NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TCHNOLOGY

COURSE CODE: BIO 414

COURSE TITLE: FISHERIES AND AQUACULTURE

BIO 414: FISHERIES AND AQUACULTURE

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NATIONAL OPEN UNIVERSITY OF NIGERIA

COURSE GUIDE

INTRODUCTION

Shortage in the supply of protein of animal origin precipitated the prominence fish in the diet of most Nigerians. Drought, desert encroachment, disease outbreaks, cost and scarcity of feeds are contributory factors diminishing production from livestock industry hence the continuous reliance on fish to supplement protein intake. Over the years the demand for fish has been on the increase with supply never up to demand. However, reducing the widening gap between fish demand and supply and achieving the ultimate goal of self-sufficiency in fish production has been the major concern of Fisheries and Aquaculture.

Fish culture is one form of aquaculture. Aquaculture is the rearing of fish in artificial or natural bodies of water by manipulation of the environment with the aim of increasing production beyond natural limits.Aquaculture has grown tremendously over the last few decades. This sector alone now accounts for about a third of the world's supply of fish products (and about half of its food fish supply) compared to only 4% in 1970. Fisheries and aquaculture are receiving increasing attention, not only because they represent an important source of livelihoods and food, but also because of our increasing understanding of aquatic ecosystems. Human impacts on ecosystems – in the form of invasive alien species, pollution, habitat fragmentation and changes in the flood cycle – reduce the ability of fish stocks to recover from fishing pressure. Fishery and aquacultureproduction provide direct employment and revenue to an estimated 43.5 million people; mainly fishers but also increasingly fish farmers. Detailed statistics are often not readily available, especially for small-scale fishing activities in developing countries. The general trend is that the number of jobs for fishers is stagnating and that opportunities in aquaculture have been increasing.

Despite the social and economic importance of fisheries, attempts at sustainable management have been unsuccessful in many parts of the world and a global response is urgently needed. An ecosystem approach to fisheries is called for, protecting and conserving ecosystems while providing food, income, and livelihoods from fisheries in a sustainable manner. A combination of measures has been proposed within this framework, including banning some fishing practices, setting up marine protected areas, and constraining access rights.

Nigeria is richly blessed with a vast area of perennial fresh and brackish water swamps covering a total area of 1,751,509 ha (mostly unexploited) and suitable for aquaculture. One of the advantages is that such lands relatively unsuitable for other forms of agriculture can be utilized for the culture of fish. Besides, production per unit area is reported to be higher for fish than "animal" husbandry.Fish production in natural waters is finite while production by fish farming is elastic hence the main area of great potential for enhanced fish production in Nigeria is through the culture of fish.

Fisheries resources provide an important source of protein in many countries and their use is of major importance to local communities and the indigenous people. Sustainable utilization of such resources offers increased potentials to meet nutritional, social and financial requirements particularly in developing countries. The primary purpose of this book is to provide baseline date essentials for fisheries and aquaculture.

The Course

This course Guide tells you briefly what to expect from reading this material which bothers on fisheries and aquaculture. The study of fisheries and aquaculture is of imperative importance to a nation's economy. The management and maintenance of quality captured and to a lesser extent the structure (age, size and species) of the catch within certain limits, is the challenge of fisheries management. Resources assessment and relevant data on biology of these aquatic living resources of which age and growth, food and feeding habits, artificial feeds formulation and others data for both short life-span and conventional resources will enable the control of pathological tendency towards overfishing.

The importance of fish identification cannot be overemphasized in the study of fish and for taxonomic purposes. The rudiment of basic anatomy is essential for accurately identifying fish in the field. The major species are readily identifiable through mouth orientation, finnage and coloration; all these with emphasis on external anatomical features are discussed here.

The best approach to feed formulation is to use high-quality feedstuffs to manufacture a diet that meet the nutritional and energy requirements of the aquaculture species in question. If a portion or all of the fishmeal in a diet can be replaced successfully with other high-quality protein sources, doing so will contribute greatly towards protecting the surrounding environments and promoting a sustainable aquaculture industry. Within commercial fish farming operations it is also of importance that feed producers are able to deliver a high and consistent pellet quality.

Good water quality management is a pivot upon which a successful aquaculture programme rests. Regardless of the approach to the culture system adopted,ammonia, dissolved oxygen (DO), nitrite, pH and alkalinity are major water quality parameters that should be measured on a daily basis. Poor water quality can cause massive fish kills. It is often a major factor contributing to fish disease and parasite infection. Water quality does not remain constant.

Course aim:

The aim of this course, therefore, is not only to provide the basic background information on fish but also to integrate it with recent developments in vital areas of fisheries and aquaculture.. Capture fisheries and aquaculture are linked and are both contributing immensely to the supply of food fish as a cheap source of protein in human diets and fishery products for industrial usage.

Course objectives:

Besides the aforementioned aims, this course is set to achieve some of the following objectives:

- To understand the gross and external morphology of fish (cartilaginous/bony fishes)
- To know the different functions of organs and systems of fish
- To identify the various fish culture system
- To have a basic knowledge of hatchery and pond management
- To appreciate the importance of fecundity to fish
- To explain the basics of fish feed formulation
- To highlight the importance of age and growth studies of fish
- To know the food and feeding habits of different fish
- To understand the basics of artificial propagation of fish.

Working through the Course

A great effort was put into this course thereby enriching it with a lot of useful information. This accounts for why you find it an irresistible companion both in the class and for field purposes. However, it requires that concerted effort is made in reading through these materials for appreciating the effort in a commensurable manner so you will be required to spend a lot of time to read it. You are also encouraged to work through and practice all assignments contained in this materials.

Course Materials

You will be provided with the following materials course guide and study units. In addition, the course comes with a list of recommended textbooks which though are not compulsory for you to acquire or indeed read, are necessary as supplements to the course material.

Study Unit

The study units in this course are given below:

Module 1: The gross and external morphology of bony and cartilaginous fish

Unit 1: External anatomy of a bony fish

Unit 2: Cartilaginous fish

Unit 3: Basic piscine shapes

Module 2: Basic function of Pisces organs and major systems

Unit 1: Basic organs and systems in a fish

Module 3: Food and feeding habits of fish

Unit 1: Methods of food studies of fish

Unit 2: Food organisms and feeding habits of fishes

Module 4: Age and growth of fish

Unit 1: Methods of age studies

Unit 2: Methods of growth studies

Module 5: Fecundity

Unit 1: Methods of determination

Module 6: Fish culture techniques

Unit 1: Techniques of fish culture

Module 7: Pond construction and management.

Unit 1: Pond construction

Unit Pond management

Module 8: Hatchery

Unit 1: Operating principles of hatchery

Module 9: Fish feed formulation

Unit 1: Feed formulation

Module 10: Fish breeding and hybridization techniques

Unit 1: Induced spawning in fish

Unit 2: Methods of hormones administration

Module 11: Major fish processing techniques

Unit 1: Fish preservation and processing

Unit 2: Advanced fish processing method

Module 12: Water Quality Management in Aquaculture

Unit 1: Water quality management in ponds

Textbooks and References

Peter B, Moyle &Joesh, J. Cech, Jr. (1982) Fishes An Introduction to Ichthyology Prentice Hall, Upper Saddle River 612pp.

Adiaha, A.A. &Obih Alex Ugwumba (2007) Food and feeding ecology of fishes in Nigeria. Crystal Publishers Ajah, Lagos 91pp.

Akande, G.R &Tobor,G.R. (1993). Prospect for fish smoking venture in the Middle belt area of Nigeria. NIOMR Tech. Paper, No. 95, 1-15.

Clucas, I.J. & Ward, A.R. (1996) Post-harvest fisheries development: a guide to handling, preservation, processing and quality. Catham Maritime, Kent ME4 4TB, UK 433p.

Huet, M.V. & D.E. Canfeid Jr. (1972) Textbook of fish culture. Fishing News Books. Survey, England 436pp.

Rawson,G.C. (1976). A short guide to fish preservation.FAO, Rome, Italy. 67p.

Volunteers in Technical Assistance. 1975. Village Technology Handbook. VITA, Mt. Rainier, Maryland. 387p.

Tobor, G.R. (1984) A review of the fishing industry in Nigeria and status of fish preservation method and future growth prerequisites to cope with anticipated increase in production. NIOMR Tech. Paper, No. 17 1-14.

Adebisi, A.A. (1981) Analysis of the stomach contents of the piscivorous fish of the upper Ogunriver in Nigeria. *Hydrobiologia* 79:167-177.

Fagade,S.O.(1983) The food and feeding habits of the lower River Benue(Nigeria). Bulletin de l' I.F.A.N Ser.A 45(3-4) 316-341.

Fagade,S.O. &Olaniyan, C.I.O.(1973). The food and feeding interrelationship of fishes of Lagos Lagoon. J.Fish.Biol,5:205-225.

Assessment

There are two components of assessment for this course. The Tutor Marked Assignment and the end of course examination

Tutor Marked Assignment (TMA)

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. You will be given 4 TMA's to answer. Three of these must be answered before you are allowed to sit for the end of course examination. The TMA's will be given to you by your facilitators and returned after you have done the assignment.

Final Examination and grading

This examination concludes the assessment for the course. You will be informed of the time for this examination. It may or not coincide with the university semester examination

Module 1: The gross and external morphology of bony and cartilaginous fishes.

Contents

Unit 1: External anatomy of a bony fish

Unit 2: Cartilaginous fish

Unit 3: Basic piscine shapes

Unit 4: Other piscine features

Unit 1: External anatomy of a bony fish

1.0 Introduction

2.0 Objectives

3.0 Main contents

3.1 Body shapes of fish

3.2 Body covering

3.3 Body division of fish

4.0 Conclusion

5.0 Summary

6.0 Tutor-Marked Assignment

7.0 Reference/Further Reading

1.0 Introduction

The term “fish” most precisely describes any non-tetrapod craniates (that is an animal with a skull and in most cases a backbone) that have gills throughout life and whose limbs, if any, are in the shape of fins. Unlike groupings such as birds and mammals, fish are not a single clade but a paraphyletic collection of taxa, including hagfishes, lampreys, sharks and rays, ray-finned fishes, coelacanths and lungfishes. A typical fish is ectothermic, has a streamlined body for rapid swimming, extracts oxygen from water using gills or uses an accessory breathing organ to breathe atmospheric oxygen, has two sets of paired fins, usually one of two (rarely three) dorsal fins, an anal fin, and a tail fin, has jaws, has skin that is usually covered with scales, and lays eggs.

Fish display a great variety of forms and are adapted to the environment in which they live in many ways. There are two groups of fish in the class that differs in the composition of their bones. These are the bonyfish(fish with well developed hard bones) like tilapia, catfish and the cartilaginous(fish with soft flexible fibrous bones called cartilage) fish like the shark. Fish serve as a major source of food to other living beings. Humans consume a lot of fish. Fish by-products are used in animal rations as a good protein source.

2.0 Objectives:

At the end of this unit, student should be able to

1. Know the various body shapes of fish
2. The body divisions of fish
3. The body covering and parts of fish

3.0Main Content

3.1Body shapes of fish

The shape of the body of a fish is well adapted for little resistance in water. This enables the fish to move quickly through water. The body of a fish is spindle (oval body that tapers down on both sides) shaped with the broader portion in front; and it is flattened on the sides. Although there are variations on the mentioned shape, the variations serve the individual most of the time to adapt to its immediate surroundings.

3.2 Body covering

The body cover of fish assists the animal to travel rapidly through the water. The skin develops scales. Scales reduce the resistance of the fish’s movement through water. Large numbers of mucous glandsoccur in the skin of fish. These glands secrete mucus, which makes the body smooth and allows easy movement through the water medium. Even the gill slits **(**openings of the gills**)** assist with the movement of the fish through water.

3.3 Body divisions of fish

There are a lot of variations in the shape and size of fish. Even with these variations in mind, the body of a fish can be divided into a head, trunk and tail. No definite division can be seen between these parts. The head extends to the external gill slits; the tail begins just behind the external cloacae opening.

Illustration of a fish

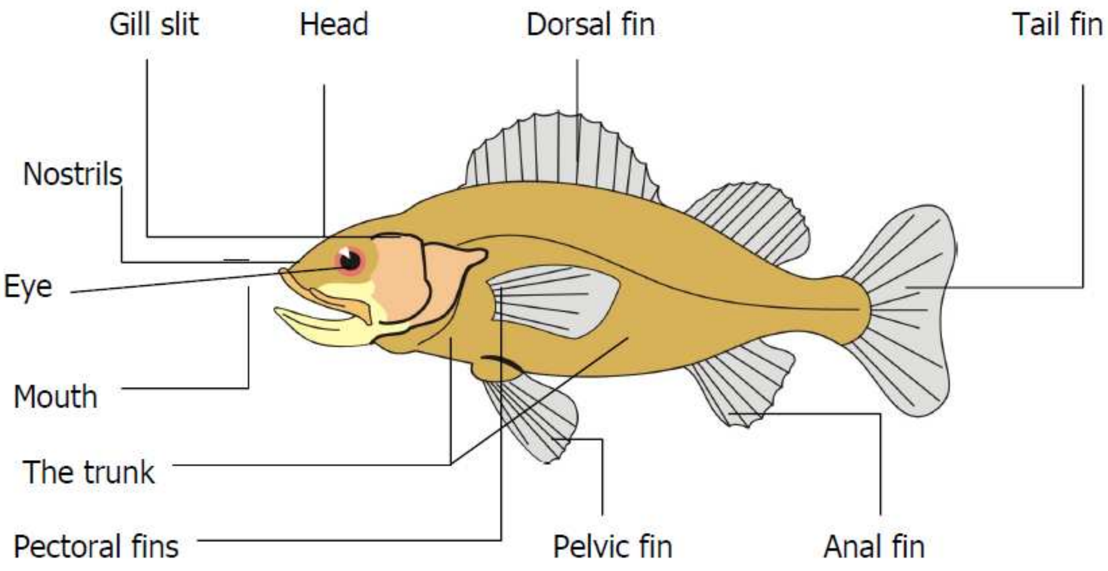


Figure 1: Illustration of a bony fish

THE HEAD

The external parts on the head are the following:

- **The mouth**

The mouth is situated on the front part of the head. Two movable lips can close the mouth.

- **The eyes**

There are two eyes without eyelids, one on each side of the head. Each eye is covered and protected by a thin transparent epidermis (thin transparent skin).

- **The nostrils**

Usually there are two external openings of the nose above the mouth. The nostrils are used for smelling. The sense of smell is well developed.

- **The gills**

Between the head and trunk are two bony gill covers, one on each side. They cover the gills and protect them. The gills are the respiratory organs of the fish.

- **The trunk**

The largest part of the body is the trunk and the following anatomical features can be distinguished.

- **The cloacae**

Both the digestive tract and the ureters (the ducts from the "kidneys") of the fish end in the cavity of the cloacae (external opening of the digestive and urinary tract). The opening is situated at the rear end on the underside of the trunk.

- **The lateral line**

The lateral (on the side) line extends on either side of the trunk of the fish. The lateral line serves as a gauge for the fish to orientate the fish according to its depth in the water.

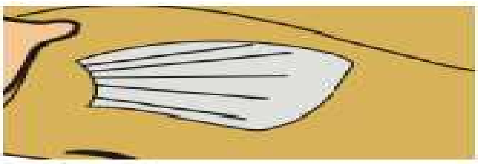
- **The fins**

The fins of a fish represent the limbs of other vertebrate animals. There are two types namely, paired and unpaired fins. The fins serve as locomotors (help the fish to swim) organs.

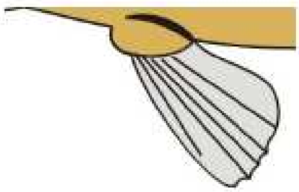
- **The paired fins**

There are two pairs of paired fins:

- **The pectoral fins**



These fins are situated just behind the external gill slits on the side of the trunk.

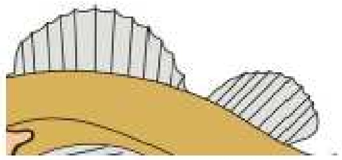


- **The pelvic fin**

They are found towards the lower surface of the trunk. Their positions vary in different species but is usually situated below the pectoral fins. The function of the paired fins is to balance the fish. They also allow the fish to steer slowly through the water

- **The dorsal fin**

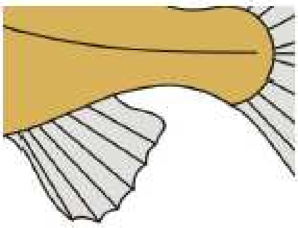
There is also an unpaired fin found on the trunk of the fish namely the dorsal fin.



This prominent fin is found on the upper surface of the trunk.

- **The anal fin**

The other unpaired fin is called the anal fin and occurs below the lateral line on the lower surface of the trunk



Both the dorsal and anal fins help to keep the body of the fish upright when it changes course in the water.

- **The tail**

The trunk narrows gradually and then widens out again into an unpaired fin that forms the tail. This enlarged tail with a big surface plays an important part in the forward and other movements of the fish.

- **Respiration**

Fish breathe by means of their gills. The gills are situated on each side of the head. Four vascular (rich in blood vessels where the blood exchanges oxygen and carbon-dioxide) gills are found in each gill chamber on each side of the head .Water passes through the open mouth to the gill chambers and surrounds the gills. Gas (oxygen and carbon dioxide) exchanges between the water and the blood-filled capillaries (small blood vessels) within the gills.The water leaves the gill chambers through the gill slits covered by the gill covers on each side of the head

- **Reproduction**

Fish are unisexual (both male and female fish exist). The female lays eggs in the water and the male releases sperm into the water over the eggs. Fertilization occurs externally, that is: outside the body of the female. (The sun heats the water and the young fish emerge from the eggs on their own.)

4.0 Conclusion

In this unit you learnt: the various parts of a fish, the coverings as well as the body division of a bony fish.

5.0 Summary

The external anatomy of a bony fish includes head (mouth, eyes, nostrils and gills), trunk, cloacae, lateral line, fins and tail, each with a specific function. Head, trunk and tail are the major body divisions of a fish; each characterized with a number of appendages.

6.0 Tutor-Marked Assignment

1.0 Characterize the body division of a fish with their appendages/structures
2.0 Make a well-labeled diagram of a bony fish.

7.0 References/Further Reading

Maddock*et al.*1994a; Vaderer,1993.

UNIT 2: CARTILAGINOUS FISH

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1.0 Introduction
2.0 Objectives
3.0 Main Contents
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6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 Introduction

The internal skeleton of this fish is made up of cartilage only. It does not contain bones. They have two dorsal fins, a caudal fin, an anal fin, and ventral fins. These fins are supported by girdles. There is no swim gland. Their skin is very rough because they are covered withdenticles.They are rough like sand paper. Hence their skin was used as sand-paper for manyyears.They have no bone marrow. So the spleen and the special tissue around the gonads produce red blood cells.Some of them have an organ called leydis's organ that produce red blood cells. The tiger shark, whale shark and the sting-ray belong to this category.The whale shark is a slow moving filter- feeding shark. They can live up to seventy years.The sharks have tiny teeth .They take the respiratory water through themouth, extract the oxygen from the water in the gills and pass it out through the gill slits.Sharks have five gill slits one spiracle, dermal teeth on the upper body surface, a tooth jaw and an upper jaw while chimeras have one gill openingon each side, tooth plates and a skull with a firmly attached upper jaw.

2.0 Objectives

2.1 At the end of this unit, the student should be able

i. to compare and contrast the anatomical different between cartilaginous and bony fishes.

3.0 Main Body

3.1 Comparison and contrast between cartilaginous and bony fish using external anatomy

You can tell a bony fish from a cartilaginous fish without looking at its skeleton. The way the fish looks on the outside gives you many clues (figures 2a and 2b).

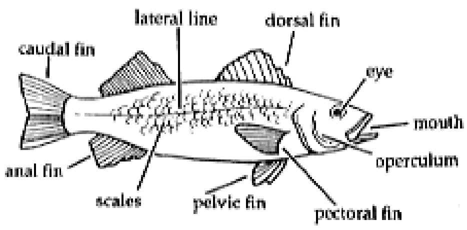

Figure 2a: Bony fish

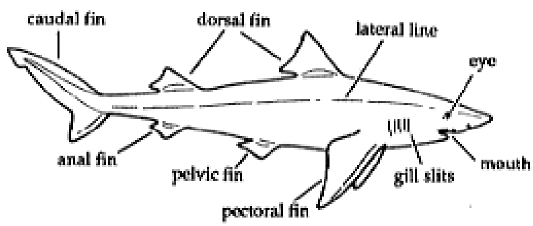

Figure 2b: Cartilaginous fish

Fish Anatomy	**Shark Anatomy**
caudal fin	caudal fin
lateral line	dorsal fin
dorsal fin	lateral line
eye	eye
mouth	mouth
operculum	gill slits

pectoral fin	pectoral fin
pelvic fin	pelvic fin
scales	anal fin
anal fin	

Scales: Most fish have scales. In sharks the scales are called dermal denticles. They are tiny tooth-like structures in the skin. They give the shark's skin a smooth appearance that feels like sandpaper. Bony fish scales are made of bone and look like the shingles on a roof.

Fins: Fins move, stabilize and sometimes protect the fish. A fish may have paired fins (pectoral and pelvic fins), and unpaired fins (anal, caudal, and dorsal fins). Some fish do not have all of these fins, and their placement shows great variability. The very flexible fins of most bony fish have visible supporting rays and spines. The skeletal supports of cartilaginous fish fins are not visible, and these fins are fairly stiff.

Gills: Oxygen enters the bloodstream at the gills. The gills are feathery structures found along the sides of the head. The gills of a healthy fish are bright red due to the large amount of blood present. In bony fish the gills are usually covered by a bony plate called an operculum. In sharks there are five to seven gill slits on the sides of the head which allow water to pass out of the gill cavity.

4.0 Conclusion

The internal skeleton of this fish is made up of cartilage only. It does not contain bones. They have two dorsal fins, a caudal fin, an anal fin, and ventral fins. These fins are supported by girdles. There is no swim gland.

5.0 Summary

There are two groups of fish in the class that differs in the composition of their bones. These are the bonyfish(fish with well-developed hard bones) like tilapia, catfish and the cartilaginous(fish with soft flexible fibrous bones called cartilage) fish like the shark. The most obvious external anatomical differences between bony and cartilaginous fish are seen in their gills, scales and fins.

6.0 **Tutor-Marked Assignments**

Outline the unique features of a cartilaginous fish

7.0 References/Further Reading

Blake,1983b; Maddock*et al.*1994a;Wooton,1990.

UNIT 3: BODY SHAPES

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1.0 Introduction

The great ecological diversity of fish is reflected in the astonishing variety of body shapes and means of locomotion they possess. Indeed, much can be learned about the ecology of a fish simply by examining its anatomical features. Equally important is that these features also form the basics of most schemes of classification and identification.

2.0 Objectives

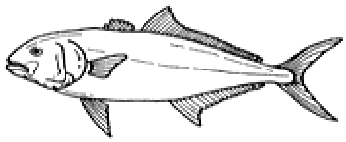
At the end of this unit, student should be able to identify the diverse body forms of fish.

3.0 Main Body

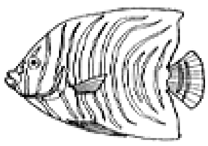
3.1 Basic Piscine Shapes

Most fishes fall into one of six broad categories based on body configuration: fusiform (rover-predator, piscivores (lie-in wait predator), surface oriented fish, depressed (bottom fish), deep bodied fish, and eel-like fish.The way a fish looks is a good indicator of how it "makes a living." Body shape, mouth location and size, tail shape and color can reveal a lot about a fish's lifestyle.

Fusiform: Fusiform, or streamlined, fish like the barracuda or jack are capable of swimming very fast. They usually live in open water. This is the body shape that comes to mind when most people think of fish: streamlined (fusiform), with a pointed head ending in a terminal mouth and a narrow caudal peduncle tipped with a forked tail. The fins are more or less evenly distributed about the body providing stability and maneuverability. Such fish typically are constantly on the move, searching out prey, which they capture through pursuit.

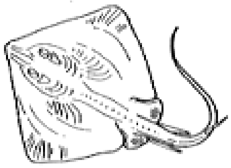


Laterally compressed: Fish that are laterally compressed (flattened from side to side or flatfish) usually do not swim rapidly (some schooling fish are an exception). However, they are exceptionally maneuverable. Many, like the angelfish, are found near coral reefs. Their shape allows them to move about in the cracks and crevices of the reef. A flounder is a laterally compressed(deep-bodied) fish that live on its side on the bottom. In these fish, the eye on the downward side migrates during development to the upward side, and the mouth often assumes a peculiar twist to enable bottom feeding. Flat fish have the most extreme morphologies of bottom fish

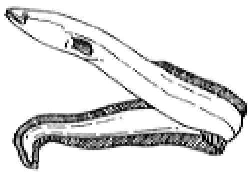


Depressed: Depressed fish (flattened from top to bottom), like stingrays, live on the bottom. Bottom fish possess a wide variety of body shapes, all of them adapted for a life in nearly continuous contact with the bottom. In most such fish, the swim bladder is reduced or absent, and most are flatten in one direction or another. Bottom fish can be divided into five overlapping types: bottom rovers, bottom clingers, bottom hiders, flat fish and rattails. Bottom rovers have a rover-predator-like body except that the head tends to be flattened, the back humped, and the pectoral fin enlarged. Many sharks with their inferior mouths, flattened head and large pectoral fins, can also be classified as bottom rovers.

