UNIT I : AGE AND GROWTH: SCALE METHOD, LENGTH-WEIGHT RELATIONSHIP

A.GROWTH AND AGE OF A FISH

- Growth is a bioenergetic process, and is difined as a change in its length and weight over a period of time.
- It indicates the health of the individual and of the population, and has been extensively studied for various species of fishes.
- The growth and age of a fish are closely related to each other and depend on several factors.
- The rate of Fertilization,
- Development and Growth
- Growth varies in different species, and in the same species living in different environmental conditions.

The life cycle of fish comprises the following periods: 1. embryonic, 2. larval period, 3. immature organism period 4. adult organism period, and 5. selinity period.

From periods 1 to 3 the main food resources, which enter the body, are utilized for growth.

Each life period is characterised by a particular character of growth.

For example, the period of most rapid linear growth occurs usually before the onset of maturity.

The following growth patterns are generally recognised:

Absolute growth: It means the highest or perfect growth of fish from embryonic to selinity period.

Relative growth: It means growth comparison from one life period to another. For obvious reasons growth is never similar during any two life periods.

Isometric growth: Isometric means having equality of measure, having the plane of projection equally inclined to three perpendicular axes of the cubic system, or referable three equal axes at right angles to one another. If the fish is following the cube law, the growth is called isometric.

Allometric growth: It is lopsided growth. There may be various patterns of this type of growth. For example, several fish species grow more in length than width or weight

The two parameters, which exhibit growth of fish are **length and weight**. It should be noted that growth in length indicates long-term change, whereas growth in weight is more subject to seasonal variation.

Factors Influencing Growth of a Fish

- Several factors are known to influence the rate of growth in fishes.
- These are temperature, photoperiod, quality and quantity of food available, dissolved oxygen, ammonia, salinity, age and the state of maturity of the fish, interspecific and intraspecific competition among the individuals and crowding and disease etc.
- Of these, temperature is one of the most important factors influencing growth, as it affects the optimum consumption of food.
- Maximum growth rate is achieved in Salmon at 15° C. In many fishes slower growth rate occurs during December to February.
- Dissolved oxygen is also an important factor influencing growth rate, and is temperature dependent.
- It appears that if the DO falls below a certain level, the fish is deprived of 'extra' energy required for growth.
- Growth rate also slows down if ammonia is present in higher concentration. Population density influences growth rate due to competition for available food.
- Higher density slows down the growth rate and lower density increases it.

- Availability of food is temperature dependent.
- Growth is rapid during warmer months when food is in plenty, and is slow during winter. Thus, there is seasonal growth of the fish. Similarly, photoperiod, age and maturity of the fish are also important factors. Fish grows at a faster rate during first few months or years of its life. Later, after becoming mature, large amount of energy is diverted for the growth of gonads and growth of the body slows down. Hence, a young fish grows at a higher rate than the mature one.
- However, a mature fish is heavier per cm of length than the immature fish, which may be due to large and heavy gonads. This is shown by the higher condition factor (k), which indicates the relative health or the robustness of the fish. Condition factor (coefficient) represents the condition of the health of the fish during a certain period, and is the ratio of the length to the weight of the fish, as calculated by the following formula proposed by Fulton (1902)

CONDITION FACTOR= The cube of the length is taken because the growth in weight is proportionate to the growth in volume (Nikolsky, 1963).

- The condition factor is generally used by fish biologists as an indication of the health of a fish population.
- A high value of K shows that plenty of food is available to support both somatic and gonadal development of the fish.
- For such a study, total length and weight of a large number of fish are recorded in fresh condition, and the average values are analysed separately in groups of fishes consisting of individuals varying in length by 5 cm, and the mean values are then calculated.
- The values of K differ with the season, and are influenced by maturity and spawning.
- The value of K is maximum during the spawning season.

REGULATION OF GROWTH

Certain hormones, especially the growth hormone, regulate the growth of a fish.

Growth ceases in a hypophysectomised fish, and injection of mammalian growth hormone brings about an increase in the growth rate.

This may be due to increase in the food conversion rate, which can be the result of stored fat mobilisation, protein synthesis and secretion of insulin.

Thyroid hormone also brings about enhancement in growth rate, by increasing food consumption.

