

Population Age Structure

Introduction

- Population structure is of adaptive significance by enabling the species to exist under given conditions.
- To certain extent the population can adopt to changes in the environment. Even between species of aquatic fauna, differences exist.
- The age of population is controlled both by biological and ecological forces.

Laws of population structure

- The size of a population at any given time may be taken to be a convenient end index of many forces that act upon population.
- The growth of a population is determined by natality, mortality and dispersion.
- These are controlled by various ecological forces namely density dependant and density independent factors.
- Under optimal ecological conditions, a population in the absence of human intervention grow to its maximum size.
- This depends on the carrying capacity of ecosystem in which the fish lives.

Laws of growth

- Growth is quantitative aspect of development, the individual or a population grows and the growth show variations with the food supply.
- When a fish feeds actively, it undergoes maturation quickly and the rate of growth of an individual is also high.
- Rapid growth and larger size provide protection against enemies and escape from predators.
- The increase in length before maturity is more dependent on the food intake than after maturity.

Laws of growth contd.....

In principle, growth of fish is determined mainly by

- I. Conversion efficiency which mainly depends on physiology of metabolism and quality of food.

- II. Trophic condition of the ecosystem in which the presence of favourite food sought by the fish.

Fish growth in tropical and temperate waters

- Fishes in temperate waters live long compared to those in warmer regions. The growth coefficient, natural mortality are generally higher in tropical waters compared to temperate waters.
- Fish tend to mature according to a fixed portion to their asymptotic size (L_{∞}). Larger the asymptotic size, larger is also the size at first maturity.
- Hence for a given family of fish L_m/L_{∞} is a constant ratio (Cushing, 1965).

Fish growth in tropical and temperate waters

contd.....

- The asymptotic length and minimum maturity are generally higher in fishes of temperate waters.
- Because these two parameters are at higher side, it could be said L_m/L_∞ is inversely related to M/K . This is due to the inverse relation between K and L_∞ .
- In elasmobranch fishes of tropical waters, unlike teleosts grow slowly, live long and attain very large size.
- In general, elasmobranchs have long life with slow growth rate; the reproductive rate is also high with low reproductive stress.

Biological features of population

- In a population, after it ages, reproductive potentiality decreases and omission of some spawning season is also common.
- The age structure of a population, its growth, sexual maturity changes with regard to the availability of food.
- This influences the size of fish and fecundity, as the number of eggs laid by a fish change with food supply and many recruits are released in a spawning season of a fish.

Biological features of population conted....

- The growth in length and weight and fecundity of a population always follows sigmoid curve.
- In the initial life cycle, all the above biological factors will increase with age but once the population reaches a maximum size, the above factors shows decline

Theory of life tables

Introduction

- Data on age specific mortality and fertility are organized in a life table. The life table has an important role in fish population.
- The structure of a population is specific of a species or subspecies and the environment.
- The population structure of a species or groups within species has certain stability.
- Once the environmental condition changes, the population of a species changes continuously, hence the structural resemblances and other features of the species show changes.

Life span of a fish

- The life of fish varies greatly. About 75 percent of the fish species have life span between 2 and 20 years, 60 percent have life span of 5 to 20 years Less than 10 percent have life span of over 30 years (Nikoloskii, 1980.)
- The largest fish with longest life span will usually have large predators. The life span of a fish stock is much influenced by food supply, maturation and even the number of recruits released.
- One form of the life table takes a cohort of individuals born at the same time and records the numbers remaining alive at regular time intervals until all dead.

Construction of life table

Construction of life table is a simple method, and it keeps the tracks of births, deaths and reproductive output of a population.

Three methods are used for construction of life table. They are

(i) Cohort life table

- The cohort life table follows a group of same aged individuals from birth throughout their lives.
- This life table may work out for semelparous species, i.e. showing one reproductive event in their life time. This life table could be worked out easily by counting all individuals of a population during its life span.

Construction of life table

(ii) Static life table

The static life table could be worked out for those organisms having complex life histories. This life table instead of working on a single cohort, it compares the population sizes of different cohorts of all life spans at a single point of time. The life table could be worked out with the assumptions that the proportion of individuals to each age class does not change and the size of the population nearly consistent.

(iii) Life table could be made from mortality data collected from a specified time period with a stable age distribution.

Both cohort and static life tables will be of less use to tropical fishes which shows year class variations and the pattern of recruitment is also not constant, as most of the species are prolific breeders. In such cases, the life tables could be worked out using mortality records.