Bottom clingers are usually small fish with flattened heads, large pectoral fins and structure (usually modified pelvic fins) that allow them to adhere to the bottom. Such arrangements are handy in swift streams or intertidal areas that have strong current e.g. the gobies. Bottom hiders are similar in many respects to the bottom clingers, but they lack the clinging devices and tend to have more elongated bodies and smaller heads. These forms usually live under rock or in crevices, or lie quietly on the bottom in still water. In contrast, skates and rays are flattendorsoventrally (depressiform) and mostly move about by flapping or undulating their extremely large pectoral fins. Not only is the mouth completely ventral in these fish, but their main water intakes for respiration (the spiracles) is located on top of the head.



Eel-like: They have elongated bodies, blunt or wedged shape, and tapering or rounded tails. If paired are present they are small, while the dorsal and anal fins are typically quiet long. Scales are small or embedded and even absent. In cross section, their bodies can range from compressed to round. Eel-like fish are particularly well adapted for entering small crevices and holes in reefs and rocky areas, for making their ways through beds of aquatic plants, and for burrowing into soft bottoms.

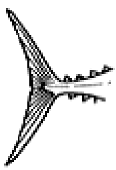


3.2 Other piscine feature

Many fish like the boxfish and porcupine fish do not fit into any of these categories. They are slow swimmers with special protective mechanisms.

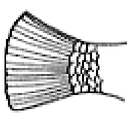
Tails

The shape of the tail can be an indicator of how fast a fish usually swims.



Crescent-shaped: Fish with crescent-shaped tails, like swordfish, are fast swimmers and constantly on the move.

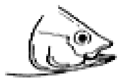
Forked: Fish with forked tails, like the striped bass, are also fast swimmers, though they may not swim fast all of the time. The deeper the fork, the faster the fish can swim.



Rounded: Fish with a rounded or flattened tail are generally slow moving, but are capable of short, accurate bursts of speed.

Mouths

The location and size of the mouth can be a good indicator of the food a fish eat and where it lives. Fish with large mouths generally eat large food items like another fish; however, the whale shark eats very small organisms which it strains from the water with its huge mouth. Fish with small mouths eat small food items: small crustaceans or molluscs; and, fish with tiny mouths eat tiny things like zooplankton



Terminal: A terminal mouth is located on the end of the head. Fish with terminal mouths may chase and capture things, like the tuna, or pick at things, like the butterfly-fish.

Up-Pointing: A fish with an up-pointing mouth has a long lower jaw. The mouth opening is toward the top of the head. The tarpon has this kind of mouth. It feeds near the surface.

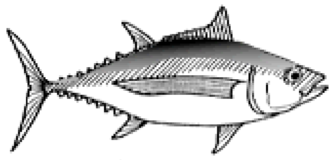
Sub-Terminal: A sub-terminal mouth is on the underside of the head. Fish with this type of mouth usually feed on the bottom. The bonefish has a sub-terminal mouth.

Some fish have **specialized** mouths. The seahorse has a tiny mouth at the end of a straw-like snout that is used to "slurp" zooplankton.

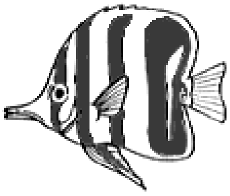
- **Colour**

Red: Red is a common color in fish. You might think that red fish would be very easy for a predator to find. However, most fish that have this coloration live in dark or deep water, or are nocturnal (active at night). In deep water red light is filtered out quickly so red is a good camouflage. At night red-colored objects appear gray. The squirrelfish has this kind of coloration.

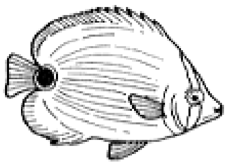
Counter-shading: Many fish are dark on top and light on the bottom. Most of these fish are found in open-ocean. When seen from above they "disappear" by blending in with the dark color of the depths or the bottom. From below the light belly blends into the sky above. The tuna is counter shaded. Seabirds like puffins are also counter-shaded.



Disruptive Coloration: This is a form of **camouflage**. The patterns and lines break up the outline of the fish or help it to blend into the background. The brightly patterned fish of coral reefs blend in with the corals despite their brilliant colors. The Moorish idol exhibits disruptive coloration.



Eye Spots: Eye spots are a form of **mimicry**. The eye spot, usually found near the tail, draws attention away from the real eye which is a target that a predator might strike. The eye spot may cause the predator to attack the wrong end and allow the fish to escape alive.



Warning Coloration: Many fish use bright colors to "advertise" the presence of poisonous spines or some other defensive mechanism. The nave surgeonfish has two bright orange spots near the base of the tail that advertise the presence of razor sharp spines.

Camouflage: Many fish have colors or patterns that match their backgrounds. The flounder is a camouflaged fish. It can even change color to match different backgrounds.

4.0 Conclusion

Although life in water puts many severe constraints on the “design” of fish, the presence of thousands of species living in wide varieties of habitats means that these constraints are pushed to their limits. This results in many very unlikely forms, such as seahorses and lumpfishes. Understanding the significance of the peculiar external anatomy of such forms practically requires study on a case-by-case basis. On the other hand, species that are more recognizably as fishlike can usually be place in some sort of functional category though the examinations of body shape, scales, fins, mouth, gill openings, sense organs and miscellaneous structures.

The great ecological diversity of fish is reflected in the astonishing variety of body shapes and means of locomotion they possess.Fish display a great variety of forms and are adapted to the environment in which they live in many ways.

5.0 Summary

The great ecological diversity of fish is reflected in the astonishing variety of body shapes and means of locomotion they possess.Fish display a great variety of forms and are adapted to the environment in which they live in many ways..Most fishes fall into one of six broad categories based on body configuration: fusiform (rover- predator, piscivores (lie-in wait predator), surface oriented fish, depressed (bottom fish), deep bodied fish, and eel-like fish, which also reflects their modes of life.

6.0 Tutor-Marked Assignment

1. Write short notes on the basic fish shapes?
2. *Most of the characteristics we recognize as fishlike are adaptations to allow the most the most efficient use of the aquatic medium by mobile vertebrate predators*- explain.

7.0 References/ Further Readings

Blake,1983b; Maddock*et al.*1994a; Vaderer,1993; Webs and Weihs, 1983

MODULE 2:BASIC FUNCTION OF PISCINE ORGANS AND MAJOR SYSTEMS IN FISH

Unit1: Organs and major systems in fish

Content

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3.1.2 Respiratory apparatus
3.1.3 Endocrine system
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3.1.5Reticuloendothelial systems
3.1.6 Cardiovascular systems
3.1.7 Urinary systems
3.1.8 Special sense organs
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

Fish have some unique anatomical and physical characteristics that are different from mammals; however, they still possess the same organ systems that are present in other animals. All fish are poikilothermic and must be able to adapt to changes in water temperature. Fish live in a variety of temperatures ranging from less than 0 C to hot geothermal springs. Yet, each species of fish

must live in its particular specific temperature range. Abrupt temperature changes in the water can be lethal to fish.
Organ systems of fish vary to some extent from that of mammals due to the aquatic environment they live in. The important differences are treated here.

2.0 Objectives:
After going through this module, learners must be able to

i. describe the nature and functions of fish organ systems such as their integument,
ii. explain the various systemsof the fish and their importance for aquatic lives.

3.0 Main Body

3.1 Basic Organs and Systems in a fish
3.1.1 Integument
Fish do not have a keratin layer over the epidermis. A cuticle composed of mucus, mucopolysaccharides, immunoglobulin’s and free fatty acids covers these animals. The epidermis is composed of a stratified squamous epithelium of variable thickness (4-20 cells thick). The outermost epidermal cells (Malpighian cell layer) retain the capacity to divide. Other cells present in the epidermis are goblet cells (responsible for secreting the cuticle), large eosinophilic club cells or alarm cells (present in most species of fish), eosinophilic granular cells (unknown function), leukocytes and macrophages. The dermis is composed of an upper stratum spongiosum and a deeper stratum compactum. Numerous melanophores, xanthophores, and iridophores (give fish their silvery color) are observed scattered throughout the dermis. Scales are calcified plates originating in the dermis and covered by the epidermis. There are two types of scales: ctenoid scales and cycloid scales. Ctenoid scales of elasmobranches have spicules extending from the external surface giving these fish rough sandpaper like texture. Cycloid scales of teleost fish have a smooth outer surface and are laid down in concentric a ring that makes them useful in determining the age of some fish. Scales also represent a source of calcium for fish; some fish will utilize the calcium in the scales in preference to the calcium in their skeleton during times of starvation or pre-spawning activity.

3.1.2 Respiratory apparatus

The gills consist of four holobranchs that form the sides of the pharynx. Each holobranch has two hemibranchs projecting from the gill arch. The hemibranch are composed of rows of long thin filament called primary lamella. The primary lamella has their surface area increased further by the secondary lamellas that are semi-lunar folds over the dorsal and ventral surface. Gas exchange takes place at the level of the secondary lamella. Epithelial cells bounded by pillar cells line the secondary lamella. A thin endothelial lined vascular channel lies between the pillar cells and is the site of gas exchange, removal of nitrogenous waste and some electrolyte exchange. The pseudo branch lies under the dorsal operculum. This organ is a gill arch with a single row of filaments. The function of the pseudo-branch is unknown, however it is believed that this structure supplies highly oxygenated blood to the optic choroid and retina and may have thermoregulation and baroreceptor functions.

3.1.3 Endocrine systems:

- **Adrenal gland**

There is no true adrenal gland present in most fish (exception is sculpins). The adrenal cortical tissue in most fish is represented by the interrenal cells. These cells are pale eosinophilic cuboidal cells associated with major blood vessels in the anterior kidney. Both glucocorticoid and mineral corticoid are secreted. The adrenal medullar cells (chromaffin cells) may vary in location. These cells are usually found with the sympathetic ganglia in clumps between the anterior kidney and spine or in the interrenal tissue.

- **Thyroid gland**

The thyroid follicles are very similar to mammalian thyroid tissue. Thyroid follicles are distributed throughout the connective tissue of the pharyngeal area and may be observed around the eye, ventral aorta, hepatic veins and anterior kidney. It is important to realize that thyroid tissue can be widely distributed. Many times pathologists have erroneously considered this distribution of normal thyroid tissue to represent metastasis from a thyroid follicular cell tumor.

- Endocrine Pancreas

The endocrine pancreas is present in most fish as islet of Langerhans and is associated with the exocrine pancreas. In some species the islets are very large and may be grossly visible (Brockman bodies). During the spawning season the size and number of islet will increase in some fish. These should not be confused with an adenoma.

-Parathyroid Glands

The parathyroid glands are absent in fish; their function is taken over by other endocrine organs. (Corpuscles of Stannius)

-Ultimobranchial Gland

This gland lies ventral to the esophagus in the transverse septum separating the heart from the abdominal cavity. This organ secretes calcitonin (lowers serum calcium levels) that acts with hypocalcin (secreted by the corpuscles of Stannius) to regulate calcium metabolism.

- Corpuscles of Stannius

These are islands of eosinophilic granular cells located in paired organs on the ventral surface of the kidney. This organ secretes a protein called hypocalcin (teleocalcin) that acts with calcitonin to regulate calcium metabolism.

-Urophysis

This is a neurosecretory organ found on the ventral aspect of the distal end of the spinal cord. These bodies are composed of unmyelinated axons terminating on a capillary wall. The function of the urophysis is unknown.

-Pineal Gland

The pineal gland is a light sensitive neuroendocrine structure that lies in the anterior brain and is a well-vascularized organ. This gland secretes melatonin that may play a role in controlling reproduction, growth, and migration.

3.1.4 Digestive system

The digestive system of fish is similar to the digestive tract of other animals. Carnivorous fish have short digestive tract when compared to herbivorous fish. The stomach and intestine contain sub- mucosal eosinophilic granular cells. The function of these cells is unknown. Some species of fish (Salmonids) have pyloric ceca, which are occasionally confused with parasites. These ceca secrete the digestive enzymes required to digest some food. Fish without the pyloric ceca have digestive enzyme production in the liver and pancreas. It is not possible to divide the intestine into large and small intestine.

The liver does not have the typical lobular architecture that is present in mammals. In many species of fish there are areas of exocrine that is present in mammals. In many species of fish there are areas of exocrine pancreas (hepatopancrease) that are present near the small vein off the hepatic portal vein. The pancreas is scattered in the mesentry, primarily near the pylorus.

3.1.5 Reticuloendothelial system

Fish do not have lymph nodes. Phagocytic cells are present in the endothelial lining of the atrium of the heart and in the gill lamella. There are no phagocytic cells (Kupffer cells) in the liver. Melanomacrophage centers are present in the liver, kidney and spleen. Melanomacrophage centers increase in number during disease or stress. The fish thymus is the central lymphoid organ. This organ is located subcutaneously in the dorsal commissure of the operculum. Fish have the ability to produce specific immunoglobulin’s (IgM only) and have both delayed and immediate hypersensitivity. Fish have the ability to produce virus neutralizing, agglutinating, and precipitating antibodies. Both B and T lymphocytes are present.

3.1.6Cardiovascular system

The heart is composed of two chambers, one ventricle and one atrium. Some authors also describe the sinus venosus as the third chamber and bulbusarteriosus as the fourth chamber. Blood flows from the heart through the ventral aorta and the afferent branchial arteries, to the gills for oxygenation. Oxygenated blood returns via the efferent arteries to the dorsal aorta. The dorsal aorta then carries the oxygenated blood to the body. Some oxygenated blood also leaves the dorsal aorta and goes to the pseudo branch to be highly oxygenated and then is sent to the retina which has a high oxygen demand.

3.1.7 Urinary system

The kidneys of fish develop from the pronephros and mesonephros. The function of the kidney is osmoregulation. In freshwater fish, the kidney saves ions and excretes water. In saltwater fish, the kidney excretes ions and conserves water. The majority of nitrogenous waste is excreted through the gills. The other function of the kidney is hematopoiesis with hematopoietic tissue located in the interstitium of the kidney. This function is primarily in the anterior kidney but can be found throughout the entire kidney.

3.1.8 **Special sense organ**

Lateral line systems
There are two types of lateral line organs. These are the superficial neuromast and the two lateral line canal organs. There are two types of superficial neuromast; these are located in pits in the epidermis located primarily on the head. Their function is not completely known but is believed to aid in movement and orientation. The second lateral line organ is the lateral line canal system that runs the entire length of the fish with continuous extensions over the head. This organ is sensitive to hydrostatic stimuli and sound.

Electricity: Some bony fish and sharks have special pores on the head that allow them to detect electrical currents. This sense aids them in navigating or finding prey in dark or muddy water.

4.0 Conclusion

The extra-ordinary diversity of fishes is related to their ability to adapt to almost every aquatic environment on Earth through their long evolutionary history. One can learn a great deal about how a fish live from simple examination of its external trait.

5.0 Summary

Fish have some unique anatomical and physical characteristics that are different from mammals; however, they still possess the same organ systems that are present in other animals.Organ systems of fish vary to some extent from that of mammals due to the aquatic environment they live in, and they include the following integument(a cuticle composed of mucus, mucopolysaccharides, immunoglobulin’s and free fatty acids. Scales are calcified plates originating in the dermis and covered by the epidermis. There are two types of scales: ctenoid scales and cycloid scales); gills for respiration, endocrines system (comprises adrenal gland, thyroid gland, parathyroid gland, endocrine pancrease, corpuscles of stannis, urophysis and pineal gland), the digestive system is similar to the digestive tract of other animals(Carnivorous fish have short digestive tract when compared to herbivorous fish; the stomach and intestine contain sub- mucosal eosinophilic granular cells. Some species of fish have pyloric ceca),reticuloendothelial system lack lymph nodules (but is able to produce virus neutralizing, agglutinating, and precipitating antibodies. Both B and T lymphocytes are present), cardiovascular system consists of a heart which has two chambers, one ventricle and one atrium, the urinary system (kidney function is osmoregulatory and hematopoiesis)and special sense organs such as lateral line, and electric organs in some species.

6.0 Tutor-marked assignment
1. *The external anatomy of fish is an evolutional adaptation to aquatic lives*: discuss using specific body parts as examples.
2 Write short notes on any 5 of fish organ-sysytems

7.0 References/ Further Readings
Eschmeyer, 1998; Greenwood et al.2000, Launder & Lieu,1983, Nelson,1994, Wooton,1990.

MODULE 3: FOOD AND FEEDING HABITS OF FISH

Unit 1 Methods of food studies of fish

Content

1.0 Introduction
2.0 Objectives
3.0 Main Body
3.1.0Methods of food studies
3.1.1 Objectives of food studies
3.1.2 Analysis of food content/somach contents
4.0 C0nclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

Food is simply referred to as any ingested material that can be digested, assimilated and utilized for energy production. Each group of living has its range of materials, which can be effectively utilized as food. For most organisms, food is the major source of energy for locomotion in search for food, escape from predators and migration for migratory species. Food is also the major source of energy for reproduction for species perpetuation, growth for elaboration of all organelles, respiration for production of energy and excretion for removal of wastes

Basic food nutrients are carbohydrates (glucose), protein (amino acids) and fats, (fatty acids and glycerol). These nutrients are required in various proportions and in combination with vitamins and minerals in the right proportions. In other words, they form a balanced diet which is essential for optimal growth of fishes.

A complete study on the food and feeding habits of a fish species would not only investigate the dietary composition, their quantity and selectivity but would also involve an examination of the functional morphology and physiology of the alimentary system as well as the fauna and flora of the environment, particularly, those that are food for fish to reveal their interrelationship with each other and the fish species

2.0 Objectives

At the end of this unit, student should know:

(i) The objectives of studying food and feeding habits of fish
(ii) Understand the various method of analyzing food of a fish
(iii) Procedure for fish studies

3.0 Main Body

3.1 Methods of food studies of fish

- **Collection of Fish**

The best collection method is the use of gears that produced unbiased samples. This makes the use of a combination of gears most appropriate. Collection is best around the feeding period of fish, firstly to remove the bias posed by differential digestion of materials and further, to avoid catching fish with mainly empty stomachs. Any method of collection used should be consistent at all times.

Sampling for fish should include all sizes, ages and sexes of the particular species. The date, time of collection, location of capture and method of collection should also be recorded.

- **Preservation of fish**

The preservation of sample must begin immediately after capture and must be consistent. Thus, 4-10% formalin or deep freezing can be used to maintain some degree of good condition and moistness of food in the stomach. This prevents decay and breakdown of food organisms. If samples are to be deep-frozen, they should be transported in ice chest to the laboratory (if facilities are not available for freezing immediately after capture). Preservation in formalin can commence immediately after capture in the field

Preparation of Fish

This involves dissection of the fish and then the stomach or/and in some cases the intestine after measuring the length and weight of the fish. The sample should be mopped dry with filter paper or clean towel (after thawing for frozen samples) before weighing. Irrespective of the part chosen (stomach or intestine), what is expected to be analyzed is last meal of the fish.

- **Examination of Stomach/ Intestine content**

The condition of the stomach should be determined visually before dissection and categorized as follows:

0/4 - empty stomach

¼ - one quarter full stomach

2/4 – half full stomach

¾ - three quarter full stomach

4/4 – full stomach

This will shed light on the commencement of feeding and feeding period of the fish. The condition of the stomach also provides information on whether the fishes are feeding properly or not. The content of stomach are emptied into a petri dish and examined. A few drops of water may be added into the dish to allow for proper separation of the items so that they can be identified. Depending on the method of analysis to be employed, the number, weight and /or volume of items are taken.

3.1.1 Objectives of food studies

The major objectives of food studies in fisheries include the following:

-Food studies reveal the status of the foraging fish species e.g. predator (piscivorous and non-piscivorous), plankton feeder, herbivore, omnivore and detritivore. These are essential when assessing food and feeding inter-relationship to provide ideas of the niches of the various species within the ecosystem.

-Food studies can be used to determine the rate of growth of fish since growth represents the food converted.

-The types and magnitude of food available can give information on seasonal life history changes in fishes.

-Information from food studies can be used during species selection in fish culture. This is particularly useful in polyculture because proper selection of fishes with different feeding habits will prevent or significantly reduce competition during culture.

-Data on the food items and their selectivity by fish are important in the selection of suitable food organisms for the culture of live foods. Live foods are known to be useful to fish especially during the early stages of development (fry/fingerlings) when the alimentary canal is not fully equipped to digest artificial or formulated feeds.

-Food studies provide information on possible pollution when such species which constitute fish food are indicators of pollution e.g. the euglenoids, Euglena and Phacus; the blue green alga, Cladophora and diatoms, Synedra, Tabellaria, and Gomphonema. All these are known to thrive in polluted water. In addition, macroinvertebrates which thrive in polluted water (hence indicating pollution) but form the food of many fishes includes, the annelid worm, Tubifex, chironomid and chaoborid insect larvae, Chironomus and Chaoborus.

Information on the biochemical composition and the energy levels of the ingested food and its absorption in the alimentary canal provides base-line data useful in artificial feed formulation for fishes during their culture. Such information can save the farmer a lot of money during feed formulation. Generally, the cost of producing adequate feed for predators is higher because they require a lot of protein in their while the feed of herbivores is cheaper since they require less protein.

3.1.2 Analysis of food/stomach contents

Food of fishes could be analyzed using the following methods:

1. Numerical method
2. Frequency of occurrence method
3. Volumetric method
4. Gravimetric method
5. Point method
6. Dominance method

- **Numerical Method**

This method involves counting the number of each food item present in the stomach of a fish and summing up this number to obtain the grand total number of all food items found in its stomach. The number of each food item is then expressed as a percentage of the grand total number of all food items. It is usually expressed as:

$$\text{Percentage number of a food item} = \frac{\text{Total number of the particular food item}}{\text{Total number of all food items}} \times 100$$

This method expresses the numerical importance of different food items. It gives the relative importance of each food items. A major demerit with this method is that, often, it over-emphasizes the importance of small-sized organisms since such organisms occurring in large numbers may not necessarily constitute the most important food items. For example, a hundred copepods may not necessarily give a predator enough satisfaction as a single prey fish or shrimp. Another demerit of this method is that, often, it may be difficult and cumbersome to count the number of small-sized organisms that occur in large numbers. A good example is counting the number of cells of phytoplankton, particularly, colonial and filamentous algae which form a significant part of the food of plankton feeder like tilapias. It also does not give the frequency with which the food items are consumed. There may also be the problem of counting broken organisms or parts of organisms.

- **Frequency of Occurrence Method**

This involves counting the number of times a particular food item occurs in the stomach and expressing this as a percentage of the total number of stomachs with food (empty stomach excluded). This is usually expressed as:

Percentage occurrence of a food item =

$$\frac{\text{Total number of stomachs with the particular food item}}{\text{Total number of stomach with food}} \times 100$$

This method presents the food spectrum of the species. Hence, the importance of the food items relative to the population of the species could probably be guessed. This method is, however, biased due to accumulation of digestion-resistant materials. This makes the apparent frequency with which they occur seemingly more than the actual frequency. Besides, it does not show the number of the different food items and does not give the bulk of the food items.

- **Volumetric Method**

This method involves measurement of the quantity of food. In this case, the volumes of the different food items are measured by water displacement, using graduated cylinder or convenient apparatus. The volume of each food item is then expressed as a percentage of the total volumes of all the food items in the stomach as follows:

$$\text{Percentage volume of a food item} = \frac{\text{Volume of the particular food item}}{\text{Total volume of all food items}} \times 100$$

This method shows the bulk of the different food items. Thus, it removes the wrong impression created by less important but numerically abundant food items. In this method, however, large voluminous food items tend to overshadow small-sized food items and their importance may be over-emphasized. Furthermore, materials resistant to digestion (e.g. chitin, cellulose) may accumulate from series of feeding and may influence the results. Errors could also be accrued from differential rates of digestion of food items.

- **Gravimetric Method**

This method is similar to volumetric method, but, the weights of food items are measured instead of volume. It is expressed as:

Percentage weight of a food item=Weight of the particular food item **x 100**

Total weight of all food items

This method has the same merits and demerits as those for the volumetric method

- **Point Method**

This method involves scoring points to different food items depending on their numbers and sizes; one large organisms being equivalent to many small organisms. All the points accumulated by each food item are summed-up and expressed as a percentage of the total number of points accumulated by all the food items as follows:

Percentage point of a food item= Number of points of the particular food item x 100

Total number of points of all food items

This method has been described as an approximate volumetric method. Others described it as numerical-volumetric hybrid applied subjectively because it is a compromise between numerical and volumetric methods. It is useful for on-the-spot analysis of food items especially in the field. It is a fast and easy method. This method is, however, subjective thereby introducing bias. Different workers may score different point to a particular food items; even an individual may be biased in allotting points. Due to its subjective nature, it is impossible to statistically analyze data from this method. Furthermore, it is impossible to compare data from different workers using this method even for the same species and from the same habitat.

- **Dominance Method**

This method involves counting the number of stomachs in which each food item occurs as the dominant food. This is then expressed as a percentage of the number of fish with food in their stomach as follows:

Percentage dominance of a food item =

Number of stomachs that the particular food item is dominant x 100

Total number of stomachs with food

The merits and demerits of this method are similar to those of frequency of occurrence method.

In summary, no matter the method applied, usually when large numbers of samples are examined, the results using different methods come out similar. However, it is advisable to apply a combination of at least two, but preferably three methods for accuracy, putting emphasis on number, occurrence and bulk of food.

4.0 Conclusion

Accordingly, food studies have been categorized into that which discerns dietary composition, competition, feeding rhythm and periodicity and that which attempt to estimate the total amount of food consumed by a population. The later is simply described as quantitative aspects of feeding. Most studies have emphasized more of qualitative rather than quantitative. Hence, the more common has always been what the fish has eaten and approximately in what proportion rather than show how much each species has eaten. Quantitative studies in food consumed are time consuming, and this is likely responsible for fewer quantitative studies on food and feeding habits of fishes.