Androgens, when added to the food, are also reported to bring about increase in food conversion efficiency of the common carp. (Lone and Matty, 1982).

GROWTH PERIODICITY

- Growth periodicity (seasonality) is a characteristic feature of the growth of fishes.
- In certain seasons of the year, fish grow rapidly, in others they grow slowly.
- This inequality in the growth rate is very well reflected throughout the year in the scales and some bones of fish.
- The periods of slow growth are imprinted on the scales and skeleton (for example, opercular bones) in the form of stripes or rings, which are pale in reflected light.
- These stripes are formed by small flattened cells and they appear dark in direct light.
- The periods of faster growth are characterised on the scales and skeleton by wide fields or rings, which are dark in reflected light and pale in direct light (Nikolsky, 1963).

METHODS FOR DETERMINING AGE AND GROWTH

Growth rate of a fish can be determined by measuring changes in size (length and weight) in relation to time.

This can be done by any of the following methods:

1. Direct Method: Age and growth rate of a fish can be determined directly by rearing the fish under controlled conditions.
2. Marking or Tagging the Fish:
3. By Counting Rings or Annuli on Bones and Scales:
4. Otoliths Otoliths are also used for determining the age of fish.
5. Scales: Age and growth rate of a fish can be accurately determined by counting the annuli on the scales.

B. ESTIMATION OF FISH LENGTH-WEIGHT RELATIONSHIP

Every animal in its life exhibit growth both in **length** and in **weight** and the **relationship** between these two has both applied and basic **importance**.

The**l engtth-weight relationship** is one of the standard methods that yield authentic biological information and is of great **importance** in fishery assessments.

LENGTH-WEIGHT RELATIONSHIP OF FISH

- Organisms generally increase in size **(length, weight) during development**.
- The key factors that influence the growth of fish are **the quantity of food available**, **the number of fish utilizing same food source**, **temperature, oxygen and other water quality factors besides the size, age and sexual maturity of the fish**.
- Every animal in its life exhibit growth both in length and in weight and the relationship between these **two has both applied and basic importance.**
- The length-weight relationship is one of the standard methods that yield **authentic biological information and is of great importance in fishery assessments.**
- It establishes the mathematical relationship between the two variables, length and weight, and helps in assessing the variations from the **expected weight for the known length groups.**
- This is particularly **useful for computing the biomass of a sample** of fish from the length-frequency of that sample.
- The parameter estimates of the relationship for a population of fish can be compared to average parameters for the region, parameter estimates from previous years, or parameter estimates among groups of fish **to identify the relative condition or robustness of the population.**
- Relationship between length and weight is required for setting up yield equation and sometimes it may be useful as a character to differentiate “small taxonomic units”.
- It also helps in converting one variable into another. Of the two, length is easier to measure and can be converted into weight in which the catch is invariably expressed.
- The length weight relationship also provides means for finding out the “condition factor” and the seasonal changes in the condition factor are useful to determine the biological changes in the fish.

THE RELATIONSHIP BETWEEN WEIGHT (W) AND LENGTH (L) IN FISHES HAS THE FORM:

$$W = aL^{b}$$

1. In this equation, the parameters ***a*** and ***b,*** usually termed as length weight parameters are to be estimated with the available length-weight data.
2. Each species of fish will have a specific length-weight relationships or specific length - weight parameters. It may also differ between sexes and between stocks or those belonging to different geographical regions.
3. The parameter ***a*** is a scaling coefficient for the weight at length of the fish species. The parameter ***b*** is a shape parameter for the body form of the fish species.
4. The length of a fish is often measured more accurately than the weight.
5. In theory, one might expect that the exponent ***b*** would have a value of roughly ***b*** = 3 because the volume of a 3-dimensional object is roughly proportional to the cube of length for a regularly shaped solid.

