BEVERTON AND HOLT'S YIELD PER RECRUIT MODEL

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Yield per Recruit (Y/R) is the expected life time yield per fish recruited into the stock at a specified age. The Beverton and Holt's Yield per Recruit model (1957), is a predictive model that can be used by fishery managers to understand the biological / economical effect of fishing on the stocks and helps them to take suitable measures to ensure sustainable yields from the fishery. In the Beverton and Holt (1957) yield equation, the response of a population to fishing mortality on a per-recruit basis depends on natural mortality (*M*), fishing mortality (*F*),growth rate (*K*, from the von Bertalanffy growth equation) and the age (*tc*) at first capture (depends on gear selectivity). A fishery manager will aim at arriving at a combination of measures that will ensure that the fish stocks are exploited at such a level that there is neither growth nor recruitment overfishing, and predictive models employing the Y/R concept enable these decisions. Maximum yield from a cohort can be realised only by exploiting it at an age or size (optimum age or length) at which the cohort's biomass reaches its maximum. Thus, ideally fishery managers should be implementing exploitation strategies that do not harvest fish too early (by restricting catches of juvenile fishes) or too late when most of them would die due to "senility" or similar reasons operated through natural mortality.

The Yield per Recruit model of Beverton and Holt is in principle a "Steady State Model" implying that the model is describing the state of the stock and yield in a situation when the fishing pattern has remain unchanged for a sufficiently long period of time and all the fishes alive have been exposed to it since they recruited. Hence this is based on certain assumptions which are listed below

- Recruitment is constant, though not specified
- All fish in a cohort have hatched on the same day

- knife edge Recruitment (Tr, All fish from a cohort recruit to the fishing ground at the same time) and knife edge Selection (Ts) is (Experiencing only natural mortality (M) upto the time of recruitment it is suddenly exposed to Fishing (F) mortality, which remain constant in the entire life span of the cohort after it enters the fishery)
- Complete mixing occurs within the stock
- length –weight relationship has exponent 3

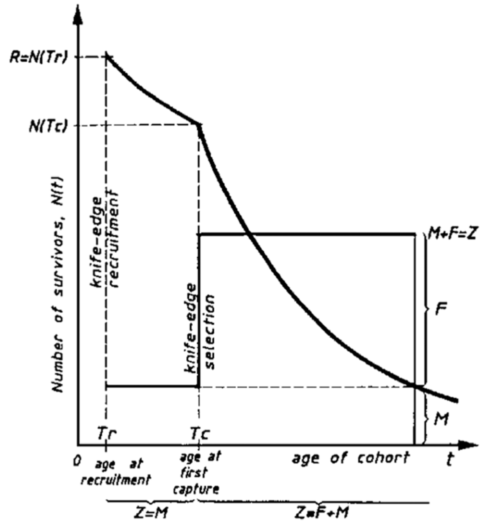

Fig. 1. Depiction of some of the assumptions in the yield per recruit model

Mathematical expression of the Beverton and Holt's Y/R model uses the total yield per recruit for the entire life span of the cohort using the equation

$$Y/R = F * \exp[-M * (T_c - T_r)] * W_\infty * [1/z - 3S/(z+k) + 3S^2/(z+2K) - S^3/(z+3K)]$$

where $S = \exp[-K * (T_c - t_0)]$

K and t_0	=	von Bertalanffy growth parameters
T_c	=	Age at first capture
T_r	=	Age at recruitment
W_∞	=	Asymptotic body weight
F	=	Fishing mortality
M	=	Natural mortality
Z	=	Total mortality (F+M)

Mortality which is divided as due to natural causes (M) and fishing (F) is a continuous process in time where the number of individuals is constantly reduced from the initial number R (number of recruits). In the Y/R model the yields are relative to recruitment and it is possible to calculate Y/R by varying the input parameters such as F (proportional to effort) and T_c (function of gear selectivity) which are possible to be controlled by a fishery resource manager.