5.0 Summary

In fisheries, the objectives of fish studies are manifold, and include to know the status of foraging species, the growth-rate of the species, and the types and magnitude of food available e.t.c. Food and feeding habits of food could be analyzed using numerical method, frequency of occurrence method, volumetric method, point method and dominance method. A combination of at least three methods taking cognizance of number, occurrence and bulk of food give the best results.

6.0 Tutor-Marked Assignment

1. 1. Identify the different methods of food studies as well as their merits and demerits
2. What are the objectives of food studies in fisheries?

7.0 References/Further Readings

Fagade, S.O. &Olaniyan, C.I.O.(1973). The food and feeding interrelationship of fishes of Lagos Lagoon.J.Fish.Biol, 5:205-225.

Ugwumba, A.A.A &Ugwumba, O.A. (2007).Food and feeding ecology of fishes in Nigeria.

UNIT 2 FOOD ORGANISMS AND FEEDING HABITS OF FISH

Content
1.0 Introduction
2.0 Objectives
3.0 Main Body

4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
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1.0 Introduction

The richness and variety of various aquatic habitats provide a wide range of possible food organisms for fishes. These originate either from within the aquatic ecosystem itself (authochthonous food sources) or from outside (allochthonous food sources).

2.0 Objectives

At the end of this unit, students should be able to understand

(i) The factors affecting feeding habits of fish
(ii) Classify the food organisms of fish

3.0 Main Body

3.1 Food organisms of fish

3.1.1 Classification of food items of fish

Based on their origin, fish food can have the following subdivisions:

A. Autochthonous food

These are food found within the aquatic community. They include the following groups:

1. **Plankton community:** Planktons are floating micro-organisms of both plants (phytoplankton) and animals (zooplankton) which do not exhibit any significant movement of their own and so they are carried by water movement. Phytoplankton includes blue-green algae, green algae, diatoms, eugleniods and dinoflagellates. Zooplankton include, some protozoans, crustaceans such as copepods, cladocerans, ostracods, larval decapods, rotifers, molluscs larvae, fish larvae and eggs

2. **Benthic community:** This is made up of organisms associated with the substratum, including various benthos, such as some protozoan, decapods crustaceans, mollusks , annelids, aquatic insect larvae, aquatic arachnids, echinoderms etc as well as decomposing organic (plant and animal) remains.

3 .**Plant community:** This is made up of higher plants mainly aquatic weeds including submerged, floating or emergent vegetation.

4 .**Neuston community:** This includes surface living insects and larvae at air/water interface.

5. **Fish community:** This includes small –sized fishes, particularly juveniles, as well as fish larvae and eggs.

6 .**Other vertebrates:** These are mainly amphibians particularly their eggs and larvae.

B. Allochthonous food

These are food from outside the aquatic habitat consisting of terrestrial organisms which include the following:

Higher plant: These are largely leaves, roots, flowers, fruits, seeds and branches of terrestrial plants growing near the water. Most of these parts drop into the water, and the fishes feed on them.

Animals: These are mainly terrestrial insects, arachnids, worms etc washed into the water from land.

Fishes make use of the available fauna and flora in their habitat as food. Based on the quantity of the various food items consumed and the frequency with which they are consumed, food items of fishes can be classified into the following groups:

1. **Main/Major or Basic food:** This is the food which the particular fish usually consume. It comprises the main part of the stomach content. For instance, phytoplankton and detritus are the major food items of adults' tilapia while that of the African pike *Hepsetusodoe is fish.*

*2. **Secondary or Supplementary food:** This food is frequently found in the stomach of the particular fish but in relatively smaller amount .This fish uses this food to augment its main food. Zooplanktons are supplementary food of adult tilapia.*

*3. **Incidental food:** This is the food that the fish rarely eats.*

4**. Obligatory food:** This is the food which the fish consumes in the absence of its basic food

3.2.1: Feeding Habits of Fish

According to their food and mode of feeding, fishes can be broadly classified as planktivores (plankton feeders), herbivores, predators, omnivores and detritivores.

1. **Planktivores or Plankton feeders**

These are fishes that feed mainly on plankton. There are two groups of planktivores: those that feed on phytoplankton are mostly are phytophagous and in the inland waters, this group is dominated mostly by tilapias. Such tilapias include*Oreochromisniloticus, Sarotherodongalilaeus and Sarotherodonmelanotheron. Other phytophagous species include mullets (Mugil and Liza species) and upside-down catfish (Synodontis species). The other group of planktivores are those that feed mainly on zooplankton and they include the glass catfish (Parailia (= Phsailia) pellcida} and silver catfish (Chrysichthysfilamentosus). The sardines (Ethmalosailisha and Pellonula species) and sardinellas species0 as well as the silversides (Aletes and Brycinus spp.) have a mixed diet of both phyto- and zooplankton.*

2. **Herbivores:** These are the fishes that feed predominantly on higher plant materials including vegetable matter. *Herbivore includes tilapia like T.zilli and T.mariae.* Another group of herbivores is composed of the grass eaters *(Distichodus spp.)*. The upside-down catfishes are also herbivore.

3. ***Predators:*** There are two groups of predators. Those that feed mainly on fish are piscivores*(such as barracuda, snake head, atlantic tarpon)* and those that feed on mainly on animals other *t*han fish(such as insects, crabs, shrimps/prawns, worms, gastropods etc) are non-piscivores e.g. *tongue sole, the silver catfish, croakers. Some predators have mixed diets. The African Lady fish, Elopslacerta*feeds mostly on fish and prawn in the brackish water and on fish and insects in the fresh water environment .Only few predatory species have bottom deposits in their diets and this is found among non-piscivorous predator.

4. **Omnivores**: These are species that feed mainly on both plant and animal materials. The mud catfish (clarias) are mainly omnivores with diets ranging from algae, vegetable matter, crustaceans, insects, mollusks and fish.

5. **Dettritivores:** These are fishes that feed mainly on detritus or organic debris. Often detritivory is an overlap with other feeding habits. For instance, all tilapias and mullets include detritus in their diet, indicative of benthic feeding habits, and are thus also detritivores. So also are the snout fishes, the grass eaters, moon fish (citharinusspp), African carb (Labeo and Barbus).

In general, the great diversity of food items encountered in the different species is an indicative of the fact that fish of fishes differ with species and also with different habitats. Wherein fishes are purely predatory in one habitat, such species have been known to include plant materials in their diets in another habitat. This justifies the assertion that when a fish is feeding, it is the most available food item that it mostly feeds on.

3.2.2 Factor Influencing Food and Feeding Habits of Fishes

1. Size: Different sizes of some fishes have different food habits. This could be as a result of competition or preference. For example, the fry of *Heterotisniloticus are planktophagous*while their adults are omnivorous. Most juveniles tilapias are omnivorous, while their adults are herbivorous/detritus feeders. Fingerlings of mud catfish, *Heterobranchusbidorsalis* are plankton feeders and they switch to a predatory feeding mainly on fish and prawn as they grow into adults

2. **Sex:** Food habits also vary with sex. Spawning female fish may change depth or location in water. This affects the food available to the fish. Some females even go without food during spawning.
3. **Season:** Seasonal distribution and abundance of preys and plankton also control the rate at which they are consumed as food. It is generally known that fishes make use of the most available items depending on season.

4. Temperature: Temperature regulates the spatial distribution of most of various fish species as well as most food items. This affects the food habits of the fishes. Fishes generally eat more and digest food faster at higher water temperatures. However, each species has its own suitable temperature range.

5. Habitats/Locality: Food habits of fishes differ with habitats and locality. The occurrence and abundance of different food items in different habitats affects the food habits of fishes therein. For instance, the major fish preys of African pike in Lekki lagoon, Lagos, Upper Ogun River and Ado-Ekiti Reservoir , Ekiti are tilapias and cyprinids (Barbus) while in River Sokoto and Epe Lagoon, Lagos, the major preys are sardines (Pellonula), silversides (Aletes and Brycinus) and juvenile African Lady fish (Elops)

6 **.Competition:** Food habits of fishes could also be influenced by competitor species. Food habits may change to avoid or minimize competition, and this diversification makes for a fair sharing of the available food items. Overlaps if feeding habits of some species in the same habitat is an attempt to reduce competition for food. There is often an overlap between planktophagous or herbivorous and deposit feed amongst many tilapias in habitats where they are found.

7. **Preference/Selectivity:** Preference for a particular food over the other (i.e. selectivity) also influences food habits. Although, different food items occur abundantly at a particular time, some fishes show preference in their selection of particular food items. For instance, tilapias actively select phytoplankton as food, while zooplanktons are passively selected.

8. **Time of Day:** The food of fish could differ with time of day; this is mainly linked to the time the food is available and when fish is feeding. Feeding could be in the day or at night. For many species, peak period of feeding corresponds to peak period of availability of their food. Peak period of feeding of the tilapias. Oreochromis and Sarotherodon inhabiting Awba Reservoir in Ibadan, is from 1300-1500hrs. This is likely due to high primary productivity during this period; hence increase in abundance of phytoplankton, a major food of these species.

9. **Shape and Nature of the Feeding Apparatus/Gut:** The shape of the mouth, teeth, stomach and intestines the food and feeding habits of the fishes to a large extent. For example, predatory fishes e.g. Nile perch *(Latesniloticus)* African pike *(Hepsetusodoe)* *and barracuda (Spyraena)* have large protusible mouth armed with powerful teeth to capture or seize large prey such as fish which form the bulk of their food. Their stomachs are larger and their intestines short. Herbivorous and phytophagous fishes, such as tilapias lack powerful teeth. Their teeth are small and they are arranged in many rows on the upper and lower pharyngeal bones, to form grinding surfaces used to crush the hard wall of their plant food. Their intestines are long typical of herbivorous species. Other phytophagous species like mullets (*Mugil and Liza sp.)* have their stomach modified to form a gizzard used to crush the food. Similarly, benthophagous/omnivorous species like the African bony-tongue, *Heterotisniloticus*has a gizzard stomach for crushing the shells and exoskeletons of bivalves, snails and insects as well as the walls of higher plant materials, which constitute significant parts of its food.

4.0 Conclusion

Like all organisms, fishes require an energy source to fuel their body machinery and processes, including growth, metabolism, and reproduction. Different fishes have evolved feeding structure and mechanisms that allow them to exploit a vast array of plant and animal food sources, ranging from the indiscriminate filtering of a large ram-feeding planktivore to the precision biting of a manipulating carnivore. Similarly fish guts incorporate numerous adaptations for the efficient breakdown and absorption of essential nutrients, including appropriate enzymes and absorptive surface areas. Finally, nitrogenous wastes must be excreted, principally as ammonia (or urea in strongly alkaline environments).

5.0 Summary

A complete study on the food and feeding habits of a fish species would not only investigate the dietary composition, their quantity and selectivity but would also involve an examination of the functional morphology and physiology of the alimentary system as well as the fauna and flora of the environment, particularly, those that are food for fish to reveal their interrelationship with each other and the fish speciesFish Food, based on their origin, could be authochthonous and allochthonous; and the feeding habits of fish could be planktivorous, herbivorous, predatory, omnivore and detrivores. Size, sex, season, temperature, habitat/locality, competition. Preference/selectivity time of the day and the shape/nature of feeding apparatus/gut are some of the factors influencing food and feeding habits of fishes.

6.0 Tutor-Mark Assignment

Write a short note on the factors affecting food and feeding habits of fishes?

7.0 References/ Further Readings

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MODULE 4: AGE AND GROWTH DETERMINATION

Unit 1 Methods of age and growth studies

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1.0 Introduction

Fish age and growth are critical correlates with which to evaluate many other biological (and pathological) processes, such as productivity, yield per recruit, prey availability, habitat suitability and even feeding kinematics.While age and growth are always used together in phraseology, it is important to remember that each term has its own distinct meaning, which was eloquently stated by DeVries and Frie (1996):

"Age refers to some quantitative description of the length of time that an organism has lived, whereas growth is the change in body or body part size between two points in time, and growth rate is a measure of change in some metric of fish size as a function of time."

2.0 Objectives:

At the end of this unit students should be able to

i. explain the important of age and growth studies in terms of
   (i) significant (ii) methods of studies and (iii) validation techniques.

3.0 Main Body

3.1.1 ***Significant of Age and Growth Studies***

- *To obtain information on stock composition.*
- *To know the age and maturity of a fish.*
- *To know the life span of a fish.*
- *To gather information relating growth and reproduction.*
- *To know mortality and production rate.*
- *For rationale fish exploitation and proper fisheries management.*

3.1. 2: Methods of age studies.

Steps Involved in Age and Growth Studies

1. *Collect a random sample of fish and this should include representative of all sizes and age of fish species present in the population.*
2. *For each species, record the date of collection, habitat and method of collection.*
3. *Measure the length and weight of each species, dissect, and determine the sex and stages of gonad development.*
4. *Collection from each the structures that will be used for age determination.*
5. *Determine the age of each specimen using more than one method of age.*
6. *Calculate growth for each sex separately and for combined sexes if the calculation for individual method is significant different using chi-square. If the different are significant both sexes can be combined.*
7. *Determine length-weight relationship for each sex separately and for combined sexes.*
8. *Calculate the condition factor according to age, size, sex and season.*

Precise and accurate age information is the key to obtaining quality estimates of growth and other vital rates such as natural mortality and longevity, and is essential for successful fisheries management. The effect of inaccurate age determinations on population dynamics studies can lead to serious errors in stock assessment resulting in overexploitation.
The determination of fish age and growth is fundamental in fisheries biology and management. Such age-determined parameters as mortality and growth underlie the population dynamics models used in fishery analyses. Age studies can furnish other basic data such as stock age structure, age at first maturity, spawning frequency, individual and stock responses to changes in the habitat, recruitment success, etc. Age and growth data also permit the determination of population changes due to fishing rates.

Although numerous methods have been used to age fish, three general methods predominate:

- **Anatomical method:** It is possible to determine the age of fish by evaluation of growth rings forming bony structures such as scales, otoliths, the opercular bone, the vertebrae and the cross section of dorsal or pectoral fin rays. Ages of fish are estimated by comparison of the readings from various bony structures and different readers Furthermore, ageing errors must be considered before deciding on the most reliable bony structure for ageing fish . Two important considerations when selecting a structure for aging a sample of fish are whether the structure yields accurate estimates of fish age and whether the structure can be obtained without killing the specimens. Other researchers have used radiochemistry as an alternative to physically age fish by measuring radioactive decay of elements present in the bony structures, with often quite conflicting results.

- **Length-frequency analysis:** It determines age by plotting length-frequency distributions(also known as the Petersen Method) from the population to reveal peaks assumed to represent average lengths for each separate age class. If the populations of fish that are characterized by regular influences of new recruits are adequately sampled, they usually reveal a size structure featuring a train of length-frequency polygons especially in the first year(s) of life, which indicates the presence of several age groups. This method requires individual lengths of large number of fish population and little overlap in the sizes of fish in adjacent age groups and is best used for fish that are fast growing with short spawning periods and short life spans. Using length-frequency data to age fish is relatively simple and inexpensive, however, the life history traits (fast growth and short spawning seasons) needed for accurate analysis are not typical of many species, for example, tropical reef fishes such as snappers and groupers.This method involves monitoring the progression through time of the identifiable modes in size classes.It cannot be used to determine the age of an individual fish.

- **Direct estimate:** This is achieved through direct measurements of growth rate of specific specimens extrapolated to the stock as a whole. Marking and subsequent recapture of fish, or monitoring the growth of captive fish of known age are two direct estimation methods. Mark/recapture approaches have been used to estimate growth, movement, and population size for many fishes. Fish are marked externally by fin clipping or through the attachment of a visible tag. Internal tags can be used as well. Assumptions are made with any tagging study that tags will not cause changes in growth, feeding, reproduction, movement, or survival of the fish and that all tags will remain attached to the fish. Directly observing growth of laboratory reared fishes can also be used to assign growth rates to fish of known ages. Although accurate, these two methods of observing growth can become expensive, time consuming, and labor intensive, especially with fish that are extremely sensitive to changes in habitat. They are the most accurate method of age determination under natural condition.

Reliable age estimates, however, are difficult to obtain for species found in tropical regions; tropical systems are characterized by species with fast growth, high productivity and high turn-over, that is, short lives.In seasonal tropical climate, the patterns of marks on hard part of fish may be difficult to interpret and unreliable for age determination. Besides, many tropical fishes are known to have annual peaks in spawning activities which are reflected in other length-frequency distribution.

3.1.3: Definition and Designation of Age

'Age-group' refers to age in years, while 'year-class' refers to the fish produced in a given year. There is yet to be a complete agreement on age designation or terminologies. The age of a fish is usually designated by reference to the annual marks on its hard structure such as otoliths and to some extent the season of the year, rather according to its exact length of life (which is not precisely known). A fish in its first growing season belong to the age-group 0, and its successive stages may be called a larval (fry or sac-fry) and fingerlings (young -of -the –year or under yearling). A fish in its second growing season is said to be a member of the age-group 1 and maybe called a yearling. In the third growing season the fish is age 2 and is called a 2-year-old and so on.

A yearling will typically have one annual mark on its hard structure. However, in some species, the time when the annual marks appear may vary for as much as two or three months.

The use of scales to age fish

Scales of fishes are remarkable structures. Much information can be obtained about the growthhistory and longevity of individual fish by close examination of their scales or other bony structures.On the population level, also, age and growth is an excellent index to well being.

Scales are bony structures that grow shingle-like from pockets within the skin. Scales are coveredwith a very thin, outer layer of skin called the epidermis. Among fishes there are basicallytwo kinds of scales: the ctenoid scale found on spiny-rayed fishes such as bass, sunfish, perch, and the cycloid scale found on soft-rayed fishes such as trout, suckers.

The ctenoid scale has small, sharp projections (ctenii) which give a rough texture tospiny-rayed fish. The cycloid scale lacks ctenii; thus soft-rayed fish tend to be smooth textured.

Scales start to form when a fish is about an inch long. The number of scales covering the bodyremains constant throughout life, and in general, scale growth is proportional to fish growth. As thescale grows, circuli (ridges) form on the edge. Circuli form a concentric pattern over the course of ayear that is related to environmental and growth conditions. During the colder months, when fish eatlittle and growth ceases, the circuli are crowded together and may be incomplete. Annuli (true year marks) arecharacterized by crowded ridges and consistent "cutting across" at both sides of the scale

Unusual events may cause false annuli to form on scales. Examples are extreme water temperatures,injury, or any other stress that causes growth to stop for a period of time during the normal growingseason. False annuli may be very similar in appearance to true annuli, but often "cut across" on onlyone side of the scale or are not evident on all scales from a particular fish.

Old fish are often under-aged from scales. As a fish becomes older, growth rate slows down and annuli become closer together. The result is that it is difficult (sometimes impossible) to recognizethe most recent annuli on very old fish scales.

Some fish (such catfish) have no scales, and other species (such as bowfin) have norecognizable pattern on their scales. For those fish, a cross-section of a spine or a vertebra should beexamined for age rings similar to rings on trees. Ear bones (otoliths), spines, and vertebrae are alsomore reliable than scales for aging, perch, bass, sucker, pikes, salmon.

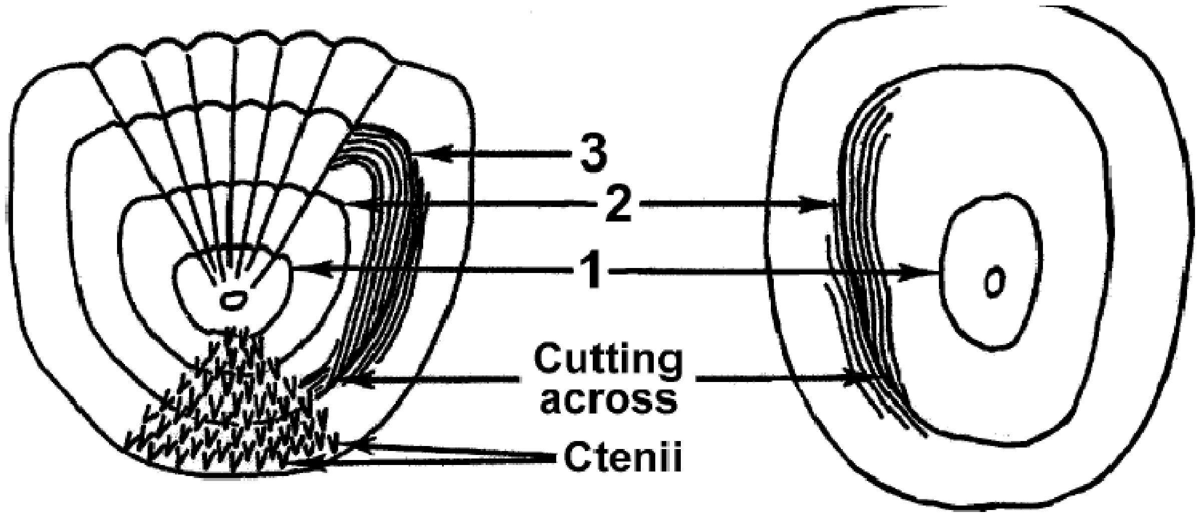

Figure 3 Ctenoid scale of bluegill (left) and cycloid scale of sucker (right). Annuli are indicated by numerals.

- **Procedures**

Recording data on scale envelopes

Record accurate and complete information on the scale envelope.Give the following information:
Species–Give common name of fish.
Locality–Give the name of the lake or stream from which fish was taken.
County–The name of the county in which lake or stream is located.
T. R. Sec–Give the Township, Range, and Section in which body of water is located. This isespeciallyneeded when two lakes with the same name occur in the same county.
Date–Date when fish was collected.
Length–Total length is defined as a straight-line measurement (not over the curve of the body)from the tip of the snout (with mouth closed) to the end of the caudal fin with the lobessqueezed together.
Weight–Total weight, accurately measured under good conditions.
Sex–Determine and record the sex when possible.
State of organs–This refers to sex organs. Record here whether the fish is immature or mature; and if mature, whether ripe or spent.
Gear–Record the method used in capturing the fish, such as gill net, trap net, seine, or angling.
Collector–Name of person who caught the fish.

Taking the scale sample

Age determination is easier if care is used when taking the scale sample. Scale samples should betaken froma definite area on the fish. The recommended location on spiny-rayed fishes is justbelow the lateral line and below the middle of the spiny dorsal fin. For most soft-rayedfishes the area between the lateral line and the dorsal fin is preferred; for trout the best spot isdirectly below the lateral line beneath the posterior end of the dorsal fin

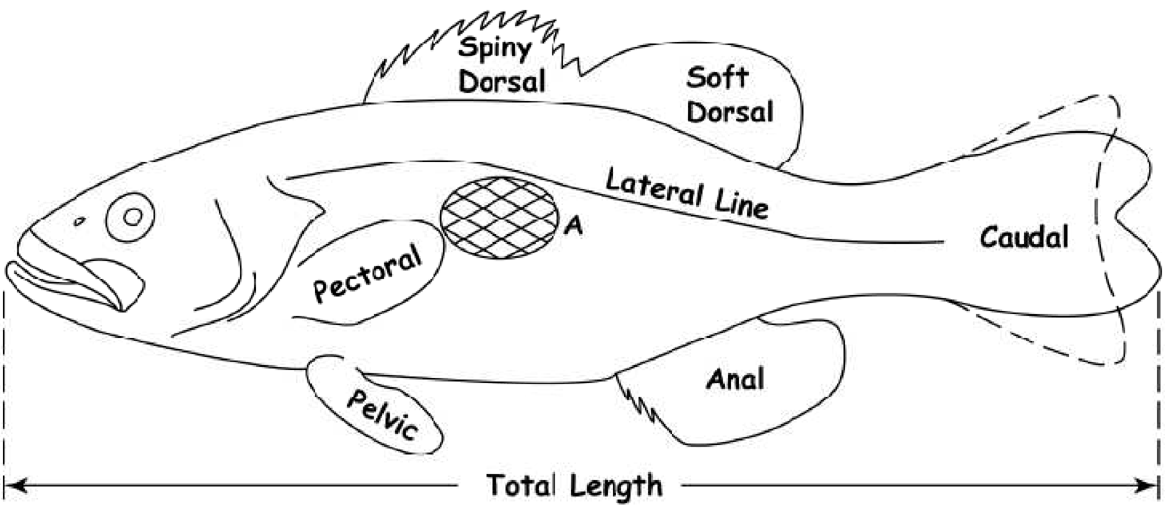

Figure4. Area for taking scale samples from a spiny-rayed fish.

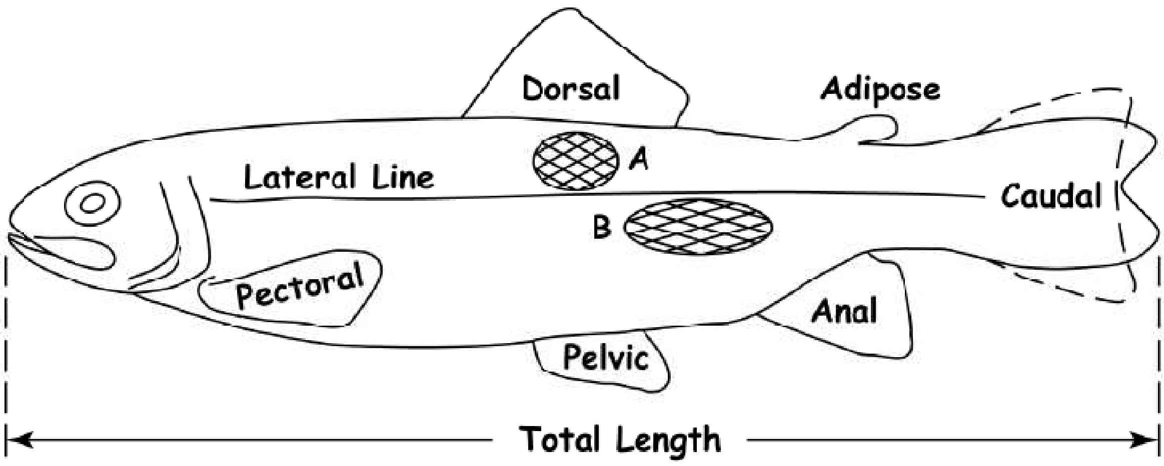

Figure 5.Areas for taking scale samples from most soft-rayed fish (A) or trout (B).