PROCEDURE FOR LINEAR REGRESSION

- Length is one dimensional whereas weight which depends on volume is three dimensional. Hence, there is thinking that weight of a fish is proportional to cube of the length of the fish. That is, there exists cubic relationship between weight and length of a fish. For an ideal fish which maintains the same shape b=3.
- Most species of fish do change their shape as they grow and so a cube relationship between length and weight would hardly be expected.
- It has also been found that while b may be different for fish from different localities, of different sexes, or for larval, immature and mature fish, it is often constant for fish similar in these respects.
- The length-weight relationship may thus be a character for the differentiation of small taxonomic units, like any other morphometric relationship.
- It may also change with metamorphosis or the onset of maturity. In practice, fish that have thin elongated bodies will tend to have values of ***b*** that are less than 3 while fish that have thicker bodies will tend to have values of ***b*** that are greater than 3.
- Thus this also help to determine whether somatic growth is isometric (b=3) or allometric. Values of *b* smaller, equal and larger than 3 indicate isometry, negative allometry and positive allometry respectively.
- When $b>3$, large specimens increase in height or width faster than in length, either as the result of a change in body shape with size, or because the large specimens in the sample are in better condition than the small ones.
- Conversely, when $b<3$, either the large specimens have changed body shape, i.e., become more elongated, or the small specimens were in better nutritional condition at the time of sampling.
- Thus the growth of fish length and weight is not proportionate or the relationship between length and weight is not linear.
- This means that when the length is increased the increase in weight is not proportionate to it. It is rather non-linear type of relationship.

- The estimation procedure for length – weight relationship is through linear regression. Since the above model of length-weight relationship is not linear it has to be transformed into linear type by applying logarithmic transformation.
  - If we take logarithm (*natural logarithm with base e*) the above model will become linear as In **(*W*) = In (*a*) + *b* In (*L*) or *Y* = *A* + *b X***
- **Where in (*a*) is the intercept and (*b*) the slope or regression coefficient**.
- The above relationship is now linear and we can use the ordinary linear regression method for estimating the parameters of the relationship.
- Data for fitting the length-weight relationship is collected randomly from the commercial catches and should represent fishes of all sizes, smallest to the biggest, and there should be enough samples for the analysis and estimation through regression.
- If our aim is to examine difference in length weight relationship between different sexes then data should be collected separately for males and females.

LENGTH-WEIGHT RELATIONSHIP

Weight can be calculated by a formula:

$W = KL^3$

where W = weight,

L = length,

K = constant; for fish showing symmetrical or isometric growth throughout.

The body form and specific gravity of a fish change constantly with the advancement of age. Thus simple cube W expression therefore does not seem to be correct throughout the life history of fish,

as the value of K is not constant but subject of great variation.

A MORE SATISFACTORY FORMULA IS:

$W = L^n$

in which W = weight,

L = length, n = constants for log W = log C + n log L.

Linear Growth and Condition of Fish- Coefficient of Condition Factor

The ratio of length and growth represents the condition at any given time.

When this ratio is calculated and if the obtained value is large,

it indicates better condition of fish.

The Fulton's formula is used to express condition of the fish.

Q = W100, where Q is coefficient of condition

I^3 W is the weight of fish and I is the length

Coefficient factor or coefficient condition is that state in which a fish remains for a certain period.

THIS VALUE IS USEFUL IN ELUCIDATING THE FOLLOWING

1. Difference in conditions of the individuals of same species in different water.
2. Differences among individuals of same length.
3. Differences occur due to seasonal changes in relation to the age and sex of the fish.

C. AGE DETERMINATION OF FISH: SCALE METHOD

AGE AND GROWTH DETERMINATION

- Determination of age and growth of fishes are one of the important aspects in the development of fisheries. Both age and growth are closely related with one other. As the fish ages, it grows, but after attaining a particular size, growth stops. Age gives an idea

about sexual maturity, spawning time, catchable size, growth rate and longevity. Knowledge of all these parameters is essential in fisheries production.

- Growth of fish or any organism is the change in length and weight with increase of age as a result of metabolism of nutrition. Hence growth is an index of healthy food and oxygen supply in the water-body. Proper growth of fish also indicates that the water body is devoid of any pollution.

KNOWLEDGE OF AGE AND GROWTH OF FISH HAS MANY APPLICATIONS

1. We can calculate the time of sexual maturity of different species.
2. Further, we can know their spawning time.
3. Growth rate of fish also indicates the suitability of particular species for a particular type of the water-body.
4. Growth rate and age of fish also indicate the size of fish at different stages, e.g., fry, fingerling, and adult of different species.
5. The study of age and growth is helpful in catching fishes by using nets of desirable mesh size.