Mathematical models

- Life tables are much needed in studying populations.
- To construct the models, the biology of the organism is an essential prerequisite. In addition to their biology, population may grow independent of their density, show exponential increase in number and are influenced by environmental factors.
- The population grow upto exponential rule but slow down when approach to carrying capacity (K). The ' r ' is the intrinsic rate of increase per individual of a population.
- The ' K ' is the maximum number of individuals of a particular habitat can sustain.

Mathematical models conted.....

(i) Equation for density independent model for organism with discrete breeding season.

$$N_{t+T} = N_t + (T.r.N_t)$$

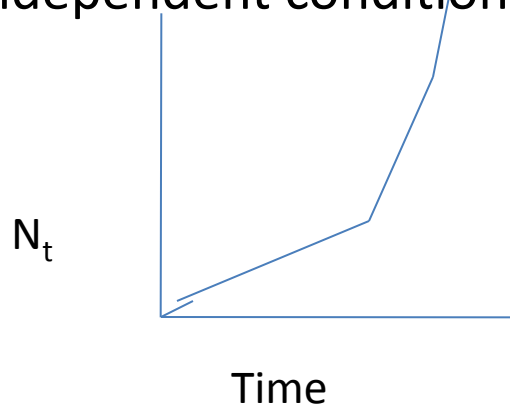
N_t = Population size at a particular time.

T = time in years.

r = intrinsic reproductive rate

N_{t+T} = Population size to the subsequent year

Plotting N_t against time depicts the population changes each year under density independent conditions.



The above Figure shows exponential increase of a population with discrete breeding season (Density independent model for organisms with discrete breeding season).

Mathematical models conted.....

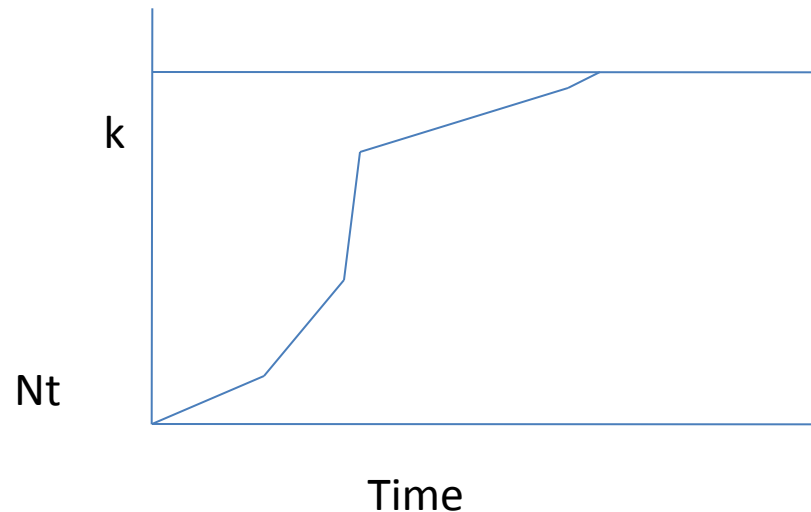
(ii) Equation for density dependent model for population with discrete breeding season.

$$N_{t+T} = N_t + [T.r.N_t.(K - N_t/K)]$$

K = carrying capacity

Once the N_t approaches K , the expression $(K - N_t/K)$ approaches '0' and N_{t+T} comes closer to N_t and at K , N_{t+T} equals N_t .

Plotting N_t against time shows increase for density dependent populations with discrete breeding seasons.



The above Figure shows the effect of 'r' and 'T' on density dependent populations.

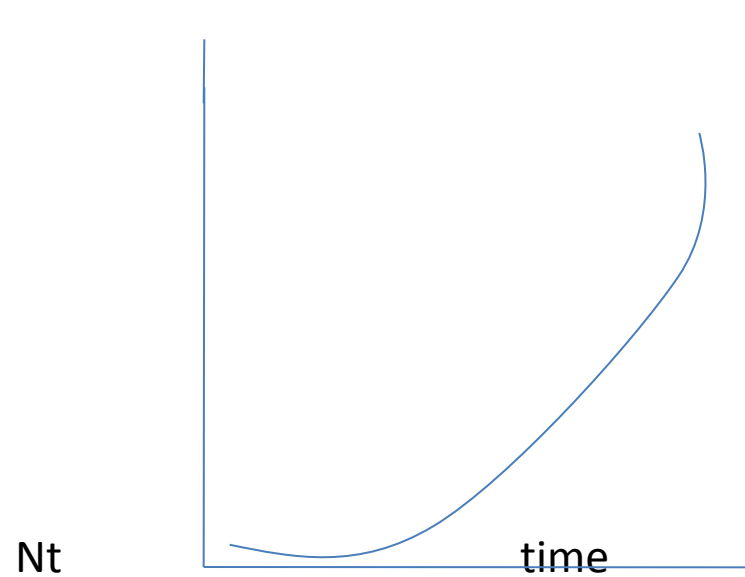
Mathematical models conted.....

