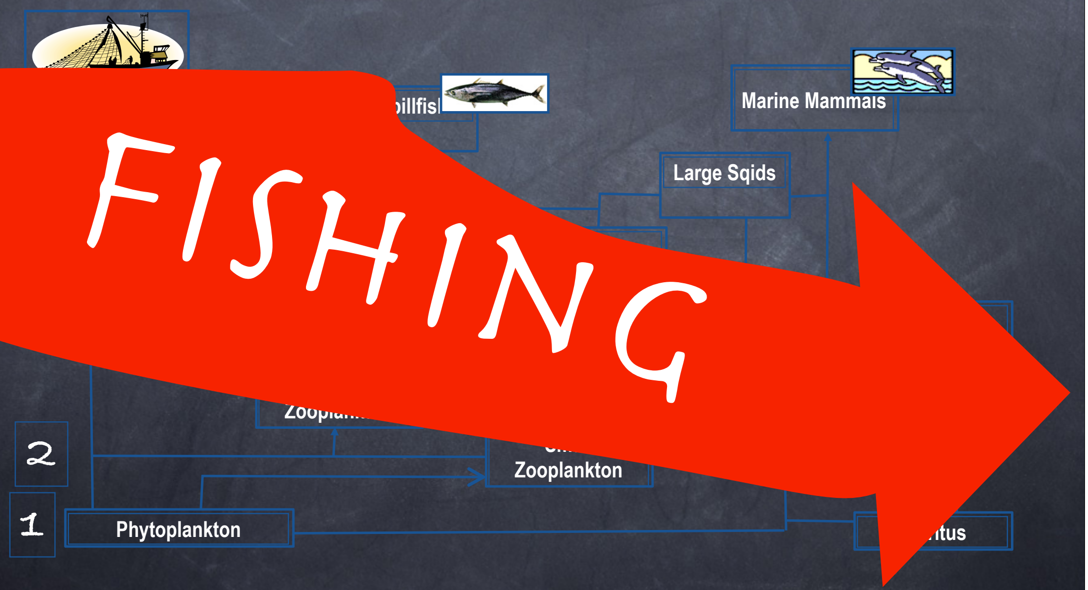


Tropical fishery systems: characteristics and basic features

- High-diversity
  - Bio-diversity (multi-species)
  - Socio-economic diversity (multi-gear/ numerous beach landing sites)
- Complex
- Continuously changing
- High sensitiveness to external disturbances
- Open-access
- Un-predictability

Example of a simple food web, representing the oceanic part of the South China Sea

(based on Pauly 1999)

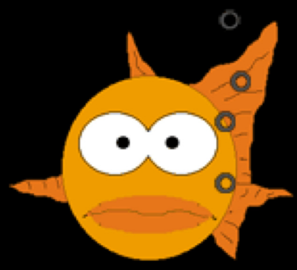


Limitations of MSY in (tropical) multi-species fisheries

- Developed for single species, temperate fisheries; does not account for species interaction;
- Does not account for the variability of fish production => optimum level of fishing effort changes over time;
- In Southeast Asia often used as a target point for fishing activities.
- Relies on increasing and extensive current and historical data on stock parameters, obtained through fishery and biomass surveys => expensive, costs may be greater than benefits/income derived from fisheries

Refugia alternative or supplementary fishery management method???

Happy Halloween!



and good fishing - always!!