METHODS OF AGE AND GROWTH DETERMINATION

VARIOUS METHODS EMPLOYED FOR DETERMINATION OF AGE OF FISH ARE:

SCALE METHOD:

- This method is most commonly used for determination of age of osteichthyes (bony fish), which are provided with cycloid and ctenoid scales.
- The structure of scale and its development is useful in the interpretation of growth zones.
- The structure of scale can be seen very easily under the microscope after washing with dilute solution of caustic soda followed by staining with borax carmine.

A WELL-DEVELOPED SCALE HAS THE FOLLOWING STRUCTURES:

1. FOCUS: It is a clear area in the centre, but may be shifted from the center due to irregular growth of anterior or posterior parts of scale caused by unusual overlapping of scales.

2. CIRCULI: These are concentric rings present around the focus, they run parallel at regular intervals or distances. They appear as ridges.

3. GROOVES: The grooves are found between the ridges of circuli and they are responsible for maintaining the regular space between them.

4. RADII: These are grooves found radially, viz., they run from focus to margin of scale. Radii cut the circuli present in their path.

5. ANNULI: These are wide circular troughs found in aged fish over one year. Each trough contains a few incomplete and narrow circuli different from the circuli outside it, which are complete and more widely spaced. The number of annuli represents age of a fish in years.

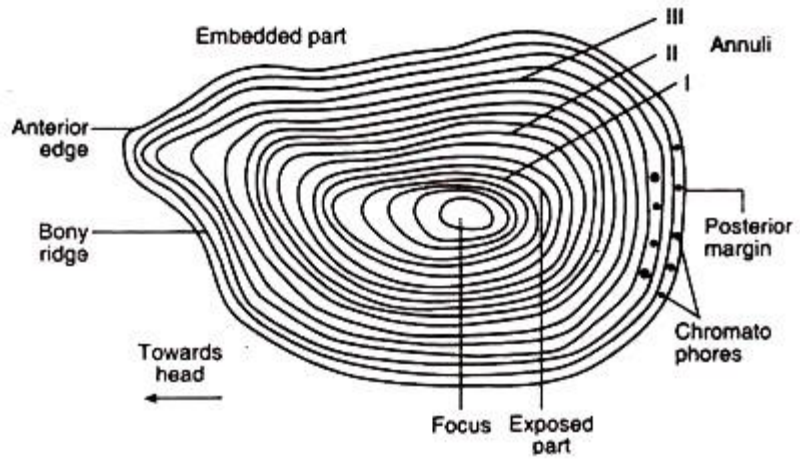

Fig. 14.1 : Scale method fish scale showing growth rings.

- At the time of development of scale, focus is established first and represents the original size of the scale.
- As scale grows older, other structures are added and perform their functions. The grooves and circuli represent growth activity.
- They also indicate osteoblastic activity as a result of which secreted material is deposited around the focus. In this way every year many such circuli and grooves are formed.
- A characteristic bone material, ichthylepidin, is deposited in circuli and thus their height increases which depends on the calcification.
- Annuli show slow growth in a year but in many fishes, during winters, annuli grow remarkably and are added yearly as fish grows.
- Thus annuli are very useful in counting the age of fish and serves as year-marks on the scale for age determination. The annuli are best seen at anterior part of the scale.

TYPES OF ANNULI:

1. TRUE ANNULI: THE TRUE ANNULI HAS FOLLOWING CHARACTERISTIC FEATURES:

(i) In cycloid scales true annuli is represented by a closely situated circuli, which is covered by widely spaced circuli.

(ii) Two complete circuli surround the trough, which is wider on the anterolateral and posterior side.

(iii) The wide part of the trough contains incomplete circuli that do not grow completely around the scale.

(iv) The trough remains narrow at the anterolateral side. In the ctenoid scales specially, the outer circulus cuts across or crosses over the incomplete circuli lying in the anterior part of the trough. Annuli are considered as year-marks in the age determination of fish in the case of the following facts.

a. When there is a correlation between the calculated age from the scale and the size of the fish.

b. The length frequency distribution should coincide with the calculated age from the scales.

c. The calculated age should be in agreement with the age determined by other methods.