iii) For populations which breeds continuously, the equation is (density independent model)

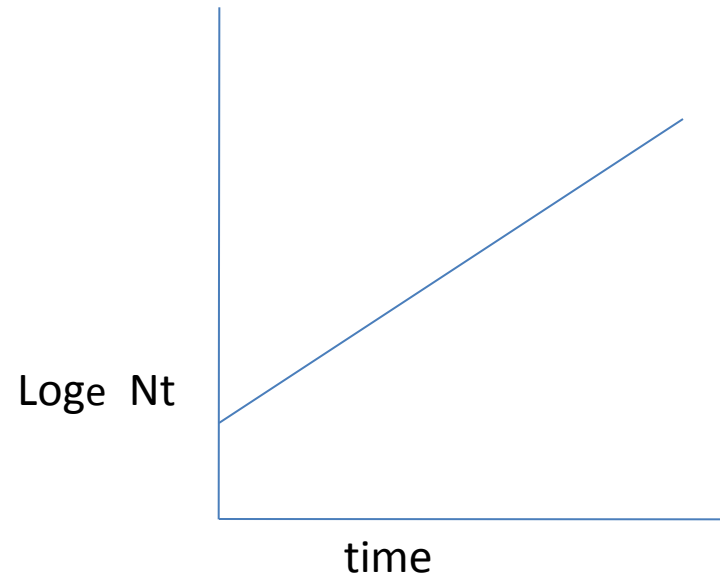
$$N_t = N_0 \cdot e^{rt}$$

N_0 is the initial population size

e is the base of Natural logarithms.



Exponential increase by plotting N_t with time



Linear curve by plotting Log_e

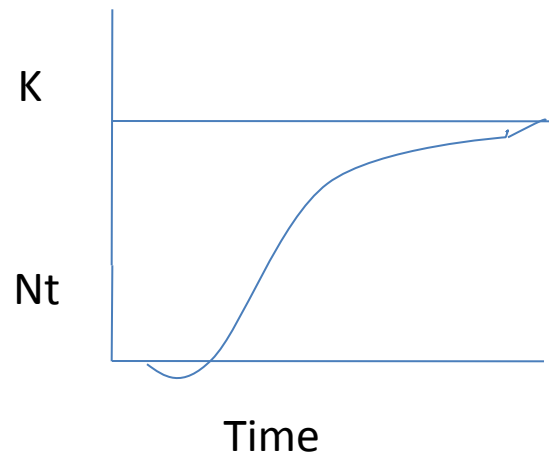
N_t with time

Mathematical models conted.....

(iv) For populations which breeds continuously the equation is (density dependent model)

$$N_t = \frac{K}{1 + e^{-rmax.t}}$$

Logistic population increase of the continuous density dependent model (N_t with time and attains asymptotic to K)



In the above graph, the population size follows the logistic pattern. It increases slowly and at a certain interval of time, it increases rapidly and once it attains K (the carrying capacity of the system) the line gets almost becomes stationary.

Virtual population analysis

- The virtual population analysis (VPA) and cohort analysis are the methods used in fish population dynamics.
- This analysis is basically an analysis of catches of commercial fisheries obtained from fisheries statistics along with detailed information on the contribution of each cohort to the catch data.
- In VPA analysis, once the history of population is known the future catches could be predicted.
- The version of VPA suitable for pocket calculator is the cohort analysis.
- This analysis is identical to VPA and the calculation is also made simple.

Virtual population analysis conted.....

- In VPA, the catch is taken continuously and in cohort analysis, the assumption is made that all fish are caught on one single day.
- The day is chosen to be 1st July i.e. when one half of year has elapsed and natural mortality (M) assumed to be constant throughout the life span of a cohort.
- The two methods namely Pope's cohort analysis and Jones length based cohort analysis are used for prediction of catches.