Making age determinations

To prepare scales for age determination, place four to six scales on a slide of clear plastic (vinylor cellulose acetate, 0.5 mm thick) with sculptured side (side with ridges) down. Then, sandwichthe slide with the scales between two more pieces of plastic and run through a roller press, usingenough pressure to make a distinct impression of the scales on the plastic slide. Store the plasticslide with the scale impressions in the scale envelope from which the scales were taken. Only

complete and normal scales can be used for age determinations. Abnormal or regenerated scalesare often found on fish. When a fish loses a scale, it grows a replacement lacking circuli andannuli in the center. Consequently, the early part of the growth history is lost.

To make age determinations (i.e., to "read" the scale), the plastic impression is viewed through a

Micro-projector or microfiche reader that magnifies the impression up to 90 times, as needed. Abinocular microscope provides suitable magnification for counting year marks, but if the scalesare to be measured, as is done in "back calculation", a micro-projector is needed.

Back calculation

The back-calculation technique is useful for determining more precisely a fish's growth duringeach year of life prior to the sampling date. The results might reveal, for example, that a fishwhich is of average size for its age now, grew fast in certain earlier years and slow in other years.The technique is especially useful if no growth samples were taken prior to a managementactivity or if only a few fish were sampled afterwards.

There are problems to be considered, however. Back-calculated lengths at age 1 and age 2 areimprecise if small fish were not sampled adequately. Generally, it is not wise to extrapolate the fishlength vs. scale radius relationship beyond the sizes actually sampled. Another problem is "Lee'sphenomenon". This is the tendency for the computed lengths of the older fish in their early years oflife to be systematically lower than those of younger fish at the same age. That is, it *appears* thatthe slower-growing fish live the longest. This error can be minimized by sampling a wide range offish sizes.

The procedure for back calculation is as follows:

1. Obtain scale samples from the same area of each fish. Ideally, use key scales (identical area)becausethey havethe same shape.
2. While projecting the scale and counting annuli, measure with a ruler the radius of the scaleand the distance to each annulus. Select a standard axis for measuring along (such as the axisfrom the focus to the middle of the anterior field) and use the same magnification for allsamples in the collection.
3. Compute the relationship between fish length (L) and scale radius (S). This linear equationwill usually give a satisfactory fit:

$L= a+bS$

4. Compute the length at each annulus (Ln) from the distance from the focus to that annulus (Sn).The process may be automated by projecting the scale image onto a digitizing pad or videomonitor linked to a computer and "marking" each annulus with an electronic mouse or stylus.

Available software will then perform all the computations.

The intercept (a), also called the correction factor, is a very important parameter that is difficulttoestimate. It may be thought of as the length at which scales begin to form, but in a practical veinit just helps make the data fit mathematically. The intercept should be determined for eachspecies and each population.

Age determination from the Otoliths

The otoliths (ear stones) are calcium carbonates materials, which are found in the brain cavity of fish and function as balancing organs. The use of otoliths is very important especially in fish, which are entirely scale less. However, it is also paramount to note that age determination from otoliths can be disadvantageous, where valuable sport or commercial fish are concerned, because the fish have to be killed.

In the determination of age of fish from the otoliths, it is necessary to establish the following:

- A recognizable pattern of rings or markings which can be visible in the otoliths by viewing directly in ordinary light of after some methods of preparation or staining

- A regular time scale can be allocated to the visible pattern, this time scale is not necessary annual, although it is usually so, particularly in temperate regions. This is the essential part for validating the otoliths for age determination.
- The otoliths have two distinguishable ring patterns: opaque and hyaline zones. The opaque zone is associated with period of fast growth while the hyaline zone is associated with period of slow growth.

Techniques for collection and preserving theotoliths

To obtain the otoliths, a dissection of the head is necessary. The otoliths are collected from under the brain tissue. After collection, they are either processed or viewed fresh or are preserved for later processing or viewing. The otoliths can be preserved dry inpaper envelopes or suitable vial after been rubbed between the fingers to remove mucus and adhering tissue. The use of formalin to preserve otoliths is prohibited. It is impossible to determine age from bones of rotten fish or fish which have lain in formalin because such bones usually become discolored and decalcified.
Sometimes the otoliths may be rinsed in water and etched in 0.1% Hcl for about 5 minutes, follow by dehydration in alcohol.

Examination and Interpretation of Growth Marks on Otoliths

There are several ways to examine and interpret otoliths from many fishes:

- Otolths from many fishes especially fresh water fishes can be examined adequately without modifications. Such otoliths is placed in water in a black dish and illuminated at an angle from above. Against this background, the opaque zone appears as white rings while the hyaline zone appears as dark rings. To enhance the appearance of the growth rings the otoliths can be examined in oil such as glycerine, cedar or cresol.
- If the otolith is thin, it can be examined directly without a dark background. Light is shone through the otolith as it is examined. Opaque zone appears as dark rings while the hyaline zone appears as white or dark rings, because the colors of these two zones are interchangeable depending on how it is illuminated, the term opaque and hyaline zones have to be used.
- If the otolithsis old and compact, one surface can be graded first to make the growthmark more visible. Alternatively the otoliths can be broken into two between the thumbs but the cut surface must pass through the nucleus of the otoliths. Then, the cut surface is then grinded flat. Grinding of otoliths is done with wet carborundum powder on a glass tile or a grinding stone (electrically or mechanically operated). After grinding the otolith is examined under the microscope, the opaque zone appears as dark rings while the hyaline zone appears white.
- Burnt otoliths technique: the otoliths of some fish species are clearer when burnt on a low flame spirit. This is applied under gauze on which the otolithsis placed. The wholeotoliths or burnt surface after grinding.
- Scanning for Photoelectric Measurement: The otoliths is scanned and the transparency of the two zones are recorded automatically on a recorder and the annuli become visible peaks on a slide.

Bones Method

Opercula, vertebrae, fin-rays and spines are the most frequently used. Except for the fin-raysand spines, collection of bones involvessacrificing the fish. Fish is dissected and the appropriate bone removed, clean of flesh and fats and store dry in a dry paper envelope. The growth marks are best examined under a projecting microscope; the opaque zones are broad and white whilethe hyaline zone is narrow and dark.

Validation of Ageing Techniques

Since attempts at ageing of fish began, there has been a need to validate whether the growth increments seen are in fact annual in nature or follow some other cycle. Most validation studies have involved injection of tagged fish with a chemical dye (typically oxytetracycline) that then penetrates the bony structures of the fish shortly after injection. These fishes are then released and if recaptured at a later date, the time period between when the chemical mark was laid down and the edge of the bony structure is known. When the bony structures from the fish are sectioned and viewed using ultraviolet light the chemically induced band fluoresces.(Cappo*et al.,2000).*The process of estimating fish age incorporates a procedural error associated with the structurebeing examined and an interpretational error due to the element of subjectivity inherentin all age estimations (Campanas, 2001). For this reason, methods of age validation and estimation of aging precision have been developed. A variety of methods exist through which age interpretations can be validated. The methods described in table 1(Campana, 2001) are the best available for insuring ageing accuracy.

Table 1: Features, advantages and disadvantages of methods used to confirm the accuracy of age interpretations. Methods are listed in descending order of scientific value. Growth structure refers to either annulus (A) or daily growth increment (D), depending on application. Methods for age corroboration (such as length frequency analysis and tag-recapture analysis) are not shown here, but are described in detail in Campana (2001).

Age Validation								
Method	Annual /daily	Applicable age range	Advantages	Limitations	Precision	Sample size required	Time required	Cost
Release of known-age and marked fish into wild	AD	all	validates both absolute age and periodicity of growth structures well suited to fishes with a longevity of < 10 yr	requires source of known-age and marked fish number of recaptures of old fish can be low or nonexistent	± 0 yr	> 1	> 1-10 yr	minimal if fish source is available
Bomb radiocarbon	A	all	validates both absolute age and periodicity of growth structures well suited to long-lived fishes does not require recently-collected samples	at least some of fish in sample must have been hatched before 1965	± 1-3 yr	20-30	< 1 yr	$700-$1000 per otoliths
Mark-recapture of chemically-tagged wild fish	AD	all	validates periodicity of post-tagging growth structures in fish of any age	number of recaptures of fish at liberty more than 1 yr can be low or non-existent identification of a single post-mark annulus can be problematic	± 1 yr	> 1	> 1-10 yr	minimal excluding cost of tagging cruise

Radiochemical dating	A	5+ yr	validates absolute age can be applied to any recently-collected samples well suited to long-lived fishes	can only distinguish between widely divergent age estimates	±25-50%	10-50	< 1 yr	~$1000 per age category
Progression of discrete length modes sampled for age structures	AD	0-5 yr	well suited for validating the first 1-2 age classes	length mode must not overlap that of adjacent mode assumes no size-selective immigration or emigration into the sampling area	± 0 yr	> 100	1 yr	minimal other than fish collection
Capture of wild fish with natural, date-specific markers	AD	all	validates periodicity of growth increments and sometimes absolute age	natural, date-specific markers are very rare	± 0 yr	> 1	> 1 yr	Minimal
Marginal increment analysis	A	all	validates periodicity of growth increments	only suited to fast-growing and/or young fish requires samples from throughout year	± 1 yr	> 100	1 yr	minimal other than fish collection

Captive rearing from hatch	AD	all	validates both absolute age and periodicity of growth structures	otoliths increments in reared fish seldom resemble those of wild fish	± 0 yr	> 1	1-10 yr	Minimal
Captive rearing of chemically-tagged fish	AD	all	validates periodicity of growth increments particularly easy for daily increments	otoliths increments in reared fish seldom resemble those of wild fish	± 0 yr	> 1	1-10 yr	Minimal

4.0 Conclusion

The most commonly used method for age determination is examination of markings which appears on the hard parts of fishes, These markings may be annual of formed during period of alternate fast and slow growth, usually caused by environmental, physiological and nutrition fluctuations

5.0 Summary

Fish age and growth are critical correlates with which to evaluate many other biological; their studies provide information on stock composition, age at maturity of a fish, life span, mortality and production rate e.t.c. Direct estimate, anatomical method and length-frequency distribution methods are the basic methods of age determination; these are validatedto know whether the growth increments seen are in fact annual in nature or follow some other cycle.

6.0 Tutor-Marked Assignment

1. Justify the important of age determination from hard structures
2. Account for age determination from (a) otoliths (b) scale) and their validation method.

7.0 References/Further Readings

Schltz, 1998; Holden and Raitt, 1974; Bagenal and Tesch,1978. Sparre*et al.,1989)*

UNIT 2: DEFINITION AND FORMS OF GROWTH

Content

1.0 Introduction
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3.0 Main Body
3.1 Forms of growth
3.2 Methods of studying growth
4.0 Conclusion
5.0 Summary
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7.0 References/Further Readings

1.0 Introduction

The growth of a fish results from the consumption of food, its assimilation and the construction from it of the organism's body. The growth process is specific for each species of fish, as for any other organisms. The knowledge of ageing fish has made it possible to estimate the rate of growth. A study of growth in fish offers system ecologists many opportunities to enquire into the dynamic balance and states of change in aquatic ecosystem. However, growth is influenced by food, space, temperature and other factors. Furthermore, since fish are poikilothermic and live permanently immersed in water, they are very affected by changes in their ambient medium.

2.0 Objectives

At the end of this unit, students should be able to

(i) Identify the form of growth
(ii) Explain the various method of studying growth

3.0 Main Body

3.1 Forms of growth

There are some important forms in which the growth of fish is estimated:

Growth in length – this estimate growth rate of individual fish called the True Growth Rates. Growth in length quit never cease.

Growth in weight – fishermen are usually interested in the weight of fish catch not the numbers. And indeed the value of a catch of a given weight often increases when the average size of the fish in the catch is greater i.e. when there are fewer individuals. The growth in weight is an important aspect of growth of fish.

Population growth – Population growth refers to change in the number of fish observed at different times of a particular fishery.

3.2 Method of Studying Growth

Though, once the age of a fish has been determined, the study of growth will appear superficially simple. In practice, there are numerous difficulties encountered. Fish growth may, therefore, be keenly studied by the following methods:

Experiments in Rearing and Holding Device
Fish of known age or size, which are placed in ponds or tanks, can easily be recaptured at a later date. Otoliths, scales and other structures can be examined for the number of marks tobe expected.

Tagging and Marking Method
When fish are tagged or marked with a numbered tag of metal or plastic or injected with tetracycline which produces a mark in the structure of the otoliths. At recapture, the number of supposed age marks on the otoliths should coincide with either the known age or with the number of years the fish has been at liberty.

Age-Length Data
The age of each fish in a random sample, caught with a gear with the least bias, and used to sample the habitat thoroughly, is determined. Then the mean length, with confidence limits, is calculated for each age group.

From Petersen's Method of Age Determination
The modal length of each age group obtained from the size frequency method, as apply to age determination.

By Cohort Analysis
Modal length of a particular age group (usually of a specially strong year class) are estimated at yearly intervals with this method, and size frequency analysis, the growth rate can be indicated without actually knowing the age of the fish.

4.0 Conclusion
Most fish continue to grow throughout their lives. Consequently, age and growth have been one of the most intensively studied aspects of fish biology because they are good indicator of the health of individuals and populations. Rapid growth indicates abundant food and other favourable conditions, whereas slow growth is likely to indicate just the opposite. Important influences of diet and environmental and social factors work via hormone-mediated mechanisms to regulate fish growth. Age and growth studies in fishes have become a well –studied integrator of fish well being in aquatic habitats and an important measure of production success to the fish culturists.

5.0 Summary
Fish age and growth are critical correlates with which to evaluate many other biological; their studies provide information on stock composition, age at maturity of a fish, life span, mortality and production rate e.t.c. Direct estimate, anatomical method and length-frequency distribution methods are the basic methods of age determination; these are validatedto know whether the growth increments seen are in fact annual in nature or follow some other cycle. Cohort analysis, capture & recapture method, age-length data and Petersen method are the principal of measuring growth. There are different forms of growth: growth in- length, growth in-weigth and growth in-population.

6.0 Tutor-Marked Assignments

1. Differentiate between age and growth and their methods of studies

7.0 References

AOAC (1995) Official method of analysis of AOAC International, 26[th]edn, P. Cunif (ed), AOAC International Arlington, Virginia, USA.
Bagenal, T.B.(1978). Age and growth.In methods and assessment of fish production in fresh water, pp101-136.(Ed. Timothy Bagebal), Blackwell Scientific Publication, Oxford. 365pp.
Campana,2001; DeVries and Frie (1996).

MODULE 5: FECUNDITY

Unit 1 Methods of Fecundity determination

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2.0 Objectives
3.0 Main Body
4.0 C0nclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

The knowledge of fish fecundity is needed in establishing its production potential andconsequently its exploitation and management rationale. It is imperative to understand andappreciate the diverse shades of meaning of this term.Fecundity, derived from the word '*fecund'*generally refers to the ability to reproduce. In demography, fecundity is the *potential* reproductive capacity of an individual or population. In biology the definition is more equivalent to fertility or the *actual* reproductive rate of an organism or population, measured by the number of gametes(eggs), seed set or asexual propagules. This difference is due to the fact that demography considers human fecundity which is often intentionally limited, while biology assumes that organisms do not limit fertility. Fecundity is under both genetic and environmental control, and is the major measure of fitness. *Fecundation* is another term for fertilization. *Super fecundity* refers to an organism's ability to store another organism's sperm (after copulation) and fertilize its own eggs from that store after a period of time, essentially making it appear as though fertilization occurred without sperm (i.e. parthenogenesis).

2.0 Objectives:

At the end of this unit, students should be able to
- (i) highlight the important of fecundity
- (ii) Identify thedifferent methods of determination of fecundity.

3.0 Main Body

3.1 Fecundity defined

The number of eggs produced per female has been variously defined in fisheries literature and different fecundity terms have been used in relation to the reproductive strategy of the fish and oocyte recruitment or stages. In most studies, fecundity usually refers to potential annual fecundity, which represents the total number of advanced yolked oocytes matured per female and year, uncorrected for atretic losses. Nikolsky viewed fecundity of fish from two aspects; individual or absolute fecundity, that is, the numbers of eggs from the generation of that year and relative fecundity which refer to the number of eggs per unit body weight. Bagenal defined fecundity as the number of ripening eggs in female prior to the next spawning season. Hansson defined fecundity as an ability of an organism to produce viable reproductive units. In general, fecundity is one of the important aspects of life history of a species. It has been used in fish stock assessment studies in egg and larval survival studies, estimate of size of a stock and for stock discrimination.

The advantages of high fecundity cannot be overemphasized since the survival and continued existence of the species depend on numbers of eggs hatched. High fecundity is also a desirable quality in aquaculture as it ensures regular (when reproduction can be obtained all-year round) and adequate supply of fingerlings for stocking culture enclosures. Knowledge of the fecundity of a fish is necessary in establishing its production potential and consequently its sexploitation and management rationale

Fish species with large eggs comparatively have a low egg production than fishes with small eggs. As a rule, fecundity of a fish is inversely related to the degree of parental care it exhibits. Low fecundity is associated with parental care during the developing stages of the embryo and fry. Generally, mouth breeders like tilapias have been associated with low fecundities.

Bagenal reported that the fecundity of a fish species approximate to the cube of the body length but noted there were several exceptions. In some fishes, fecundity approximates the square of the body length; while in others fecundity may approximate more than the cube of body length. However, in some fish species, there is no relationship between fecundity and size of fish. Several workers have reported fecundity to be directly related to fish size or weight.

3.2 Methods of determination

The estimation of fecundity usually refers to the determination of the number of vitellogenic oocytes (*i.e.,* potential fecundity). Different methods exist but their use will depend on the species under investigation, resources and laboratory facilities available. Traditionally, potential fecundity is determined by a gravimetric or volumetric method. Although these methods are simple, inexpensive and give reliable results, the work is time-consuming and tedious
The gravimetric method usually involves sub-sampling by weight is often used for fecundity estimation: preserved eggs are washed in water to drain excess preservative usually Gilson's fluid and exposed on filter paper for about 5 – 10 minutes after removal of ovarian tissue. The eggs are weighed; five sub-samples of the eggs are weigh and number of eggs in the sub-samples

counted. The total number of eggs in the ovary is calculated by proportion. This method of estimating fecundity is accurate to about 1%. The volumetric method is similar to this but volume measurement is used in place of weight.

However, new methods are developed to reduce the time and labor involved in measuring fecundity. For example, Thorsen and Kjesbu (2001) developed a method to measure oocyte density (number of eggs/g) using an image analysis system. An image analyser was used to automatically determine mean oocyte diameter of a gonad sample and the oocyte density was determined with a calibration curve. In general, it took 5 minutes to prepare the sample, measure oocyte diameter and process the data. Similarly, procedures based on image analysis have also been developed to measure efficiently and at low cost potential fecundity (Friedland*etal.*, 2005; Klibansky and Juanes, 2008). Although some validation process is necessary before using these methods, they represent a major advancement in the efficient measurement of potential**.**

3.3Biological Constraint of Fecundity

Potential fecundity is strongly influenced by female size, trade-off between egg size and egg number, reproductive strategy and spawning pattern of the species. While size of oocytes will have a direct influence on maximum number of hydrated oocytes that can be produced in one time, reproductive strategy and spawning pattern will determine the possible number of eggs that can be produced in the spawning season. Species with indeterminate fecundity where potential annual fecundity is not fixed before the onset of spawning will have the capacity to produce more eggs than species with determinate fecundity where new vitellogenic oocytes are not produced during the spawning season. In the same way, batch spawners which released hydrated eggs in batches over a protracted spawning period will have the capacity to produce more eggs than total spawners where all oocytes are hydrated and shed in a single episode.

Because female fish retain their oocytes internally during their development, maximum reproductive output will be subjected to morphological constraints. The volume of the body cavity will limit the reproductive allocation at each spawning event. This limitation will result in correlations between reproductive investment and fish size. As the volume of body cavity is related to size, the potential fecundity in many fish species is strongly related to body size.

The constraint associated with the volume of the body cavity can also result in a trade-off between egg size and egg number; larger egg volume decreasing the maximum number of eggs that can be produced. The inverse relation between egg size and egg number in spring and autumn spawning herring, a total spawner with determinate fecundity is a known example of this possible trade-off . Female attributes other than size have also been shown to influence potential fecundity. Variations in the nutritional status estimated from different indices of condition like the condition factor or liver index significantly influence potential fecundity of Atlantic cod, plaice.

3.4: Ecological Constraints of Fecundity

Besides the determinant influence of female size, potential fecundity is also modulated by environmental conditions. Numerous studies showed relations between potential fecundity and many environmental factors such as food abundance/ availability/ consumption, temperature, fish density, and biomass index. Variability in environmental conditions will directly or indirectly through their influence on growth and nutritional status result in a wide range of variation in potential fecundity. This variability is clearly demonstrated by the different potential fecundity-size relationships (length is commonly used as the measure of size) observed for many species in the literature. Annual variations in these relationships can be seen as the response of individual females to varying combination of biological and environmental influential factors detected between populations, geographic areas, and years

4.0 Conclusion

One of the most fascinating ideas to become established in recent decades is the concept that fish (and other organisms) have a life-history strategy, in which trait related to development and reproduction play a central role. The life –history strategy of a species is a complex of evolved traits related to the allocation of energy; it defines a species, along with morphology, physiology and behaviour. Life cycle of a species is fine-tuned to the environment. For example, among pelagic piscivores of the oceans, shark use a low-fecundity strategy of viviparity, tunas use a high-fecundity strategy of oviparity, and salmon use a strategy involving moderate fecundity and some parental care.

The evolutionary diversity of fishes has meant the development of unusual life-history strategies involving such things as multiple sexes, sex change and hermaphrodatism. Fecundity is important and well studied in the field of population ecology. Fecundity can increase or decrease in a population according to current conditions and certain regulating factors. For instance, in times of hardship for a population such as a lack of food, juvenile and eventually adult fecundity has been shown to decrease.

In addition to sex-ratio and proportion of mature individuals, fecundity is one of the most important determinants of a stock's reproductive potential. A number of methods have been described that could be used to estimate fecundity for a variety of fishes. However, no universal method could be recommended, Potential fecundity could be a biases method of estimating realized fecundity, if oocyte are continuously recruited into the pool of developing oocytes or if the number of this is reduced by atresia

5.0 Summary

Fecundity has been used in relation to the reproductive strategy of the fish and oocyte recruitment or stages.The advantages of high fecundity cannot be overemphasized since the survival and continued existence of the species depend on numbers of eggs hatched. High fecundity is also a desirable quality in aquaculture as it ensures regular (when reproduction can be obtained all-year round) and adequate supply of fingerlings for stocking culture enclosures. Knowledge of the fecundity of a fish is necessary in establishing its production potential and consequently its sexploitation and management rationale.). Different methods exist to determine fecundity but their use will depend on the species under investigation, resources and laboratory facilities available. Traditionally, potential fecundity is determined by a gravimetric or volumetric method. Although these methods are simple, inexpensive and give reliable results, the work is time-consuming and tedious.

Fecundity has been used in relation to the reproductive strategy of the fish and oocyte recruitment or stages.The advantages of high fecundity cannot be overemphasized since the survival and continued existence of the species depend on numbers of eggs hatched. High fecundity is also a desirable quality in aquaculture as it ensures regular (when reproduction can be obtained all-year round) and adequate supply of fingerlings for stocking culture enclosures. Fecundity is strongly influenced by biological factors such as female size, trade-off between egg size and egg number, reproductive strategy and spawning pattern of the species.Numerous studies have showed the relations between fecundity and many environmental factors such as food abundance/ availability/ consumption, temperature, fish density, and biomass index.

6.0 Tutor-Marked Assignment

1. How could fecundity be determined?

2. Write short notes on ecological limitations to fish fecundity

7.0 References/Further Readings

Friedland*etal.,* 2005; Klibansky and Juanes, 2008; Thorsen and Kjesbu (2001)

Bagenal, T.B.(1978). Aspect of fish fecundity In: .Ecology of fresh water fish production. S.D. Gerking (ed.) Third edition. FBA, Winemerelab., Ambleside, UK p. 75-101.

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MODULE 6: FISH CULTURE TECHNIQUE

Unit 1 Techniques of fish culture

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1.0 Introduction

Fish culture is the growing of fish in ponds. Growing fish in ponds, from which they cannot escape-, allows feeding, breeding, growing and harvesting the fish in a well-planned way. Fish culture is one form of aquaculture. Aquaculture is the science which deals with the cultivation/growing of aquatic organisms (fish , mollusks, crustaceans, other vertebrates, unicellular organism, microalgae and higher plants) using extensive or intensive method in order to increase the production or yield per unit area or volume to a level more than can be obtained naturally in a particular aquatic environment.

Aquaculture, a type of agriculture, is also the practice of cultivating aquatic animals and plants in managed aquatic environments. Aquaculture in salt-water or marine environments is called maricultures. Fish culture, or pisciculture, refers to the husbandryof finfish. The most popular aquaculture species are finfish grown in fresh waters, accounting for over 40 percent of total aquaculture production.

2.0 Objectives:

By the end of this unit, students should be able to

(i) explain the different fish farming techniques
(ii) enumerate the characteristics of fish farming techniques and
(iii) statethe needs for cultivable fish.