2. FALSE ANNULI: Sometimes false annuli appear on the scales of fishes due to undesirable factors like retarded growth due to paucity of food, starvation, injury, disease, and fluctuation in temperature. These false annuli resemble the true annuli but they take position on the scale closer

to the true annulus of the preceding year than the normal annulus for the next year which appear in case of normal growth (Fig. 14.2).

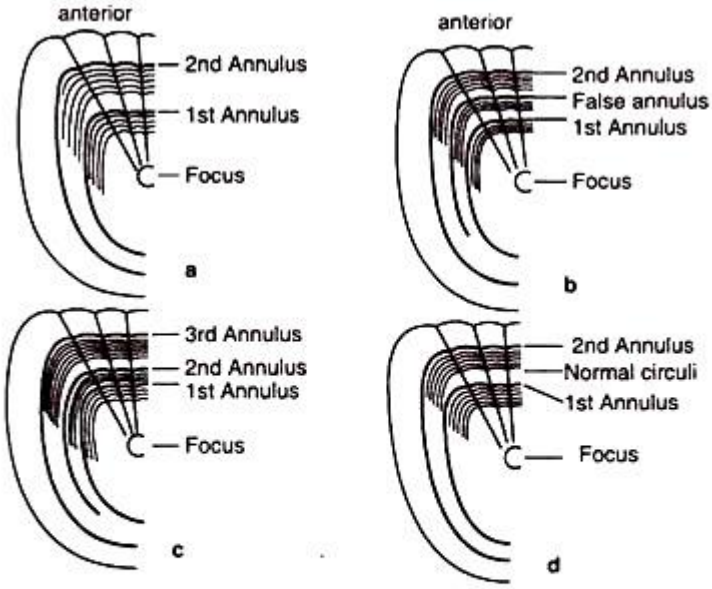

Fig. 14.2a-d : Annuli on scale in four cases of a certain species of fish. a. normal growth for a fish of a certain weight and of 2 years of age, showing annuli; b. abnormal growth for a fish of same weight and of same age, showing false annulus; c. abnormal growth in a 3-years old fish, showing skipped annulus (at 2nd annulus); d. abnormal growth for a 3-year old fish, showing overlapping annulus (at 2nd annulus)

3. OVERLAPPING ANNULI: The position of these annuli in posterior field coincide with the annuli of the preceding year while, in anterior part, it is separated from the preceding year's annuli by 4 or 5 circuli. The overlapping of scales can occur due to a slow growth during the growing period, which is represented by an increase in the length but not in the weight of body.

4. SKIPPED ANNULUS: This type of annulus by position coincides with the annulus of the preceding year, with no normal circuli forming in between. This abnormal function is due to the fact that the fish has not grown during one growing season (one summer) either in length or in weight.

APPLICATIONS OF SCALE METHOD:

1. Fish of temperate regions shows clear rings, which are true marks. This is because there is a sharp difference between the temperatures of two seasons—summer—the period of faster growth, and winter—the period of slow growth or no growth. Therefore, the calculation of the age of fish by annuli is most reliable in temperate fish.
2. This method is more reliably applicable in case of salmons, carps, cod and herrings, established a method of estimating age of fish based on scales, which is as given on next page:

Number of Annuli on the Scale	Estimated Age	Designation of Age Group
None	Less than one year old	0+
One	One year old	1
One + a few circuli	More than one year old but less than two years old	1+
Two	Two years old	2
Two + a few circuli	More than two years old, but less than three years old	2+

LIMITATIONS OF SCALE METHOD:

1. More than one annulus are added in the extreme conditions of life, e.g., extreme cold (causes cessation of feeding), change in food quality or starvation at the time of spawning. These additional rings are called supplementary rings, which cause problem in age determination by the scale method.
2. This method cannot be applied to those fishes which live in the water with more or less uniform temperatures (tropics). This may be because in these places fishes spawn more than once and, due to fluctuations in food and chemical compositions of water due to rains and floods, formation of annulus may not be an annual feature. Thus, in the fishes of tropical regions, the growth rings do not actually represent year-marks.