Cohort Dynamics

- A cohort is a batch of fish all of approximately the same age and belonging to the same stock.
- In the cohort of a stock, at birth the cohort has age zero. From age 0 to T_r , the cohort is in the “Prerecruitment phase”.
- The symbol $N(t)$ is used to designate the number of survivors from a cohort attaining age ‘ t ’. The age is usually expressed in years.
- The symbol ‘ R ’ is used to designate the recruitment. ‘ $N(T_r)$ ’ is the “number of recruits” to the fishery.

Cohort Dynamics

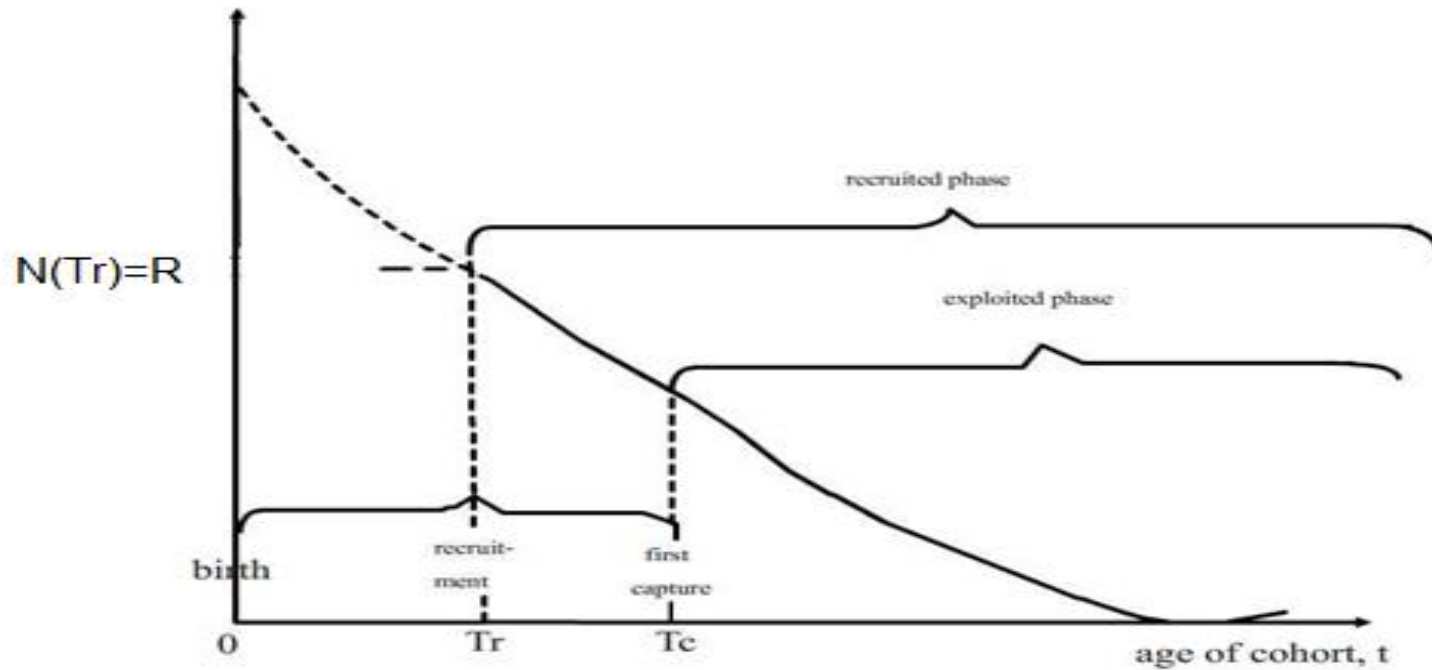
contd.....

- 'Tr' is the minimum age at which the fish can enter the fishery ie., becomes liable to encounter with fishing gears.
- 'Tc' is called the age at first capture which marks the beginning of the exploited phase.
- 'Tc' is dependent on the mesh size.

The following figure illustrates the basic features of cohort dynamics.

Cohort Dynamics

contd.....



In the above illustration, due to mortality there is a continuous decrease in the number of survivors. In the prerecruitment phase (age '0' to T_r) there is only 'M' and after age ' T_r ', the fish may be caught if suitable small meshed gear is used. At age ' T_c ', the fish get caught with the mesh size actually in use.

Cohort Dynamics

contd.....

- Length based cohort analysis is available in computer programs namely “LCOHOR” in the LFSA package of microcomputer programs developed by Sparre, 1987.
- The FISAT (Gayanilo et al 1995) contain routines for a length based analysis similar to LCOHOR.

END