3.0 Main Objectives

3.1 Criteria of Cultivable fish

Advances in controlled reproduction of desired species, feed formulation, and water quality management have helped generate the rapid growth of aquaculture. The biological selection of culture species depends on many factors. A few criteria that must be considered in choosing a species to cultivate include the following characteristics of a species:

- Growth rate;
- Place in the food chain;
- Climate and environmental adaptations;
- Disease resistance;
- Breeding characteristics;
- Compatibility with other fish species in cultivation; and
- Conversion efficiency (feed-to-flesh).

For example, aquaculturists prefer fast-growing planktivoresbecause of their short food chain. Interestingly, biotechnological selection criteria are not always the most critical; for example, growing fish unsuitable for local or export markets can readily drive a farmer out of business. Thus, consumer preference, market conditions, regulations against nonnative species, and other economic, social, and political criteria play an important role in species selection.

3.2**Purposes of Aquaculture**

Aquaculture is practiced for a number of reasons, chief among them being food production and income generation. Most fresh-water aquaculture production (over 70 percent) comes from low-income, food-deficit countries. Even in the poorest countries, fish farming is seldom solely a subsistence activity. So while farmers may consume some of their product, typically fish are sold, thereby enabling farmers to earn income to purchase other goods and services.

Additional purposes of aquaculture include:

- Utilizing land unsuitable for agriculture;
- Utilizing inland water bodies such as shallow lakes;
- Reclaiming saline soils;
- Increasing the supply of highly valued species;
- Improving the reliability of fish supplied in the marketplace;
- Offsetting losses in the capture fisheries or in native fish populations;
- Servicing the sport fishing industry;
- Controlling parasites like mosquito and snail larvae that cause diseases such as dengue fever and malaria;
- Storing water; and
- Earning foreign exchange. (Europe and the United States import aquaculture products from Asia, Africa, and Central and South America.)

3.3Techniques Fish Culture

Fish culture techniques may be classified based on the level of manipulation of the environment into three, which are:

- **Extensive Fish Culture**

This is any fish culture techniques that do not require any supplementary feeding or energy input to support growth of the species under culture. Its attributes include:

-There is relatively little or no manipulation of the environment, that is, there is low degree of control in terms of nutrition, predator, competition, disease or pathogen.

- There is low initial cost.

-Low socking density: about 1-3 tonnes of fish per hectare
- High dependence on local climate and water quality.

The system is practiced in ponds, reservoirs and pens/fences.

- **Semi- Intensive Fish Culture**

This is any system that does not depend exclusively on a natural food chain; supplementary feeding is applied to augment the natural food in water in form of fertilization or linning of the water to increase primary productivity or through wastes e.g. domestic wastes. Therefore in a semi-intensive culture system, part of the food needed is supplied through supplementary feeding; stocking density is moderate and much higher than extensive culture systems (3-10 tonnes).

- **Intensives Fish Culture**

This is any culture systems that do not depend on natural food chain. It is a highly culture system in which the nutrients requirement is supplied during the culture systems. Thus, it involves the use of adequate food both in term of quantity and quality. Its attributes include:

-there is a high degree of control i.e. land manipulation of the environment. There must be recirculation of water in the culture systems, wastes are removed and enough water is supplied.
-initial cost is high
-high technology and high production efficiency for instance electricity must be provided
-allows for high stocking density (20-100 fingerlings per hectares)
-there is tendency towards increased independence of local climate and water quality.

Based on the number and types of species cultured, fish culture systems can be classified into two:

- **Monoculture**

This is the culture of only one species of fish. It is commonly practiced in intensive fish culture systems. Fishes culture, here, have the same feeding habits. It is very useful Tilapia culture doe to their prolific breeding. (mono-sex culture)

- **Monosex culture**

It isa type of fish culture in which wild spawning is controlled and desired sex is increased e.g. female*Tilapias* in a pond cause uncontrolled breeding. To avoid this, monosex culture is practiced. The focus of this culture is to produce male seed stock. This is done by fish culturists by hand sexing (or its also calledmanual sexing) wherein the males are sorted out from the unsorted stocks of fry. The sexes can be differentiated by visual examinations of the uro-genital papillae.

- **Polyculture or composite fish culture**

It is a type of fish culture in which different types of fishes of different feeding habits are cultured to exploit the different kinds of food that is present in the different parts of the pond.

This increases the productivity of the pond. This type of farming is also called mixed fish farming.Polyculture poses no serious competition between the different species as each species renders a beneficial influence on growth andproduction of the other. For example, the Grass carp *(Ctenopharyngodonidella)* converts plant tissue into flesh by feeding on aquatic vegetation but its excreta fertilizes the pond which benefits other species. In Bengal, major carps like*Catla*, *Rohu* and*Mrigal* in the ratio of 3: 3: 4 are reported to be cultured together in ponds.It is commonly practicedin extensive or semi-intensive fish culture systems and has the advantage of utilizing more ecological systems hence; there is increased utilization of available food.

3.4 Other fish farming techniques include:

- **Caging Systems**

Nets or cages are popular methods of fishing in off shore coastal areas and freshwater lakes, ponds and oceans. Fish are raised in the cages, fed artificially and harvested when the numbers of fish meet the required demands of market. Some of the advantages of cage farming systems is,that this farming technique can be practiced in various types of water sources like lakes, ponds, seas and oceans, that offers flexibility to the farmers. Also, many types of fish can be raise together and the water can be used for various other purposes like water sports. In this farming method, superior quality cages are constructed and put in the water sources to raise the fish. Spread of diseases, poaching and concerns of poor quality water are some of the disadvantages of this farming system.

- **Ponds**

One of the small scale fish farming techniques is raising fish in the pond, especially designed for the purpose of raising fish. Small ponds can be made in the farms and houses, which can provide its owner the ability to have control over the farming system. Ponds are useful for water harvesting in the dry areas and can also be utilized for raising fish. Waste water can be contained and treated properly to raise fish. Release of untreated waste water into the environment is possible, if the ponds are not maintained properly and can cause pollution. For small farms, ponds are effective to raise fish for self consumption.

- **Raceways**

If you visit any fish farming area, you may come across narrow streams flowing between two wall type structures. These streams are nothing but raceways and their purpose is to help the farmers divert water from water systems like streams or well, so that it flows through the water channels containing fish. There are various restrictions imposed on this type of farming by the government and the farmers are strictly advised to treat the water before they divert it back to the natural waterways. Also, the farmed fish can escape raceways and interfere with the wild fish habitat of the waterways.

- **Recirculating System**

The recirculating system uses recycled water for raising fish. The waste water is treated and recycled many times. Many fish species are grown in the recirculating systems. However, the operative cost of the electricity is a disadvantage of this method.

4.0 Conclusion

Fish culture in ponds is the primary method of fish culture. However, there are other methods of fish culture used in places where ponds are not possible or advantageous.

5.0 Summary

To realize, the potential of aquaculture, opportunities for exploitation of resources, available suitable sites and cultivable species must be optimally maximized. Of immense importance is the fish culture techniques adopted, which must reflect the overall cost of construction and eventual economic project cost. Fish culture is the growing of fish in ponds and it is an important element of aquaculture. Aquaculture, a type of agriculture, is also the practice of cultivating aquatic animals and plants in managed aquatic environments. The biological selection of a species for aquaculture include: growth rate, position in the food chain, disease resistance, breeding characteristic, conversion efficiency e.t.c. Fish culture may be classified on (i) level of manipulation of environment(extensive, semi-intensive and intensive techniques), (ii) number of species culture (monoculture and polyculture). Other fish culture techniques include caging systems, ponds, recirculating systems and raceways e.t.c.

6.0 Tutor-Marked Assignment

1. Fish culture is an essential element of aquaculture: discuss
2. With reasons, account for the different farming technique in aquaculture

7.0 References/ Further Readings

Anderson, S. E. (1973). A manual of fish farming for tropical Africa.University of Minnesota, St. Paul, Min. 46P.

Francis, F (1985). Fish culture : a practical guide to the modern system of breeding and rearing fish. Routledge, Warne, and Routledge, London. 320p.

MODULE 7: POND CONSTRUCTION AND MANAGEMENT

Unit 1: Pond Construction

Content

1.0 Introduction
2.0 Objectives
3.0 Main Body
Fish Pond (or Enclosure) Sites: Types
Site selection
Pond Designs
Pond construction
Functions of some pond parts

4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

A pond is a body of standing, as opposed to free-flowing, water that is small enough to be managed for fish culture. Fish production in farm ponds can provide protein and profit for farmers. Fish such as oreochromis and carp are easy to culture and good yields are possible if a management plan is followed (Figure 1). The three different major operations undertaken in a fish farm includes hatchery and grow out , fish feed production and post harvest processing.

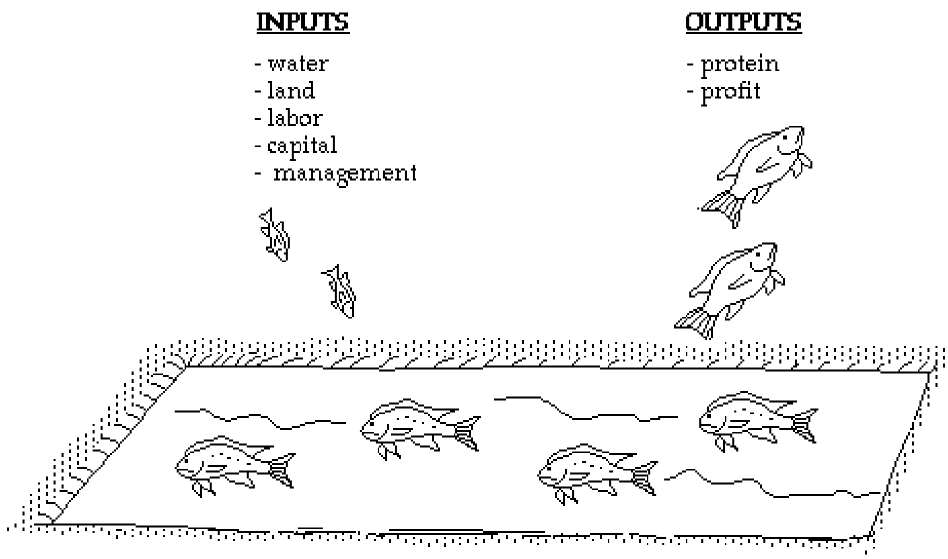


Figure 1: Ponds can provide protein and profit for farmers.

2.0 Objective

At the end of this unit, students should be able to

(i) Identify the types of fish ponds
(ii) state the criteria for site selections
(iii) explain the basics of pond designs and constructions

3.0 Main Body

3.1 Fish Pond (or Enclosure) Sites: Types

Fish ponds are fish enclosures. They fall into two categories depending on the terrain of the site under construction. These include

a. Geophore (or Land-Borne) Sites)

These are fish pond sites borne by land irrespective of the water source, design and other factors. Earthen ponds, weirs, raceways, fish tanks, throughs and tubs belong to the category of geophore sites' enclosure.

b. Aquaphore (or Water-Borne) Sites

These are fish pond sites borne by water (wholly are particularly) irrespective of design and material of construction. Cages, pens, creels, and pots are in this category. They are normally immersed in marine, estuarine, lacustrine and riverine waters.

3. 2: Site selection

Selection of suitable sites for fish farm construction is very important. The following three essential conditions guide the proper site selection:

- Topography
- Source of water and its quality
- Soil type

- **Topography**

It is economical and convenient to construct ponds in waterlogged areas, irrigation command areas or in marginal lands. In such areas construction cost is relatively low mainly due to limited earth cutting. For example, a pond of 100 m × 40 m (0.4 ha) of water area requires only 3 234 m^3 of earth to construct around a dyke of 2 m high above ground level (GL) with side slope ratio of 2:1 and top width of 1.5 m. This quantity of earth may be obtained only from 1.1 m depth of cutting. This limited depth of cutting reduces the construction cost considerably. However, full consideration should also be given to the possible effects of flood. The surface features of the area proposed for the pond or the farm is also equally important. A saucer-shaped area may be an ideal site for a large dug-out pond, because it may hold appreciable quantity of water with a small amount of earthwork.

For smaller and flat areas eye estimation is enough, but for a big area proposed for farm construction with a number of ponds for different purposes and of different sizes, it is essential to conduct contour survey for determining the topography and land configuration. The site should be easily approachable so that there may not be any difficulty in the transportation of input materials and in the marketing of the produce. The labour and materials required for construction and operation should also be locally available as far as possible. From an efficient management point of view the pond site should, if possible, be within the sight of the farmer's house. It also reduces the risk of poaching. Siting fish ponds near the farmer's other agricultural or livestock farming activities makes it easier to integrate all the farming activities.

- **Source of water and its quality**

A dependable source of water supply must be available within or near the site, even for undrainable ponds. However, unlike drainable ponds, undrainable ponds require just sufficient water to fill the ponds and to compensate the water loss through seepage and surface evaporation thereafter. Equally important is the need for avoiding excess water and hence there must be arrangement for the excess water to escape through a bypass channel or a spillway. The water supply to the pond should as far as possible be natural, preferably rain water. However, alternative arrangements of water supply should be made for dry season either from a deep tube well or irrigation canal or from perennial sources like spring, stream, river, etc. Ponds should be on the lower lands to allow accumulation of surface runoff from a larger catchment area. However, care should be taken to provide proper bypass or spillway to avoid flooding. A higher subsoil water table due to irrigation in surrounding fields and percolation from artificial or natural channels, in addition to absorption from rain water, also helps in maintaining water level in undrainable ponds.

The quality of the available water is also equally important for fish culture. Pond fish production is influenced by the physical and chemical properties of the water. Water should be clear as far as possible. Turbid waters which carry suspended solids cut the light penetration, thus reducing primary productivity of the pond. Excess of suspended solids also adhere closely to the gill filaments and cause breathing problems. Water temperature also significantly influences the feeding and growth of fish. Prevailing water temperature, ranging between 15°C and 35°C in tropical areas, is most suitable for carps. The chemical quality of water depends on its content of dissolved salts. Rain water does not carry any dissolved salts. However, it collects nutrient salts from the ground surface of the catchment area. The water should be neitherbe too acid nor too alkaline; neutral or slightly alkaline waters are most suitable for fish culture and hence acid water should be limed to make it neutral. Waters with p^H values below 5.5 or over 8.5 are not proper for fish culture. The farmer will need huge quantity of lime to neutralize it while highly alkaline water may cause the precipitation of both phosphate and iron, and if it remains continuously above p^H 9, it may be harmful to fish.

- **Soil type**

Pond soil must retain water. Soils with a low infiltration rate are most suitable for fish pond. Table 1 shows the filtration rate of different types of soils. The best soils for our purpose are thus the impermeable clay which can be easily compacted and made leak proof.

Table 1 Infiltration rates of different types of soil

Soil type	**Infiltration rate (mm/ha)**
Clay	1–5
Clay loam	5–10
Silty loam	10–20
Sandy loam	20–30
Sand	30–100

Loamy soils can also be used, but they need well compacting, and may leak slightly in the early stages, although they tend to seal themselves with time. Sandy and gravelly soils should be avoided, but if they are the only ones available they must be made impermeable with a thick coating of clay or with polythene sheeting. Soil impermeability can also be achieved by soil compaction at the pond bottom and dyke with either a mixture of soil + 1–5% cement or soil + 10–20% cow dung. Treated areas should be kept moist for 2–3 days by gently sprinkling water to avoid cracking and finally the pond is filled with water.

Peat soils have special problems, since they are usually very acidic in nature and need sufficient liming, while the organic matter decomposition may lead to dissolved oxygen deficiency. Soils rich in limestone also create special problems, since the excessive lime content tends to precipitate phosphate and iron. Such ponds would then have little plankton population and macrophytes and would be relatively sterile. This can be overcome by adding sufficient organic matter such as cow dung, poultry manure, etc.

A general and convenient field test for the soil quality is to take a handful of moist soil from the test holes made at the proposed site and to compress it into a firm ball. If the ball does not crumble after a little handling, it indicates that it contains sufficient clay for the purpose of pond construction. Accurate determination of the composition of the soil and its water-holding character is possible by hydrometer method. Several test holes may be made across the site and soil samples may be collected vertically from every 0.5 m of depth reaching up to a level of 3–4 m in a test hole. Using the results of the soil tests, a soil profile chart for the proposed site may be drawn. An arbitrary soil profile chart is presented (Fig. 2) showing the presence of clayey soil up to a depth of 3.5 m.

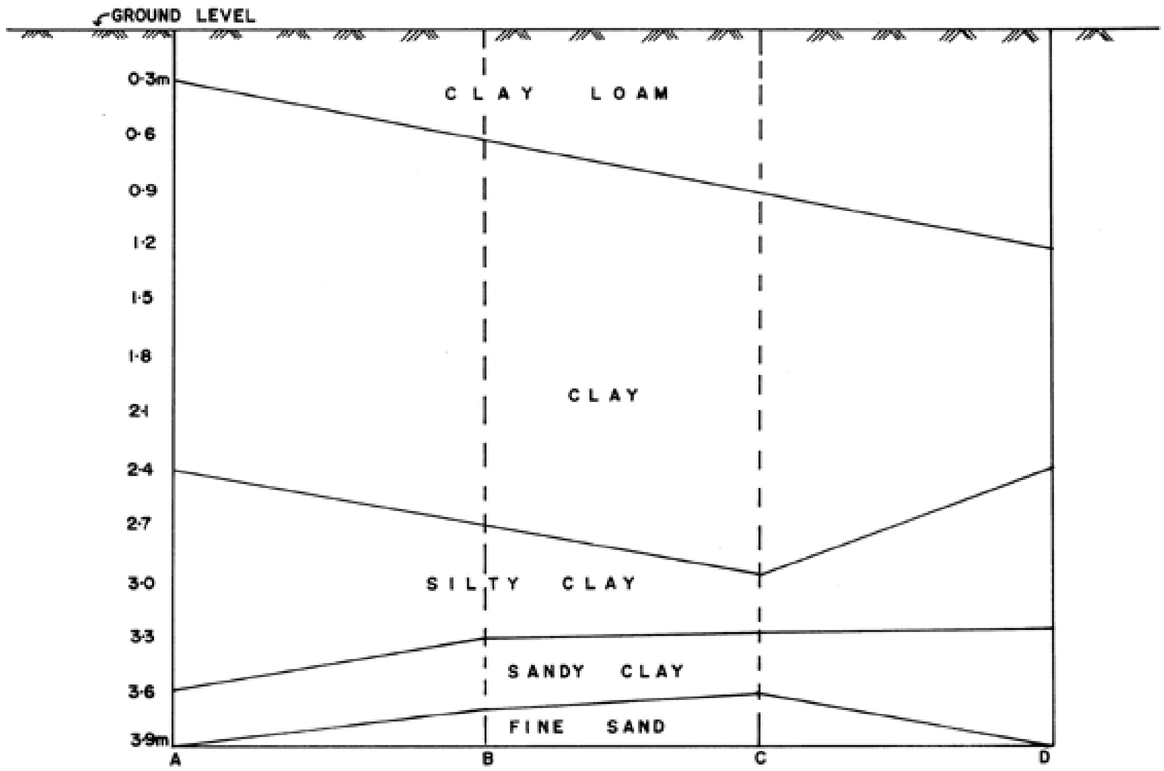


Figure 2: Soil profile.

3.3: Pond Designs

Based upon the survey on topography, soil type, water supply, etc., the detailed designing and layout of the ponds/farm are done. However, the following additional points are also to be considered.

- **Water area ratio among pond types**

The production or stocking ponds are stocked with large size fingerlings of about 10–15 cm size in the case of composite fish culture. To attain this size, the hatchlings are reared in much smaller and shallower ponds called nursery and rearing ponds for about 2–3 months. In the nursery ponds the hatchlings are reared up to fry stage and in the rearing ponds the fry are reared till fingerling stage. The ratio of water area among nursery, rearing and stocking ponds in a fish farm depend upon the basic objective of the farm. In case of a fish seed farm, only nursery and rearing ponds are to be constructed with a small area for few stocking ponds to be used for raising the brood fish, while in the case of fish production farm only stocking ponds are to be constructed for producing table size fish from fingerlings. The layout of a complete farm is given in Figure 3.

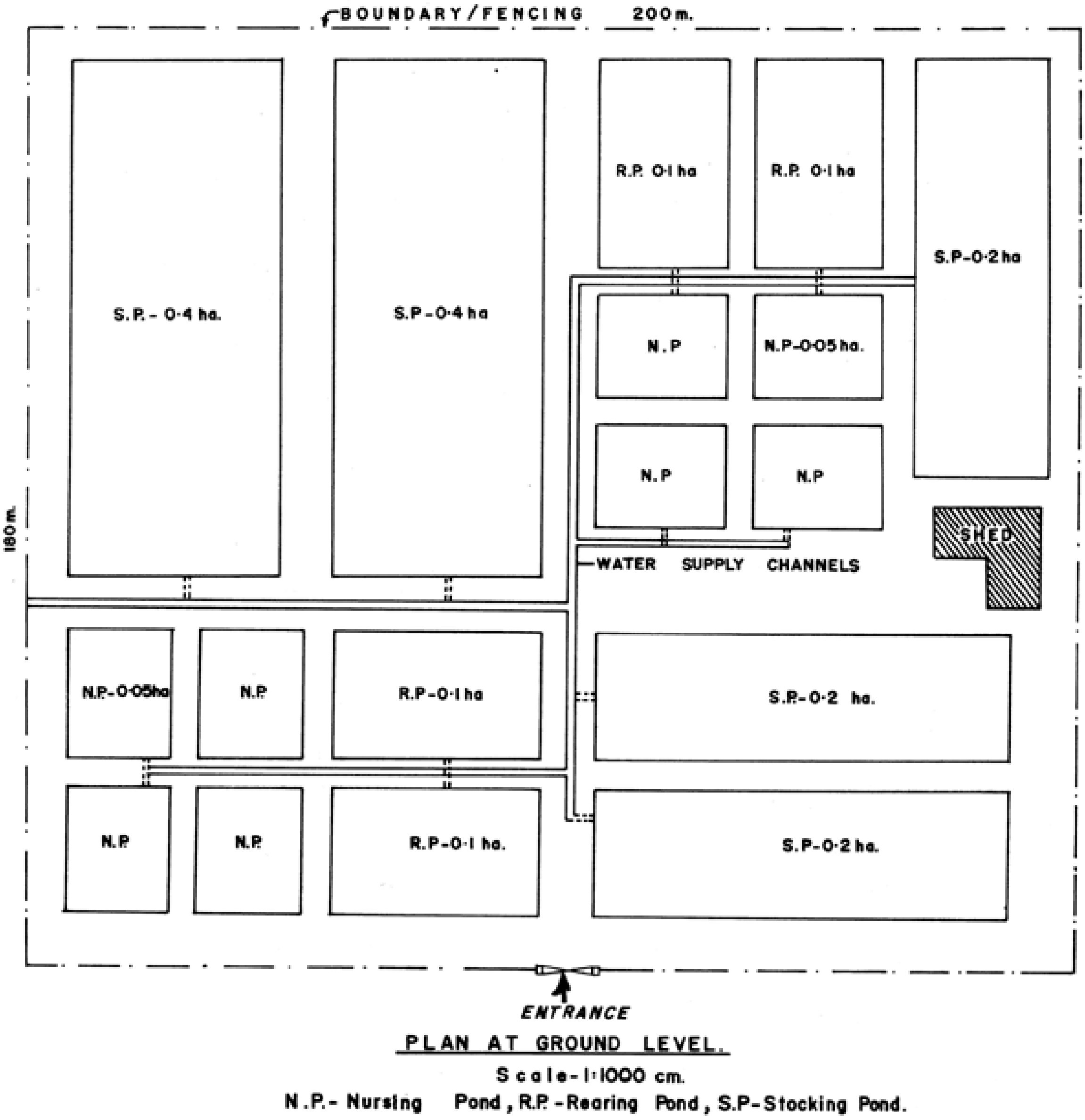
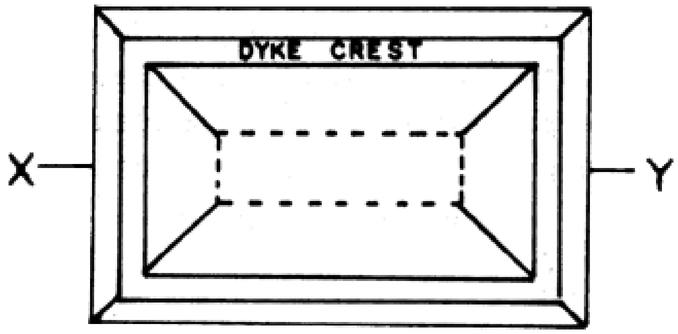


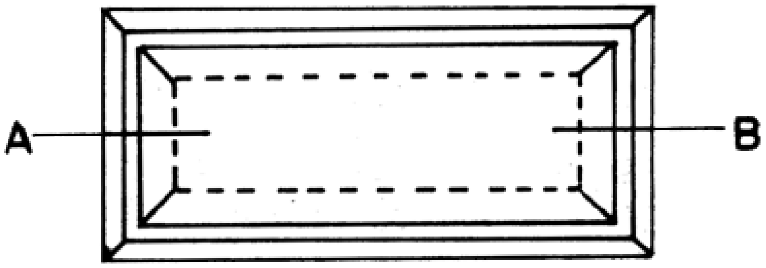
Figure 3. Layout of a Fish Farm (Land area 3.6 ha)

There is no hard and fast rule regarding the size of a pond. However, nursery ponds should be small and shallow.