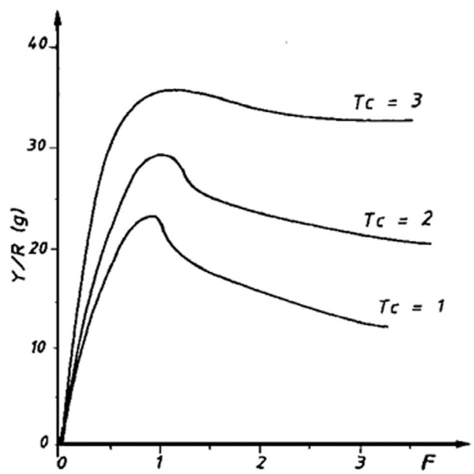

Fig. 2. Yield per recruit curves with different ages of first capture (T_c)

The Y/R curve has a maximum point known as the ' Maximum Sustainable Yield' which in turn depends on the age at first capture which in turn is influenced by the mesh size of the gear or other gear technology related factors. By combining a range of values of T_C and F and assuming that other conditions operating in the fishery are not changing, the long term sustainable yield is arrived. Originally an age based model, it can also be converted into a length based one applying certain principles, in fisheries where the data is mainly of length frequencies of the catch of particular species which has not been aged.

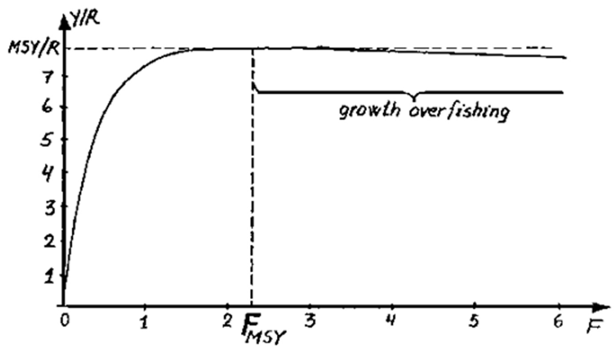

Fig. 3. A typical Y/R curve as a function of Fishing mortality

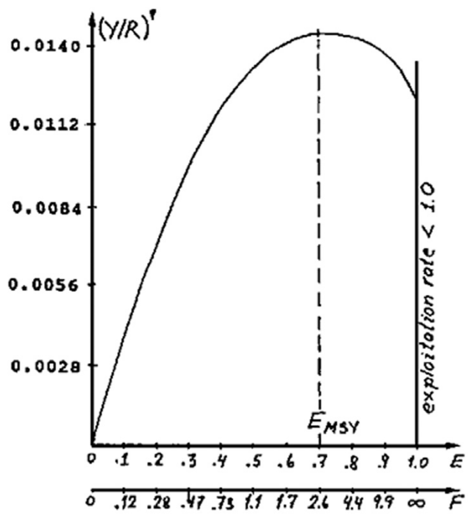

Fig. 4. Beverton and Holt's relative yield per recruit (Y/R)' curve for a given species and known length at first capture

Y/R relationships are important in arriving at two biological reference points (BRP) commonly used by fishery managers such as F_{max} (or F_{msy}) and $F_{0.1}$. The F_{max} BRP being highly sensitive to changes in growth, natural mortality and selectivity parameters adopted, its use as a target reference point is not encouraged. A more conservative estimate of $F_{0.1}$ which is the fishing mortality rate for which slope of the yield-per-recruit curve is only 10% (rather than 0%) of its value at the origin is preferred. In certain cases, Y/R curve does not have a maximum and can lead to the wrong conclusion that effort can be increased indefinitely. In such cases, often common in tropical fisheries, it is recommended to look into biomass/ recruit curves also along with the Y/R curves.

In fisheries management, frequently there is need to understand how much the yield per recruit will change in response to changes in fishing effort. In such situations, rather than the absolute values of Y/R expressed as grams per recruit, Beverton and Holt (1966) developed the Relative Yield per Recruit Model, denoted as (Y/R)' which used the life history invariants (dimensionless ratios). The (Y/R)' can be calculated for given input values of M/K, L_∞ and L_c for values of E ranging from 0 to 1 and corresponding to F values of 0 to ∞. This has been used for assessing effect of mesh size regulations effectively.

Suggested Reading

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