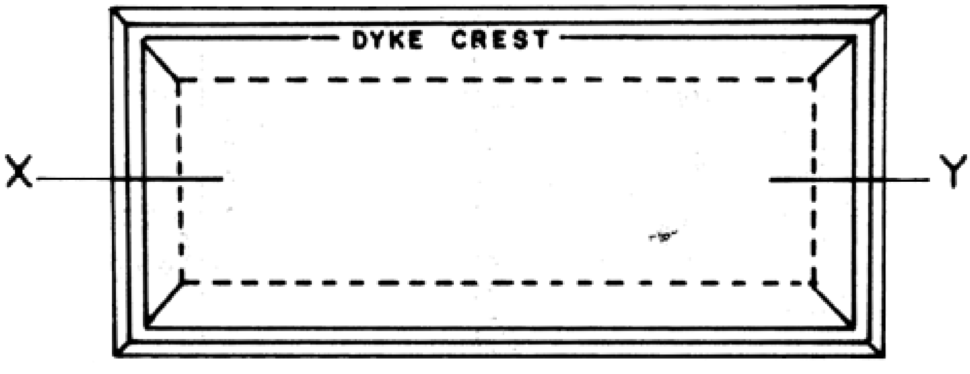
In shallow ponds the water becomes heated easily. In deeper ponds light cannot reach the bottom. In very deep ponds thermal stratification may occur with colder deoxygenated bottom layer. Dead plankton and faecal matter from fishes may fall on the bottom layer where the nutrients may be locked up. However, in case of rain-fed areas where the water table goes down during the dry season, the depth should be kept around 3.0 – 3.5 m to store more water during the rainy season.Although a square pond is economical to construct for its minimum length of dyke, a rectangular shape of the pond (length: width in proportion of 3:1) is considered to be ideal. In any case thepond width should not exceed 30 to 40 m as it is difficult to operate afishing net in broaderponds. The nursery and rearing ponds may be square, since they are too small to pose any problem for netting. The corners must be curved to avoid fish escaping the net during harvesting. The layout plans of nursery, rearing and stocking ponds are given in Figures 4A and 4B.



PLAN OF A NURSERY POND (0·02ha)



PLAN OF A REARING POND (0·1ha)



PLAN OF A STOCKING POND (0·4ha)

Figure 4a. Design of Nursery, Rearing and Stocking Ponds

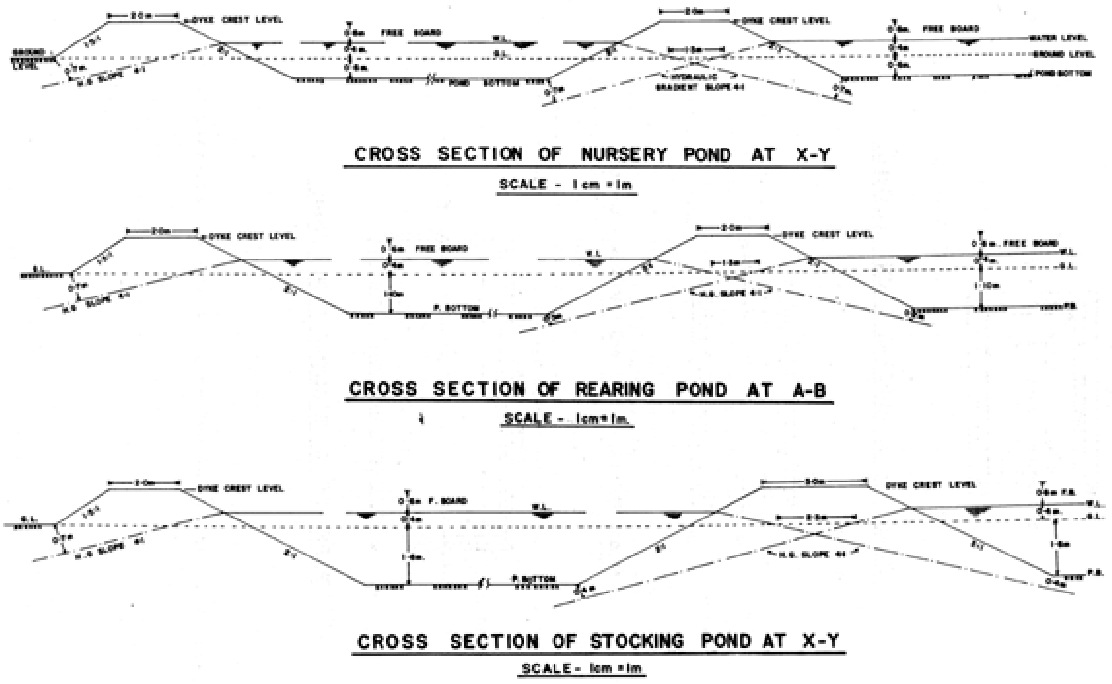


Figure 4b. Cross Section Details of Ponds

3.4 Construction

Before initiating the construction work, proper estimates have to be prepared based upon the design details, which will include the cost of all the materials and the labour. Strict supervision isrequired at every step of construction to ensure the adherence to specifications laid down in the design.

- **Time of construction**

If the construction work is taken up at the most appropriate time or season of the year, the work becomes easier and economical. The best time of the year for constructing ponds in clayey soil is post-rainy period and winter when the soil is soft rather than at the end of the dry season when it is very hard. For swampy and waterlogged areas the most desirable time is the late summer when the area becomes completely dry. However, if a pond is built during winter or early summer and is not filled immediately, weeds may grow and cover the bottom. In such cases de-weeding is needed before filling the pond.

- **Preparation of site**

The site should be thoroughly cleared of all the trees, bushes, etc. Even the roots of trees should be removed. No woody material should be left because the same will eventually rot and cause leaks. Some tree trunks rot very slowly and may cause problems during netting.

- **Marking the outlines**

This operation involves laying out the features of ponds on the ground in order to mark out the areas from where the earth will have to be cut and removed and also where earth will have to be embanked. Initially, lines are drawn according to the layout, followed by pegging and fixing stakes or posts. Strings are stretched between the tops of pegs and posts to mark the complete profile of the dyke with its correct height, width and slopes (Fig. 5).

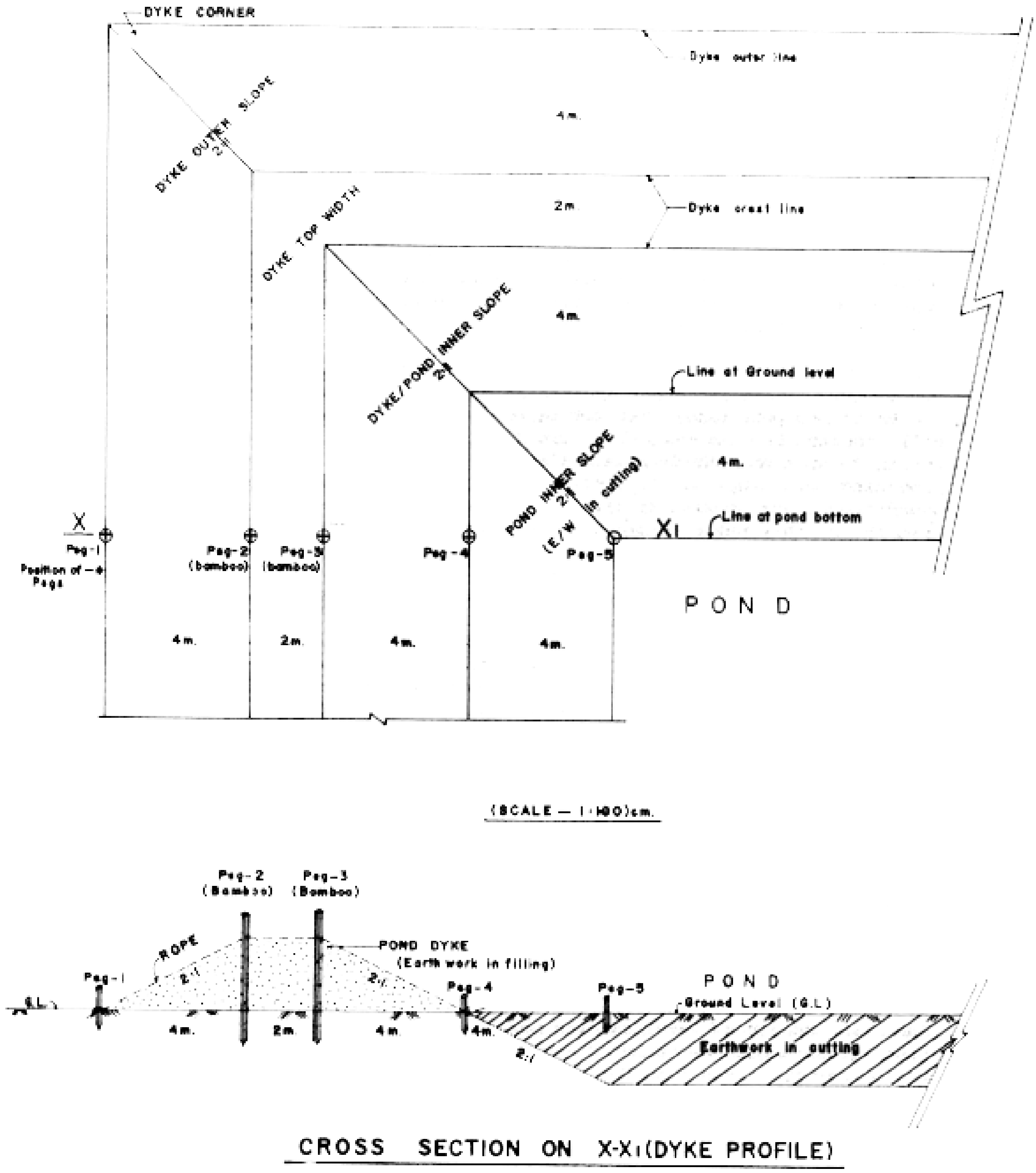


Figure 5. Layout and Pegging before Pond Construction (Corner View)

- **Pre-excavation work**

Prior to pond excavation and dyke construction, all loose surface soil should be removed from about 20 cm depth within the total outlined area of the dyke and the surface should be roughened by ploughing or digging. In order to unite the body of the dyke to subsoil, it is desirable to dig a small "V" shaped key trench (Fig.5). When the dyke is to be made on a sandy, gravelly or marshy soil base, the construction of a key trench becomes essential and in such cases digging should be done until watertight foundations are reached. The key trench is a small ditch or furrow dug along the line of the centre of the walls about 0.5 m – 1.0 m wide and 0.5 m deep. This trench is filled in with a good clayey soil and is well rammed. If good clayey soil is not available in the area, ordinary soil should be well compacted into the trench. The purpose of the trench is to stop seepage of water underneath the walls.

- **Pond excavation and construction of dykes**

The excavation work can be carried out within the area marked for the pond bottom either manually or mechanically. However, the final levelling of the pond bottom and sides should be done manually with proper ramming and finishing as per the original design. The construction of the pond becomes economical if earthen dykes are made around the pond using the excavated earth from the pond bed. All dykes should be raised, dumping the earth layer by layer stretching right across the whole section, and in such cases each layer should not exceed 20 cm in thickness. All large clods should be broken and each layer should be thoroughly consolidated by watering and ramming. The sides and top of the dykes should be properly dressed and finished with wooden thappies (wooden block with handle for ramming).

In case the soil quality is not suitable for making dykes, a clay core is provided in the dyke to make it watertight. A mixture of 1:2 of sand and clay is used to make the clay puddle. This should be consolidated, compacted and deposited in 10–15 cm thick layers. Each layer should be adequately moistened before the next layer is laid and precaution should be taken to prevent the puddle from becoming dry and cracking.

Dykes must be well compacted to render them stable and the top should be rammed flat so that small vehicles can also run along when needed. Short creeping grass is recommended to be grown on the top and sides of the dyke. Trees are not desirable since their dense shade inhibits the productivity of the pond.

- **Water inlet structure**

Since we are concerned here with static and undrainables ponds, a feeder stream running directly into the pond should be avoided. The feeder stream must therefore be diverted along the side of the pond and from a suitable point water is channeled to the pond when required. An inlet structure should be provided through which water can be let into the pond. A proper inlet enables the quantity of water flowing into the pond, to be regulated, preventing the entry of undesirable fish and other aquatic animals and the escape of stocked fish. For small ponds the best inlet structure is a galvanized iron pipe of about 10 cm diameter with a control tap and a screen basket (Fig. 4 A). The downstream end of the pipe should be 30–40 cm above the water level. A sluice is also suitable for this purpose, especially for larger ponds. A screen is also fixed to check the entry of undesirable fishes and other animals (Fig. 4 B). To avoid scouring when the pond is being filled, a concrete apron can be built at the sluice, or more cheaply, a layer of gravel lay down. Similarly, if water is let in with a pipe there should be a gravel bed laid down where the water stream falls into the pond. If gravity feed is not possible, water must be pumped from the supply source into the channel leading to the pond or even directly into the pond; but, in that case, the intake should be securely wrapped by a firm net to prevent undesirable fish and other animals from entering into the pond along with the water.

Function of some Pond Structures

- **Drainage Installations**

Drainage is the disposal of pond water as required by the procedures of fish farm management. Many different draining systems are used, but special mention should be made of the monk and sluice gate. For clearer terms, a monk is usually associated with fresh water fish pond while sluice gate is associated more with brackish water fish pond.

- **Monk**

Monk is known to be the best drainage system and it must be built before the construction of embankment. Monk consists of two main parts namely the shaft and the horizontal pipe. Two or three pair of grooves are incorporated in the shaft, one for the screen, the other two for wood boards. The monk has two important functions. When the pond is being filled, it controls the level of the water and prevents escape of the fish. When it is being emptied it permits progressive draining of the pond.

- **Sluice Gate**

There are two main types of sluice gate notably concrete and wooden sluice gates. Both have the same basic, basic principle of construction, but strong and flexible sluice gate should be fitted to brackish water ponds, despite the fact that the wooden is cheaper to construct. Like the monk sluice gate is located at the lowest point of the pond bed within the dyke base. Two component parts of the sluice gate are the floor and the twp walls (with grooves for sluice gate boards). Sluice gate is a water control structure associated mostly with brackish water pond. It serves the dual role of letting water in and out of the pond during high and low tides respectively.

- **Water Inlet**

Pond water inlet has been amply described by experts as the point or place where water can be let into the pond system. As an important structure water inlet should functionally assure not only a regular and regulatable supply of water for the system, but prevent both the escape of fish from the pond, and the introduction of unwanted fish into the same pond. All ponds should be installed with a water inlet structure with the exception of ponds fed by springs with a regular flow.

3.5 Pond Factors

<u>Factors determining the size of a Fish pond</u>

(i) Cost of construction.
(ii) Time required for filling and draining water out of the pond.

(iii) Topography of the area may enhance or limit pond size.

Factor determining the shape of a Fish pond

(i) Anticipated method of harvesting.
(ii) Purpose or function
(iii) Topography
(iv) Ratio between embankment and water body

Typed based on water supply

There are two major types of ponds based on water supply:

(i) **Barrage pond:** This type of pond is constructed along the main path of flow of river water or stream. Both up-streams and down streams are barricaded with in-let and out-let respectively
Advantages
It does not cost much to construct. There is usually sufficient amount of water all through the culture period.
Disadvantages
When flood occurs, there is the likelihood that the whole pond system can be washed off.

(ii) Diversion or contour pond

This type of pond is constructed in the by-pass of a stream or river. A water supply channel is built for this purpose with a sluice or inlet gate at the entrance to control the volume of water coming in or going out of the pond and also to check on the influx of extraneous materials.

Advantages

It is not prone to any hazard resulting from excessive flooding as compared to barrage type. There is better control over the site contrary to barrage.

Diversion pond is divided into two types:

(a) Parallel ponds:

Ponds constructed this way are independent of one another in their source of water supply and discharge. All activities relating to filling and draining of water are limited to each pond respectively.

(b) Series ponds:

These are built such that each pond derives its water supply from the other and also empties into another. This is the worst approach to pond design hence it is not recommended as whatever affects one would definitely affect the other.

<u>Types of Ponds Based on the usage</u>

(i) Holding pond: Used to hold fish temporarily in readiness for either transportation or fattening for induced breeding purpose.
(ii) Spawning pond: Used to hold the set of fish intended for artificial propagation
(iii) Segregation pond: Used to hold fishes either of the same sex or same species.
(iv) Nursery pond: used to nurse the fry produced during induced breeding into fingerlings.
(v) Grow-out pond: Used to raise fingerlings to table size fish.

Methods of pond construction

The actual construction work entails some knowledge of surveying. Surveying which can be described as measurement science is carried out in three dimensions- distance, elevation and direction. In specific terms, the three types of survey of relevant to pond construction are:

(i) Coastal survey

This has to do with establishment of some defined boundaries of the proposed land for pond construction with appropriate bench mark.

(ii) Topograhis survey

It is constructed to determine the configuration of the land. This is through measurement of the shape and size of any position or portion of the earth surface and representing same on a reduced scale in map form

4.0 Conclusion

Fish ponds are the structural systems designed for fish culture. Their designs vary according to the site of location. Such sites are selected based on the consideration of a variety of factors which determine suitability. Fish pond sites must be carefully selected to achieve the best production results. A well-selected fish pond site already puts some construction economic in view. It goes without saying, that fish ponds built on properly selected sites have a better chance of returns on investments, especially when management is adequate.

5.0 Summary

Fish ponds are enclosure for fish culture, and there are two types based on the terrain of the site under construction: geophore (land-borne) sites and aquaphore (water-borne) sites. Fish pond site selection depends on the nature of the sites: geophore or aquaphore and vary accordingly. The purpose for which fish pond is being planned will affect the choice of site. This may include fish culture, water-storage, irrigation, hydro-electricity, water storage, flood control, lake resort systems, integrated production (rice-fish, poultry) and vegetable growing. The actual constructive of ponds entails some knowledge of surveying which could be cadastral survey and topographic survey. There are two major types of pond based on water supply (barrage and diversion ponds) and five types based on usage (holding ponds, spawning ponds, segregation ponds, nursery ponds and grow-out pond).

6.0 Tutor-Marked Assignment

1. Give a detailed account of different types of pond with the criteria for classification.
2. With well-labelled diagrams, explain the process of improving aeration in a fish pond.
3. Explain the following terms:
   (i) Sluice gate
   (ii) Monk
   (iii) Dyke

7.0 References/Further Reading

Moav,R; Shroeder, G., Hutala,G., and Barash, A. (1977). Intensive polyculture of fish in fresh water pond l. substitution of expensive feeds by liquid cow manure. Aquaculture 10: 25-41.

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UNIT 2: POND MANAGEMENT

Content

1.0 Introduction
2.0 Objectives
3.0 Main Body
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

The success of any enterprise (including fish farming) depends mainly on good management in order to maximize profit. To achieve maximum fish production, fish pond must be properly managed. Fish pond management involves preparation of the ponds, stocking, feeding, maintain good water quality, fish sampling, maintenance of the pond structures, fish harvesting and record keeping.

2.0 Objectives

At the end of this unit, students should be able to

(i) explain and itemize the steps involves in effective pond management

3.0 Main Body

3.1 Pond Management

<u>3.1.1Pond Preparation</u>

(i) Drying the pond bottom: The pond must be completely drain of water and the bottom allows drying until it cracks. De-silting of the pond is carried out if the pond is very muddy.

(ii) Repair of pond structures: The embankments, monks, fish screens and water supply structures are checked and repair carried out before the pond is filled with water. Eroded dykes are strengthened or water filtering structures if clogged are thoroughly cleaned or replaced.

(iii) Removal of unwanted organisms and aquatic weed: While the pond is being dried undesirable organisms e.g. frogs, mollusks, fish predators are eliminated. They are prevented from entering the pond by use of proper screens at the inlets or fencing the farm/pond and keeping the surrounding vegetation low. Dense aquatic vegetation occurring either along the pond margin or inside the ponds are controlled. These weeds compete with phytoplankton for the nutrients available in the water and hence diminish pond productivity. Aquatic weeds can be removed manually, mechanically (using rakes) or biologically (using grass eating fish e.g. Distichodus).

(iv) Liming: Lime is used to improve the pond bottom, and to kill parasite or undesireable organisms in the pond. It also prevents water from becoming too acidic. Liming increases the alkalinity of the water, thereby increasing the availability of carbon dioxide. Materials use for liming and their rates of applications are:
Quicklime (caustic lime) = 200 – 500 kg/ha
Slake lime (Hydrated lime) = 300 – 500 kg/ha
Agricultural lime (limestone) = 500 – 2000 kg/ha.

The lime material should be finely ground and is spread over the entire dry pond bottom. After liming, the pond is left to dry for 1 – 2 weeks to ensure proper mixing of lime with the soil.

(v) Filling of water): The pond after liming is partially filled with water to a depth of 0.6m and left for 2 – 4 days to observe any leakages or seepage. It is later completely filled up and fertilized.

(vi) Fertilizer application: To make water more productive, fertilizers are added. They contain important nutrients which help in production of natural fish food organism (plankton). There are two basic types of fertilizers: organic and inorganic.

3.1.2 Stocking

Stocking a pond means releasing into the pond an adequate number of selected fish species which are of the right size. The fish pond is stocked a week after fertilization. The stocking density of the pond depends on the fish culture system adopted and the species cultured. Generally for pond culture and for species which do not reproduce early, the stocking rate vary from 1- 3 fish/sq.m (i.e.10,000 – 30,000 fish/hectare). However, stocking rates can be higher with high technology.

In stocking fish ponds; monoculture (one type of fish) or polyculture (mixed fish species) can be adopted. For polyculture systems, the following stocking ratios may be used.

Tarpon + Tilapia = 1: 2

Mudcatfish + tilapia = 1: 3

Grey mullet + tilapia = 2: 1.

Fish fingerlings for stocking ponds can be produced by the farmer or purchased from reputable hatcheries. The ponds are stocked either early in the morning or late in the evening. This is to avoid stressing the fish during hot weather. The total number and weight of fish stock are recorded. The fish pond is checked the next morning for any mortality. Dead fish are removed, counted and replaced with live one.

3.1.3 Feeding

In the water natural food is available to the fish. Some fish e.g. *Heterotis, Tilapia*feed on microscopic plants or soft plant parts and are called herbivore. Some feed on other aquatic animals as well as fish and are called carnivore e.g. Tarpon, Niger perch, while others feed on both plants and animals and are called omnivore e.g. Mudcatfish.

In culture systems, fish is given supplementary or artificial diet to make them grow faster. There are a variety of fish feeds formulated from different feed ingredients. Feeding of fish is carried out by broad casting at selected spots 9 feeding spots) in the pond. Automatic or demand feeder may be used. Pelleted feeds are preferred to powdery feed. However, the size of the pellets must not be too big for the fish to swallow.

3.1.4 Fish Sampling

Periodic check on fish growth is vital for pond management. Monthly or bi-monthly fish sampling is carried out to check growth rate and to calculate the feed ration.. During sampling, a small quantity of the fish stock is scooped out, counted, weighed, and returned to the pond. Any fish showing signs of disease condition is removed for thorough examination

3.1.5 Harvesting (Cropping)

Harvesting a fish pond is undertaken when the fish stock or part of it has attained marketable size. Market size of fish is determined by consumer acceptability and preference. Most culturable fish species; with proper feeding and good management attain market size within 6 – 9 months of stocking. Cropping of pond can be partial, that is, removal of bigger fish and allowing the smaller one to grow to the desired size or complete (total) i.e. removal of all fish in the pond. Feeding is stopped 2- 3 days before cropping. The pond is completely drained and fish scoped out. They are sorted into different sizes and/or different species, counted and weighed. Small fish are returned to the nursery ponds for stocking. Tools used for stocking include seine or drag nets, scoop nets, traps, hook and line e.t.c.

3.1.6 Marketing and fish preservation

Harvested fish can be marketed live, smoked of frozen. Fish can be sold direct to the consumers or through a distributor. It may be necessary to advertise fish sales to minimize high post harvest lose. Unsold fish (live) can be preserved by storing in deep freezers or cold rooms. Smokings, sun-drying, salting and canning are other methods of fish preservation.

4.1.7 Record Keeping

It is important for the fish manager to keep accurate records of all fish farm activities. Such records may include labour cost, cost of lime/fertilizer and rate of application; cost of fingerlings and fish feed; harvest and sales. Fish farm records aim in good farm management and in evaluating the economic viability of the project.

In general,fish ponds require management and maintenance. Some basic practices should be followed.

1. Keep unwanted fish out of the pond.

Carnivorous fish can eat fingerlings stocked into a pond (Figure 6). Other wild fish will compete with stocked fingerlings for food causing slow growth. Wild fish should be removed from fingerlings being stocked into a pond. Pond water inlets should be covered with a fine mesh screen or similar materials to prevent entry of wild fish. Screens should be inspected daily and cleaned if necessary to prevent clogging. The pond should be completely drained and dried (preferably until cracks appear in the mud) before refilling and stocking new fish. Any fish remaining in undrainable areas may be killed with poisons which are not dangerous to humans.

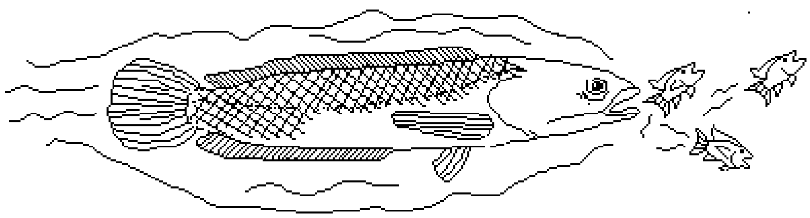


Figure 6: Carnivorous fish will eat fingerlings and should be kept out of a pond.

2) Lime and fertilize the pond.

Natural fish food organisms are usually not abundant in clear pond water, but are abundant in ponds having greenish colored water. The green color indicates the presence of phytoplankton and other natural food organisms. Liming (Figure 8) and fertilization help increase the abundance of these organisms. Lime is not available in many areas and may not be necessary if the pond soils and/or water are not acidic. Soil and water may be tested in a laboratory or with a kit to determine whether liming is required. Testing for acidity can save a farmer time, labor and expense. An agricultural extension agent should be contacted for information on soil and water testing and lime requirements.

Chemical and organic fertilizers may be applied separately or in combination to ponds (Figure 7). Figure 7 illustrates a useful technique for determining whether enough fertilizer has been added to a pond. Numerous factors are linked to the effectiveness of liming and fertilization on stimulating natural fish food production. Further details on liming and fertilization are contained in brochures from this series entitled: "Introduction to Fish Pond Fertilization", "Chemical Fertilizers For Fish Ponds" and "Organic Fertilizers For Fish Ponds".

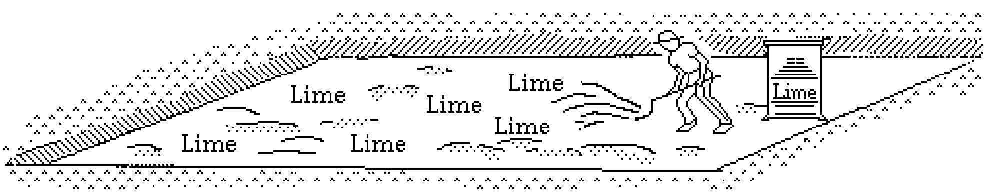


Figure 7: Spread lime evenly over the pond bottom.

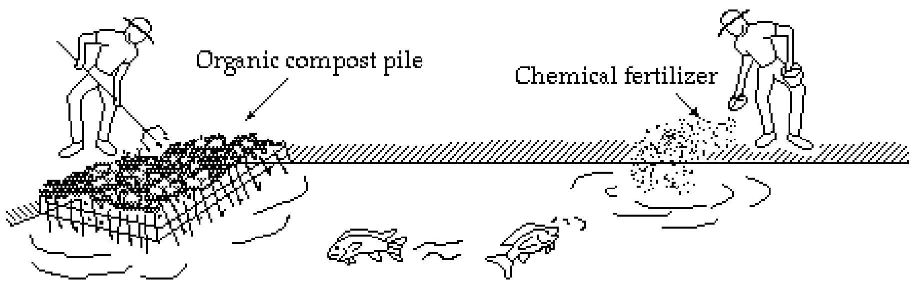


Figure 8: Add manure and/or chemical fertilizer.

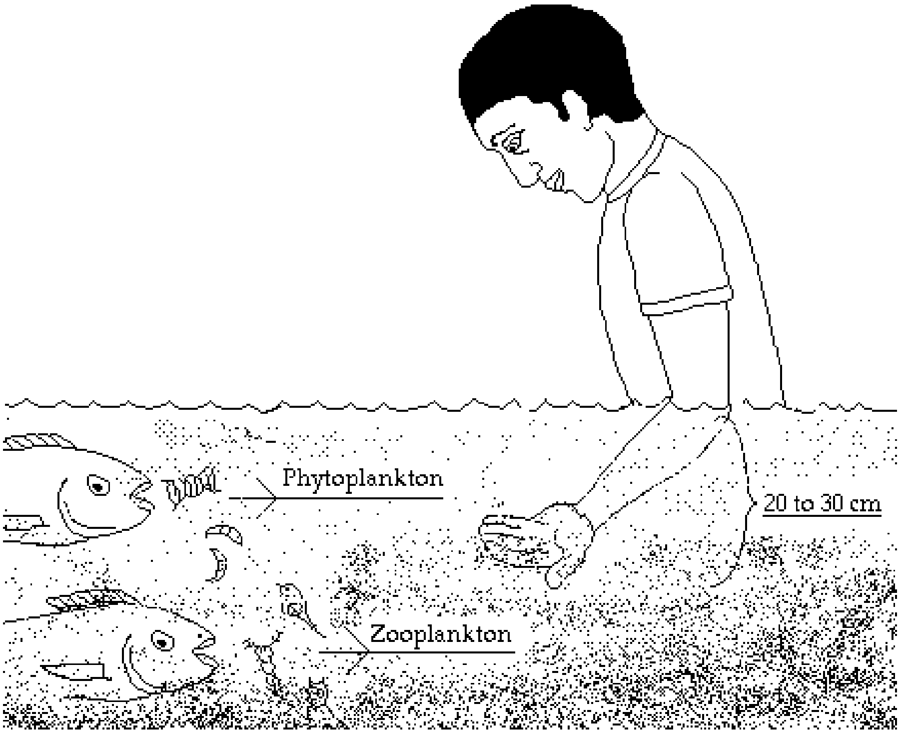
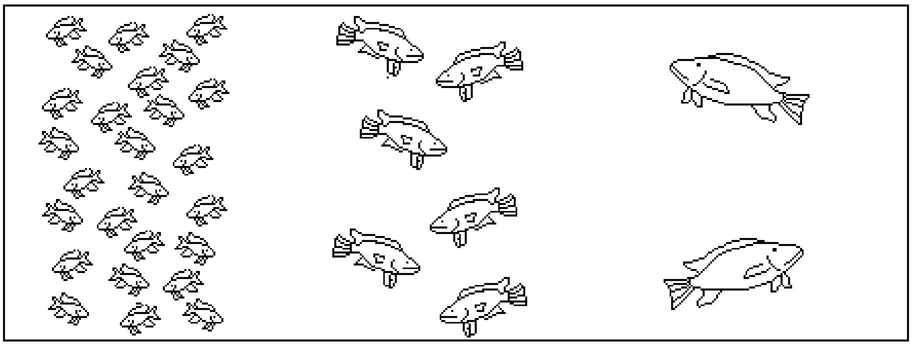


Figure 9: Inspect pond water for plankton abundance using the upturned palm of hand and elbow as guides. Visibility of the palm to a depth of 20 to 30 cm (elbow depth) indicates abundant plankton.

A common misconception about growing fish in ponds is that fish require continuously flowing water. Fresh water is added to a pond only as needed to correct poor water quality, as will be mentioned later, or to replace evaporation and seepage. Excess water flow washes out fertilizer nutrients and inhibits plankton growth. Diversion canals channel excess water away from ponds and prevent fertilizer nutrients and natural food from being flushed out of the ponds.

- 3) Stock the right number of fish.

  The proper number of fish should be stocked into ponds to ensure good fish growth and yield (Figure 10). Overstocking results in crowding and slow growth. Understocking results in poor utilization of natural food organisms in the pond and low fish yield. Proper stocking rates for tilapia range from 1 to 2 fish per m2 of pond surface area. Common carp are stocked at 1 to 2 fish per 10 m2 of pond surface area. The higher stocking rate is used for both tilapia and carp when fish are given supplemental feed. Stocking more than 2 carp per 10 m2 will cause the water to become muddy as a result of bottom feeding activity.



Overstocking results in:
- scarce food
- small size
- slow growth

Proper stocking results in:
- adequate food
- large size, high yield
- fast growth

Understocking results in:
- underutilized natural food
- large size, low yield
- fast growth

Figure 10: Stocking rates affect the growth of fish, their utilization of natural food and their final size at harvest.

FEEDING YOURFISH

Fish in fertilized ponds will grow faster when they are provided with supplemental feed. Tilapia and carp will consume a wide variety of feeds, many of which are available to rural farmers. Examples of supplemental feeds are rice bran, wheat bran, corn gluten, African palm seed meal, dried and ground leaves from mullberry and ipil-ipil trees and manioc plants, dried blood, chopped earth worms, termites, chopped snails and insects. Two daily feedings (morning and mid-afternoon) are suitable under most situations. The amount fed depends on the number of fish stocked and their average weight. Fingerlings are generally fed 10 to 12 % of their body weight. The feeding rate is gradually reduced to 2 to 3 % of body weight by the time fish reach market size.

4.0 Conclusion

Fish pond management is imperative for an effective and productive ventures

5.0 Summary

Fish pond management involves preparation of the ponds, stocking, feeding, and maintaining good quality water, fish sampling, maintenance of pond structures, fish harvesting/marketing and record keeping.

6.0 Tutor-Marked Assignments

Outlines and explain the major steps involve in effective pond management

7.0 Further reading

Anyanwu, P.E. (1994) Fish Pond Management. In: Proceeding of fish farming work-shop (Ed. Ajana. A.M.).Pp 48-56. Organized by Shell Development Company, Lagos (1994).

GLOSSARY OF TERMS FOR POND MANAGEMENT.

Anti-seep collar - a plate, usually constructed of cement or steel, which is attached around a drain pipe and extends about two feet outward from it. It is buried in the pond dike to retard the seepage of water through the dike along the drain pipe.

Chemical fertilizers - manufactured fertilizers containing nitrogen, phosphorous and potassium in varying proportions.

Fertilizer - a substance added to water to increase the production of natural fish food organisms.

Fingerling - a fish weighing from 1 g to 25 g or measuring longer than 2.5 cm in total length.

Fish toxicant/poison - A substance used to kill fish in ponds prior to stocking fingerlings.

Organic fertilizer/manure- animal or plant matter used as fertilizer in ponds.

Natural fish food organisms - plankton, insects and other aquatic organisms that fish eat.

Oxygen depletion/low oxygen - a condition, normally occurring at night, in which oxygen dissolved in pond water has been depleted mainly because of the decomposition of organic matter and respiration of organisms in the pond.

Phytoplankton - the plant component of plankton.

Plankton - the various, mostly microscopic, aquatic organisms (plants and animals) that serve as food for larger aquatic animals.

Pond dike - the wall of a pond which is constructed to hold in the water.

Predatory/carnivorous fish - a fish species that eats other fish.

Supplemental/incomplete feed - a feed that does not contain all the vitamins and nutrients essential for growth, and which is produced outside of the pond.

MODULE 8: HATCHERY

Unit 1: Operating principles for hatcheries

Content
1.0 Introduction
2.0 Objectives
3.0 Main Body
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

A fish hatchery is a place where large numbers of fish eggs are artificially fertilized and fry and are hatched in an enclosed environment. Fish hatcheries can increase a fish population quickly ain the wild only 2% of the eggs survive (versus 80% using a hatchery). Some hatcheries raise the fry until they reach adulthood and have commercial value; others release the fry into the wild with the intent of building up the wild stock.

For fish culture, it is necessary to ensure the supply of suitable sized good quality fish seed in sufficient quantities. The main source fish seeds are spawn produced in government and private hatcheries, and some collected from rivers. The seed collected from natural breeding grounds have many problems such as the inclusion of seed of predatory fishes or disease. Wild seedis collected and handled in crude and unscientific methods that can potentially lead to large scale mortality during transportation from collection centers to nursery ponds and also in the nursery ponds after release. Therefore, emphasis should be placed on expansion of hatchery facilities to supply high-quality fish seed required to support aquaculture development.

The hatchery phase is often the aspect that limits aquaculture expansion. Water environments that may be adequate for adult fish may not be sufficient for breeding, fish eggs and hatchlings. Any number of environmental factors can cause adults to become infertile. Fish eggs and baby fish are a favorite food for some predators like frogs, turtles and other fish. Some adult fish even eat smaller fish and eggs of their own species. Fish hatcheries resolve these problems.

The entire life cycle of the aquaculture (figure 1), from egg to market-size product, is completed in a *production line* composed of these stages:

Hatchery :	Parental brood stock produces high quality hybrid fry.
Nursery :	Young fry are raised to juveniles.
Grow-out :	Juveniles are raised to market size product.
Processing Plant :	Processing and packaging of fish fillets.
Support & service :	ensuring supply of feed, disease control, etc.
Marketing :	Distribution to local and foreign markets.

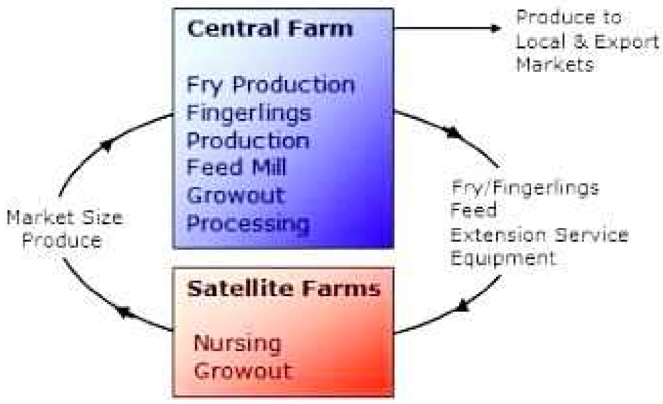


Figure 1: Life cycle of aqua-cultural products

2.0 Objective

At the end of this unit, student should be able to

1) explain the needs for fish hatchery
2) enumerate the various purposes of fish hatchery
3) itemize hatchery pollutants
4) state the differenthatchery requirement
5) describe theoperating principles for hatchery management

3.0 Main Body

3.1 Needs for Fish Hatchery

A fish hatchery is a facility designed to raise fish. It provides an optimum environment for fish eggs to develop and hatch by maintaining proper water temperature and oxygen levels, and providing adequate food supplies and safety from predators. A fish hatchery works to raise baby fish and prepare them for release in another environment for various reasons, as well as for food

One purpose of a fish hatchery is to raise a certain kind of fish in order to stock a lake or pond for fishing. Certain types of fish, such as trout and salmon, are favorites among fisherman. Sometimes, in a popular fishing hole, the fish are harvested too quickly to allow them to breed and grow. A fish hatchery provides a safe haven until the fish are mature enough to be caught.

Another reason that a certain fish may be raised in a fish hatchery is for environmental conservation. Every animal has its place in the ecosystem. Sometimes, human activity makes it impossible for fish to breed or causes them to disappear from a body of water altogether. A fish hatchery can reintroduce mature, healthy fish to a previously inhabited body of water where they will maintain the ecosystem by doing their part in the food chain.

A fish hatchery may also be used to farm fish for human food consumption. Hatching and raising fish for food has many advantages for humans and the environment. First, because of pollution, many wild fish are contaminated with dangerous pollutants such as mercury and polychlorinated biphenyls (PCBs). Consuming these pollutants is hazardous to human health. Farm raised fish contain lower levels of contaminants, which helps to reduce this risk. Raising fish in a hatchery also helps to relieve the environmental pressures in an area due to over-fishing.

3.2 Purposes of fish hatchery

- **Fish farms**

Fish farms use hatcheries to cultivate fish to sell for food or ornamental purposes, eliminating the need to find the fish in the wild, and even providing some species outside of their natural season. They raise the fish until they are ready to be eaten or sold to aquarium stores.

- **Fish stocking**

Other hatcheries release the juvenile fish into a river, lake or the ocean to support commercial, tribal, or recreational fishing or to supplement the natural numbers of threatened or endangered species, a practice known as fish stocking. Some fish hatcheries are used to mitigate the effects of development, such as construction of a dam, hydroelectric plant or water diversion.

- **Ornamental fish**

The ornamental fish industry uses fish hatcheries to produce fish for the aquarium fish trade; this has helped to limit the overharvesting of native fish populations both in fresh and salt water ecosystems.

3.3 Hatchery Requirement

The efficient operation of a fish hatchery depends on a number of factors. Among these are suitable site selections, soil characteristics, and water quality. Adequate facility design, water supply structures, water source, and hatchery effluent treatment must also be considered

- **Site Selection**

Water quality is among the most critical of considerations during site selection. This is of equal importance to both fresh and saltwater resources. Listed in figure 2 are water quality ranges required during various hatchery production phases.

Water quality requirements

Temperature:	28 – 32°C
DO	> 5 ppm
CO_2	< 20 ppm
pH	7 – 8.3
Salinity	0.5 – 35 ppt
Chloride	> 300 ppm
Sodium	> 200 ppm
Total hardness as $CaCO_3$	> 150 ppm
Ca hardness as $CaCO_3$	> 100 ppm
Mg hardness as $CaCO_3$	> 50 ppm
Total alkalinity as $CaCO_3$	> 100 ppm
Unionized ammonia NH_3	< .03 ppm
Nitrite (NO_2)	< 1 ppm
Nitrate (NO_3)	< 60 ppm
Total Iron	< 1ppm
Hydrogen Sulfide (H_2S)	< 2 ppb
Chlorine	< 10 ppb
Cadmium	< 10 ppb
Chromium	< 100 ppb
Copper	< 25 ppb
Lead	< 100 ppb
Mercury	< 0.1 ppb
Zinc	< 100 ppb

Hatchery water requires significant pre-treatment inclusive of solids removal, disinfection, carbon filtration, and binding of heavy metals.
Hatchery design needs to be scaled in proportion to required post larvae (PL) production for grow-out. Species with seasonal availability of brood stock or spawning capabilities require larger infrastructure because facilities are not in continuous production. Hatchery sizing should be based upon species and production requirements.

- **Water Quality**

It determines to a great extent the success or failure of a fish cultural operation. Physical and chemical characteristic such as suspended solids, temperature, dissolved gases, ph, mineral content and the potential danger of toxic metals must be considered in the selection of site of a suitable water source.

- **Temperature**

No other single factor affects the development and growth of fish as much as water temperature. Metabolic rates of fish increase rapidly as temperatures go up. Many biological processes such as spawning and egg hatching are geared to annual temperature changes in the natural environment. Each species has a temperature range that it can tolerate, and within that range it has optimal temperatures for growth and reproduction. These optimal temperatures may change as a fish grows. Successful hatchery operations depend on a detailed knowledge of such temperature influences.
The temperature requirements for a fish production program should be well defined, because energy must be purchased for either heating or cooling the hatchery water supply if unsuitable temperatures occur. First consideration should be to select a water supply with optimal temperatures for the species to be reared or, conversely, to select a species of fish thatthrivesin the water temperatures naturally available to the hatchery.

It is important to remember that major temperature differences between hatchery water and the streams into which the fish ultimately may be stocked can greatly lower the success of any stocking program to which hatchery operations may be directed. Within a hatchery, temperatures that become too high or low for fish impart stresses that can dramatically affect production and render fish more susceptible to disease. Most chemical substances dissolve more readily as temperature increases; in contrast, and of considerable importance to hatchery operations, gases such as oxygen and carbon dioxide become less soluble as temperatures rise.

- **Dissolved Gases**

Nitrogen and oxygen are the two most abundant gases dissolved in water. Although theatmosphere contains almost four times more nitrogen than oxygen in volume, oxygen has twice the solubility of nitrogen in water. Therefore, fresh water usually contains about twice as much nitrogen as oxygen when in equilibrium with the atmosphere. Carbon dioxide also ispresent in water, but it normally occurs at much lower concentrations thaneither nitrogen or oxygen because of its low concentration in the atmosphere.
All atmospheric gases dissolve in water, although not in their atmospheric proportions; as mentioned, for example, oxygen is over twice as soluble as nitrogen. Natural waters contain additional dissolved gases that result from erosion of rock and decomposition of organic matter.

Several gases have implications for hatchery site selection and management. Oxygen must be above certain minimum concentrations. Other gases must be kept below critical lethal concentrations in hatchery or pond water. As for other aspects of water quality, inappropriate concentrations of dissolved gases in source waters mean added expense for treatment facilities.

3.4 Hatchery Pollutants

Generally, three types of pollutants are discharged from hatcheries: (l) pathogenic bacteria and parasites; (2) chemicals and drugs used for disease control; (3) metabolic products (ammonia, feces) and waste food. Pollution by the first two categories is sporadic but nonetheless important. If it occurs, water must be sterilized of pathogens, disinfected of parasites, and detoxified of chemicals. Standby detoxification procedures should be in place before the drug or chemical is used. The third category of pollutants — waste products from fish and food — is a constant feature of hatchery operation, and usually requires permanent facilities to deal with it. Two components — dissolved and suspended solids — need consideration.

Dissolved pollutants predominantly are ammonia, nitrate, phosphate, and organic matter. Ammonia in the molecular form is toxic, as already noted. Nitrate, phosphate, and organic matter contribute to eutrophication of receiving waters. For the trout and salmon operations that have been studied, each kg of dry pelleted food eaten by fish yields 0.032 kg of total ammonia, 0.087 kg of nitrate, and 0.005 kg of phosphate to the effluent (dissolved organic matter was not determined separately). The feed also contributes to Biological Oxygen Demand (BOD), commonly used as an index of pollution; it is the weight of dissolved oxygen taken up by organic matter in the water.

More serious are the suspended solids. These can, as they settle out, completely coat the bottom of receiving streams. Predominantly organic, they also reduce the oxygen contents of receiving waters either through their direct oxidation or through respiration of the large microbial populations that use them as culture media. For the trout and salmon hatcheries mentioned above, each pound of dry feed results in 0.3 kg of settle ablesolids — that part of the total suspended solids that settle out of the water in one hour. Most of these materials have to be removed from the effluent before it is finally discharged. Typically, this is accomplished with settling basins of some type.

3.5 Operating Principles for Hatchery Management

(1) Hatchery management and reform will generally proceed from the following hatchery premise: The ideal hatchery removes as many random mortality effects as possible without having any other influence on the natural life or experience of native fish and their habitats. The hatchery premise has five main components that managers shall strive to incorporate into hatchery programs:

(a) Removing random mortality occurring in the natural environment;

(b) Simulating selective mortality operating in the natural environment;

(c) Minimizing artificial selection;

(d) Providing fish rearing and training experiences to reduce unnatural behaviors; and

(e) Minimizing ecological impacts associated with hatchery operations (e.g., competition and predation associated with release location and number, pathogen transfer and amplification, pollutants, passage barriers, over harvest of weak stocks in mixed stock fisheries).

(2) Success moving toward the premise in subsection (1) will be largely dependent on funding, research, program type, and facility or operating flexibility.
(3) Hatchery program management plans shall be developed and implemented in consultation and cooperation with management partners and the public, and in coordination with native fish conservation policy plans at local and regional scales.
(4) Hatchery programs shall be managed to provide optimum fishery and conservation benefits, based on the best available scientific information. Most programs will contribute toward fish management objectives primarily by raising fish for harvest while minimizing the impact on, or benefiting, fish that spawn naturally.
(5) Hatchery facilities shall be operated to maximize fish quality and minimize adverse impacts to watersheds, consistent with fish management objectives, applicable permits and agreements.
(6) Monitoring and evaluation shall be adequate to measure progress toward fish management and hatchery program objectives, contain risks within acceptable limits, and provide feedback for adaptive management.

4.0 Conclusion

Originally devised to mitigate for fish production lost through development and supply the demand for fishing from an expanding human population, fish hatcheries have been criticized for producing poor quality or genetically inferior fish. Several researchers have raised concerns about hatchery fish potentially breeding with wild fish. Hatchery fish may in some cases compete with wild fish. There is debate among the scientific community regarding the risks and benefits of hatchery programs. Proving negative (or positive) effects of hatchery programs on wild fish is challenging due to numerous other environmental and anthropogenic factors that simultaneously affect fish. In the United States and Canada, there have been several salmon and steelhead hatchery reform projects intended to reduce the possibility of negative impacts from hatchery programs. Most salmon and steelhead hatcheries follow up to date management practices to mitigate potential risks.

5.0 Summary

A fish hatchery is a place where large numbers of fish eggs are artificially fertilized and fry and are hatched in an enclosed environment. Fish hatcheries can increase a fish population quickly but in the wild only 2% of the eggs survive (versus 80% using a hatchery). Some hatcheries raise the fry until they reach adulthood and have commercial value; others release the fry into the wild with the intent of building up the wild stock.The hatchery phase is often the aspect that limits aquaculture expansion.Generally, three types of pollutants are discharged from hatcheries: (l) pathogenic bacteria and parasites; (2) chemicals and drugs used for disease control; (3) metabolic products (ammonia, feces) and waste food. Pollution by the first two categories is sporadic but nonetheless important.The third category of pollutants — waste products from fish and food — is a constant feature of hatchery operation, and usually requires permanent facilities to deal with it.Operating Principles for Hatchery Management outline the standard operating procedure for successful hatchery.

6.0 Tutor-Marked Assignments

1. Write an essay on the roles of fish hatchery in fish production?
2. Discuss the operating principles for hatchery management.

7.0 Reference/ Further Reading

Huet, M.V. & D.E. Canfield Jr. (1972).Textbook of fish culture.Fishing News Books. Surrey, England. 436pp.

Fish Hatchery Management Policy May 9, 2003 Oregon Department of Fish and Wildlife

Terms associated with fish hatchery

Aquaria species: means those fish commonly sold in the pet store trade for use in home aquaria. "Aquaria" are any tanks, pools, ponds, bowls or other containers intended for and capable of holding or maintaining live fish and from which there is no outfall to any waters of this state.
Brood stock: means a group of fish, generally from the same population that are held and eventually artificially spawned to provide a source of fertilized eggs for hatchery programs.
Disease: means problems caused by infectious agents, such as parasites or pests, and by other conditions that impair the performance of the body or one of its parts.
Fish Hatchery: means a facility at which adult brood-stock are held, or where eggs are collected and incubated, or where eggs are hatched, or where fish are reared.
Hatchery produced fish: means a fish incubated or reared under artificial conditions for at least a portion of its life.
Hatchery production system: means the fish, facilities and operations associated with collecting, spawning, incubating, rearing, distributing and releasing hatchery produced fish.
Hatchery Program: means a program in which a specified hatchery population is planted in a specified geographical location.
Native fish: means indigenous to Oregon, not introduced. This includes both naturally produced and hatchery produced fish.
Naturally produced: means fish that reproduce and complete their full life cycle in natural habitats.
Natural production system: means the fish and environment associated with completing the life-cycles of naturally produced fish populations.
Production: means the number fish raised in a hatchery or resulting from natural spawning and rearing in freshwater, estuarine, or ocean habitats; also used in reference to harvest.
Propagation of fish: means the spawning, incubating, and/or rearing of fish by a human for sale, release or other uses.
Random mortality: means fish mortality that generally does not affect the genotypic or phenotypic traits of fish populations.
Selective mortality: means fish mortality that generally affects the genotypic and phenotypic traits of fish populations.

MODULE 9: FISH FEED FORMULATION

Unit 1: Feed formulation

Content
1.0 Introduction
2.0 Objectives
3.0 Main Body

3.1 Choice of ingredients
3.2 Quality control
3.3 Steps In feed formulation
3.4 Best-Buy Techniques
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

Feed formulation represents translation of nutrient and energy requirements of a given species for a given response into an acceptable diet using a balanced mixture of ingredients which is economically sustainable. The reliability of knowledge on the quality of ingredients and the constraints retained both have an impact on the quality of diet formulation.
A fish feed should supply all essential nutrients and energy in tune with the animal's needs for the maintenance of vital physiological functions such as growth, reproduction and health. Besides, in aquaculture as in other animal production systems, another major issue is that of ensuring flesh and environmental quality, both of which are related to nutrition. Since the nutrient requirements for all the new species under aquaculture are not known, it is rather a common practice to extend data from more or less closely related species. In the formulation of diets, it is essential that, even when the diets are formulated theoretically to contain all the essential nutrients in adequate quantities, the availability of these nutrients from the raw materials used can vary significantly. The diet should be supplied in a form which is easily accepted by the cultivated animal and should have little adverse environmental impact.

2.0 Objective

At the end of this unit, students should be able to

1) explain how to choose high quality ingredients for feeds formulation
2) enumerate the different steps in feed formulation

3.0 Main Body

3**1 Choices and Quality of Ingredient**

Despite much research, both intensive and semi-intensive aquaculture relies upon a relativelysmallnumber of feed ingredients. Under semi-intensive culture conditions, cereal bran-oilcake mixtureremains the major aqua-feed. In intensive aquaculture, the diets are formulated to be nutrient andenergy dense, based mainly on ingredients of marine origin. Since most teleosts are known to utilize dietary carbohydrates rather poorly, the chosen ingredients are necessarily protein and energy-rich.When it comes to finding alternatives to fishmeals as a protein and amino acid source, several otheragricultural by-products such as animal by-products, cereals (wheat, corn), pulses (lupin, peas, fababeans), oil seeds (soybean, rapeseed) hold potential interest (Table 1), depending upon localavailability and cost.

Table 1. Crude protein (CP) levels of different alternatives to fishmeal

CP levels	Ingredients
<25%	Whole cereals, pulses, oil seeds
25-50%	Oil seed meals
>50%	Animal by-products (meat meal, blood meal), plant protein concentrates, isolates, extractives, single cell proteins

Feed formulation is essentially applied nutrition. A number of terms and expressions are introduced that will be put to practical use as information is presented on the nature and qualities of various feedstuffs and the information presented on the nutrient requirements of fish. Precise understanding of these terms is essential to their correct application. One must recognize that some of these terms have a built-in error that cannot be escaped. This does not eliminate their usefulness in feed formulation. However, one must appreciate the fact that some are useful approximations of the values and not true values.

The terms that one needs to understand to formulate practical fish diets are: crude protein level; energy level, either expressed as metabolizable energy (ME) or as digestible energy (DE); specific amino acid levels; crude fibre level; and ash level. Since most complete practical fish diets are supplemented with a vitamin premix at levels in excess of the dietary requirement, this category of nutrients will be ignored temporarily. The potential problems occur when one fails to recognize that all of the above mentioned terms, except ME and DE, represent the quantity or level of a nutrient in the feed as determined by chemical tests on a specific sample of a feedstuff. These chemical tests generally correlate well enough with biological methods of feed evaluation (growth studies, tissue, levels) to be very useful to feed formulators, but they are still chemical tests that are subject to experimental error during nutrient level determination. For example, the proximate composition of fish meals changes during the spawning season. Generally, the lipid levels increase before spawning and decrease after spawning. This will alter the percent of protein, ash, and carbohydrates in fish meal as the seasons change. Similarly, many plant feedstuffs vary in proximate composition with their stage of maturity at harvest, location grown, and other environmental conditions, such as the weather. Tabled values represent an average value that is usually close enough to the actual value to allow accurate feed formulation. However, one must be aware that assumptions are being made in order to recognize the potential sources of error that may exist

Metabolizable, energy and digestible energy values are obtained biologically and, thus, should accurately represent the true energy value of feedstuffs to fish. However, ME values may be obtained in different ways (faeces collection methods) and thus may be subject to experimental error. It has recently been reported that the digestibility of feed by rainbow trout was lower at 7°C than at 11°C or 15°C. At 11°C and 15°C body size (18.6 g, 207.1 g or 585.7 g) did not affect feed digestibility. The digestibility of carbohydrate and energy was slightly reduced by meal size in rainbow trout fed at 1.6 percent body weight. Protein and lipid digestibility was not reduced by meal size. Obvious differences exist between fish species in nutrient digestibility, especially in the carbohydrate fraction of feed. Herbivorous and, to a lesser extent, omnivorous fish have longer digestive tracts than do carnivorous fish and are able to obtain more digestible energy from carbohydrates. An awareness of these facts will prevent misuse of ME and DE values.

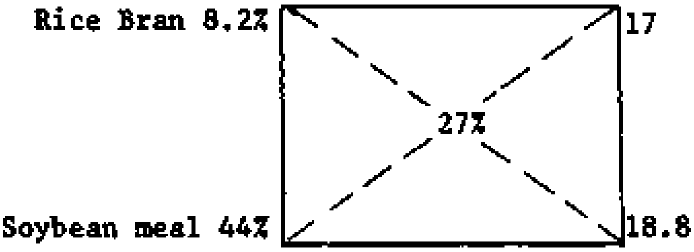
Each feedstuff in any diet formulation should be present for a specific reason; i.e., it is a good energy source, it is rich in a limiting amino acid, etc. In addition, each feedstuff in a particular diet formulation should be the least costly ingredient available for its particular function in the diet. This leads to another assumption in feed formulation; that is, any nutrient in a particular feedstuff, such as an amino acid, is just as valuable as the same nutrient in any other feedstuff. This allows feed formulators to interchange one feedstuff with another as cost and availability change. Thus, it is assumed that there is no "ideal formulation", but rather an almost infinite number of possible feed formulations that met the nutritional needs of the fish equally well. While this assumption may not be entirely valid and some nutritional judgement must be employed in any feed formulation, it does seem to be valid in most cases. As with the previously mentioned assumption, an awareness of the potential pitfalls involved is necessary for the fish feed formulation so that allowances can be made in diet formulation and problems can be anticipated and avoided.

- **Physical characteristics of ingredients**

Since most fish do not possess the necessary grinding appendices in the mouth, dietary particlesize should be sufficiently small to be ingested whole and available for digestive processes. Generally, it is recommended that the particle size of all ingredients be below 250 microns but this should naturally be much lower when dealing with diets for larval or juvenile stages offish.The significance of reducing particle size on improving physical characteristics of the finished feed is related to improved digestibility. Reduction in particle size improves gelatinisation ratio, increases pellet durability and water stability, but is economically rather expensive. Since most ingredients used for terrestrial animal production are rather coarse, fish feed manufacturers resorting to such ingredients have to pay special efforts to reduce the particle size of such ingredients.
Another aspect which has practical significance for the feed processing engineer is the possibledifferences in physical characteristics of the ingredients such as pack density, specific gravity, compressibilityviscosity, heat capacity and conductivity, etc. The adaptability of the feedmanufacturer and his machinery to such changes in the physical characteristics of ingredients is important in fine-tuning the final product still meeting the nutritional standards.

3.2Quality control

For formulating feeds for experimental purposes, it is necessary that all ingredients are controlledfor all essential nutrients. But, under practical conditions, such a control is difficult to set forth and mostly restricted to rapid proximate composition analyses. Specific attention should however be given to obtain guarantees for absence of anti-nutritional factors, to avoid adulteration of products and for homogeneity between batches. Besides such quality control of incoming ingredients, a strict control of material flow within the factory is of utmost importance to avoid deterioration of the nutritional value (oxidation, potency of vitamins) of ingredients and premixes.

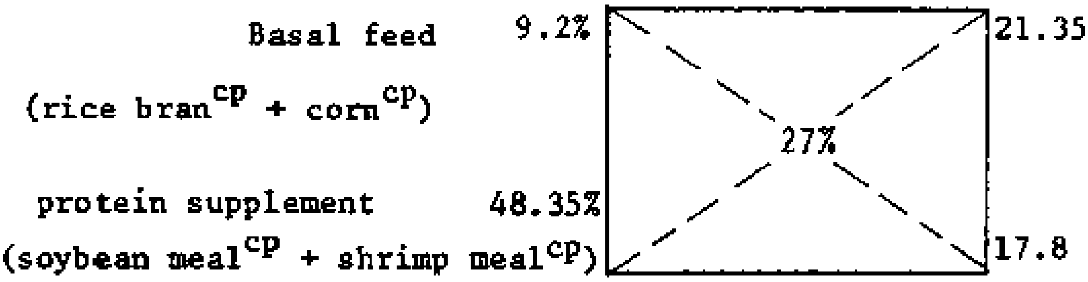


To make the 27 percent crude protein carp feed, we must mix 17/35.8 of rice bran with 18.8/35.8 soybean meal.

Rice Bran 17/35.8 = 47.5%
Soybean meal 18.8/35.8 = 52.5%

So to make 100 kg of this feed we must mix 47.5 kg of rich bran with 52.5 kg of soybean meal.

If more than two feedstuffs are used in a feed, they may be grouped into basal feeds (CP < 20 percent) and protein supplements (CP > 20 percent), averaged within each group, and plugged into the square method. For example, suppose shrimp meal and corn were also available for the carp feed mentioned above. The crude protein levels of the shrimp meal (52.7 percent) and of corn (10.2 percent) are averaged with soybean meal and rice bran, respectively.



Basal feed = 21.35/39.15 = 54.53%
Protein supplement = 17.8/39.15 = 45.47%

Thus, to make 100 kg of this feed one would mix the following:

Rice bran	27.265 kg
Corn	27.265 kg
Soybean meal	22.735 kg
Shrimp meal	22.735 kg

The square method is helpful to novice feed formulators because it can get them started in diet formulation without the need to resort to trial and error. The square method can also be used to calculate the proportion of feeds tuffs to mix together to achieve a desired dietary energy level as well as a crude protein level

3.3: STEPS IN FEED FORMULATION

The first step in diet formulation is balancing the crude protein and energy levels. This can be accomplished by trial and error, by the square method for either crude protein level or energy level and then adjusting, or by solving simultaneous equations. At first, it is helpful to use at least three feeds tuffs during the initial balancing of protein and energy levels: one high in protein and high in ME, one low or intermediate in protein and high in ME, and one low or intermediate in both protein and ME. Once practice makes one more proficient at diet formulation any number of feedstuffs can be used. One must remember to reserve room in the formulation for any feed additive, such as a vitamin or mineral pre-mix.

The second step in diet formulation is to check the levels of indispensable amino acids in the formulation to be sure the dietary levels meet the requirements of the animal to be fed. The requirements of fish for indispensable amino acids is expressed as the dietary level (as a percent of the diet) or as a percent of the dietary protein level. To convert an amino acid level from the percent of diet to percent of protein, divide the dietary level of each amino acid by the dietary protein level. It might be of interest to calculate the dietary levels of all of the indispensable amino acids, but it is not practical to do it all of the time. If the levels of arginine, lysine, methionine, and tryptophan meet the dietary requirements of the fish to be fed, the levels of the other six indispensable amino acids will most likely be above required levels. When using unconventional protein supplements, the levels of all ten indispensable amino acids should be checked.

If the diet formulation is low in any amino acid, a feedstuff that contains high levels of that amino acid must be added to the diet at the expense of another ingredient. Once the amino acid requirements are met, the dietary protein and energy levels must be rechecked to, see if any substitution of ingredients has imbalanced the formulation.

A diet mixing sheet should be constructed to standardize diet formulation. A sample sheet is shown in Table 1. The amino acids listed are for illustration purposes only and may be changed to suit different circumstances.

In practical feed formulation, pellet quality and acceptability must be considered in addition to nutrient levels and cost. These considerations will vary from species to species and with the type of pellet being made, and are dealt with in other sections of this manual.

3.4: BEST-BUY TECHNIQUES

The price of the feedstuffs used in diet formulations must be considered to formulate a cost-efficient diet. Feedstuffs can be compared with one another on the basis cost per unit of protein, energy, or amino acid. For example, suppose one has wheat middlings and wheat millrun available for a fish diet, which feedstuff would be the least expensive source of energy?

Wheat millrun costs US $ 0.0858/kg, and contains about 1200 kcal ME/kg.

$$\text{Cost / kcal} = \frac{.08758}{1200} = \text{US \$ 0.0000715 / kcal.}$$

Wheat middlings cost US $ 01883/kg and contain 1663 kcal ME/kg.

$$\text{Cost / kcal} = \frac{0.1883}{1663} = \text{US \$ 0.0001132 / kcal.}$$

Thus, the wheat millrun which has a lower ME value for fish is the better buy because it costs less per kcal.

To compare oat groats and wheat middlings on a cost per unit ME basis one would do the following:

Wheat middlings = US$ 0.0001132/kcal, and

Oat groats cost US $ 0.2652/kg, and contain about 2450 kcal ME/kg.

$$\text{Cost / kcal} = \frac{0.2652}{2450} = \text{US \$ 0.001082 / kcal.}$$

Oats groats, although costing more than wheat middlings, constitute a better buy on an energy basis.

The cost of protein is often the greatest part of the cost of a fish diet. Therefore, substantial savings can be made by using best-buy techniques to determinate least expensive protein supplement. To compare anchovy meal and herring meal, the following calculations are made:

Anchovy meal costs US $ 0.5357/kg, and contains 70.9 percent protein.

$$\text{Cost per kg protein} = \frac{0.5357}{0.709} = \text{US \$ 0.7556 / kg protein.}$$

Herring meal costs US $ 0.4709/kg, and contains 76.7 percent protein.

$$\text{Cost per kg protein} = \frac{0.4709}{0.767} = \text{US \$ 0.61395 / kg protein.}$$

On the basis of cost per unit protein, herring meal is less expensive as a dietary ingredient than is anchovy meal.

To compare feedstuffs on the basis of cost per unit of an amino acid, one can calculate the best buy in the same way as before.

For example, sesame oil cake which has twice as much methionine content as does groundnut cake on a per unit protein basis would be a more attractive buy at comparable prices.

These kinds of comparisons are only valid if the nutrient in one feedstuff is as valuable or available to the animal as the same nutrient in another feed. Such comparisons should be made whenever prices change.

4.0 Conclusion

For any aquaculture venture to be viable and profitable it must have a regular and adequate supply of balanced artificial diets for the cultured fishes. This is so because the dissolved **nutrients** that promote primary and secondary production in the natural environment are seasonal and might be insufficient or may not occur in the required proportion to meet the nutritional demand for culture fishes. Supplementary feeding satisfies this need and ensures that fish gets the appropriate spectrum of its basic food requirement for maximum growth. Supplementary diets are often called artificial diets could be mainly or partially made from natural or synthetic materials. Such preparations are made to meet the nutritional requirement of a particular fish species with provision for fishes of different size/age intervals. Adequate feeding with supplementary diets improves fish resistance to diseases, ensures increase fish production and may enable more than one cropping session per year.

5.0 Summary

Feed formulation is essentially applied nutrition.For formulating feeds for experimental purposes, it is necessary that all ingredients are controlled for all essential nutrients. But, under practical conditions, such a control is difficult to set forth and mostly restricted to rapid proximate composition analyses.Feedstuffs can be compared with one another on the basis cost per unit of protein, energy, or amino acid and the best-buy technique is very effective for this objective. Materials that are cheap and available in large quantity are favoured for fish feed. Such materials include agricultural and industrial waste e.g. palm-kernel cake, , groundnut cake, milltet/corn ban, rice bran, brewer waste and flour mill sweeping as well as animal waste including chicken offal, blood meal bone meal, shrimp meal and dung. The use of cheap feeds without reduction in effectiveness is desireable in reducing over-head expenses

6.0 Tutor-marked assignment

1. What is feed formulation and account for the choice of ingredient requirement for feed formulation?
2. Write short note on the necessary steps for feed formulation.
3. Elucidate on the term “Best-buy-technique”.

7.0 References/ Further Readings

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MODULE10: INDUCED BREEDING AND HYBRIDIZATION TECHNIQUES

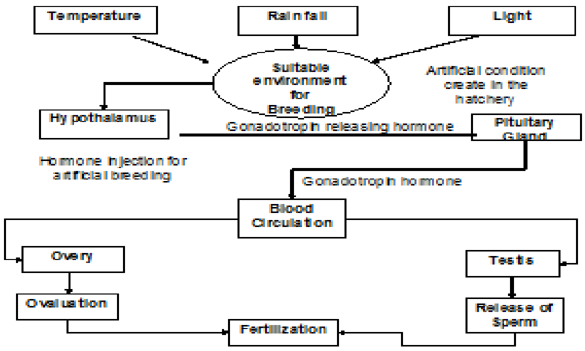
Unit 1: Induced spawning in fish

Content

1.0 Introduction
2.0 Objectives
3.0 Main Body
3.1 Induced spawning in fish
3.2 Techniques in Induced Breeding
3.3 Induced Spawning by Hormonal Approach
3.4 Hypophysation
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction:

Some kind of intervention by man in the natural propagation of cultivated or cultivable fishes may help to achieve a better survival of their offspring. The techniques of artificial propagation/ induced breeding of fish are manifold, all of which are aimed at producing plenty of spawn, fry and fingerlings for utilization in culture of for restocking water bodies or water courses. The demand for quality fish seeds is particularly great for modern intensive and super-intensive culture systems. The polyculture system has further increased the demand for the seeds of fishes of different feeding habits. Breeding is the biological activity of individuals to produce offspring which is usually controlled by environmental stimuli (figure 1), but in aquaculture it implies to reproduce and raise individuals, especially for commercial purposes.The breeding mechanism of a fish is a bio-chemical mechanism of an individual in which environmental stimuli forced that particular individual to show breeding behavior, and also help in gonad development.



A chart of Breeding mechanism of fish (source: manual, 2005.DOF)

Figure 1 Breeding mechanisms of fish.

A basic precondition of fish breeding is to have sexually mature male and female fish producing milt and eggs. Breeders of fish species which cannot be cultured or kept domestically, are collected before spawning from rivers or lakes , their milt or eggs are stripped and then they are released again. These species are sturgeons (mullets) mugils (Mugilidae), and salmonids (Salmonidae).

The brood stock of cultured fish species are sorted out with aimed selection and cultured in fish ponds up to sexual maturity. The males and females of breeders are cultured in the same fish pond while they are young. Then, when sexually mature they are selected and cultured in separate fish ponds.

2.0 Objective

At the end of this unit, student should be able to

1) explain the process of induced spawning in fish
2) state the techniques in induced breeding

3.0 Main Body

3.1 Induced spawning in fish

Induced spawning in fish embraces all the processes involved with inducing gonad maturation and consequent release of the gamete in fish. In female, induced spawning is normally carried out at the end of vitellogenesis when the ova areripped and it involves the following processes:

- The induction of germinal (nucleus of an oocytes before formation of polar bodies) vesicles migration to the pepriphery. The movement of nucleus towards micropyle. Sometime induced spawning may start from this stage
- Geminalvesilcle breakdown or final oocyte maturation, that is, resumption to meiosis.
- Ovulational follicular rupture.

- Oviposition or spawning i.e. the release of ova to the outside. This step may be replaced by stripping.

All these processes occur in a female. However, in a male the following processes are involved:

In males, the processes involved are

- Spermiation which is the release of spermatozoa from sertolic cells into the lumen of the tubules.
- Seminal hydration refers thinning of the seminal fluid of plasma.
- Ejaculation is release of sperm to the outside. This can also be replaced by stripping.

3.2Techniques in Induced Breeding

There are two approaches to induction of spawning in fish, and these are:

- Hormonal approach
- Environmental approach

After treatment, the fish in each approach may be stripped for artificial fertilization or left for natural spawning and fertilization. The fertilized eggs are then incubated and the hatched larvae raised to fry or fingerling stage – the hatchery. The steps involved in induced breeding are illustrated in figure 2:

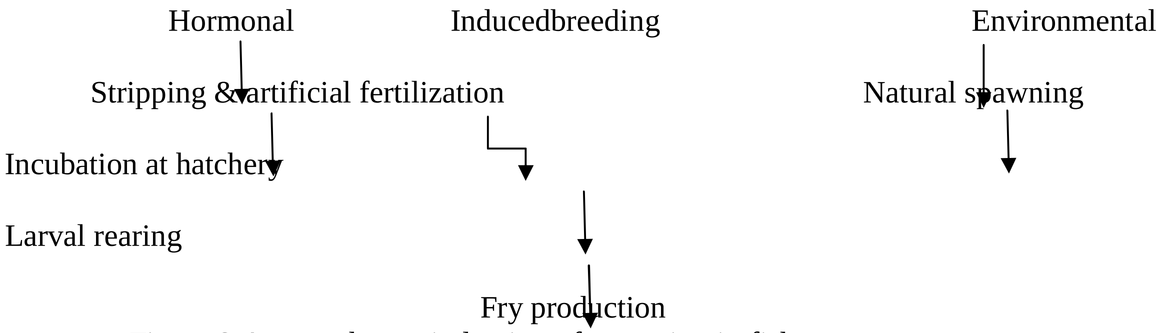


Figure 2 Approaches to induction of spawning in fish

The two approaches may and are often combined to obtain the best results in induction of spawning in fish.

3.3 Induced Spawning by Hormonal Approach

Induced spawning by hormonal approach is based on the understanding of neuroendocrine control of oocyte maturation, ovulation and spawning behaviour in females and of spermiation and seminal hydration (males).

Generally, in fish hormonal treatment is known to:

- stimulate the release of gonadotropins (Gonadotrophic hormones – GTH) into the blood streams
- when a certain level of GTH is reached the germinal vesicle migrate to the periphery and grannula cells of the follicle are stimulated to secrete a maturation-inducing steroid (MIS)
- the MIS Induces germinal vesicle breakdown (GVBD) , that is, resumption of meiosis or final oocyte maturation and other associated events such as hydration of eggs, grouping and the condense of yolk granules and or lipid droplets in some species.

In the males, steroid induction and seminal hydration is not clear, in essence, how gonadotropins act on the testis to produce steroid which bring about spermation and seminal hydration is not properly understood.There are several method of hormonal inducement of spawning in fish

3.4 Hypophysation (Fish Pituitary Extracts)

The use of pituitary extracts to induce spawning in fish is known as hypophysation. Induced ovulation and spawning achieved through hypophysationamounts to a "short cut" of the natural process. In nature, ovulation in fish is regulated andbrought about by its own gonadotropic hormone(s) , produced and stored by the pituitary gland. The stored hormone is released into the blood when all the requisite conditions become favourable. But in the hypophysation technique, gonadotropic hormone extracted from the pituitary of some other fish (donor) is injected into the breeder and this bring about the final ovulation. Hypophysation is presently the most commonly used technique for the artificial propagation of fish. It is employed not only in propagation experiment, but also in the commercial production of millions of young fish.

Hypophysation is effective only when the eggs in the ovary have reached resting or vitellogenesis (stage iv). At this stage, the eggs are maternally ready for further development to be triggered by gonadotropins. Therefore, it is important to chose the right time and fish for collection of the pituitary glands. Usually, the pituitary glands are obtained from sexually maturing or mature donor fish. Pituitary glands of donor fishes, collected fresh or preserved are used in hypophysation. It is necessary that these glands contain an adequate amount of stored gonadotropic hormones to bring about successful spawning.

The pituitary gland (hypophysis) acts as an intermediary between the brain and the gonads. Its cells produce and store gonadotropins, and release them only when the gland receives the necessary command. The gonadotropins content of the pituitary gland varies during different season and during different stages in the life cycle of a fish. Immature fishes have only small quantity of gonadotropins in their pituitary glands while after natural spawning, spent fish are completely without gonadotropins in their pituitary. On the other hand, gonadotropin is at the highest in pituitary of sexually ripped, matured fishes when their gonads have reached the resting phase or through-out the duration of the resting phase.

4.0 Conclusion

Artificial propagation as practiced in different parts of the world may vary, depending on local conditions and facilities. It may start with the collection and further rearing of naturally produced eggs, spawn or fry, or with the production of the egg itself through artificial inducement/induced breeding, followed by controlled fertilization, hatching and rearing of larvae and fry. Artificial propagation, therefore, involves human intervention in the process of natural propagation and has the advantages of (a) better rates of fertilization and hatching, (b) protection against enemies and unfavorable environmental conditions and (c) better conditions for growth and survival.

5.0 Summary

The techniques of artificial propagation/ induced breeding of fish are manifold, all of which are aimed at producing plenty of spawn, fry and fingerlings for utilization in culture of for restocking water bodies or water courses.Induced spawning in fish embraces all the processes involved with inducing gonad maturation and consequent release of the gamete in fish.There are two approaches to induction of spawning in fish, and these are:

- Hormonal approach

- Environmental approach

The use of pituitary extracts to induce spawning in fish is known as hypophysation. Induced ovulation and spawning achieved through hypophysation amounts to a “short cut” of the natural process. In nature, ovulation in fish is regulated and brought about by its own gonadotropic hormone(s) , produced and stored by the pituitary gland. The stored hormone is released into the blood when all the requisite conditions become favourable. But in the hypophysation technique, gonadotropic hormone extracted from the pituitary of some other fish (donor) is injected into the breeder and this brings about the final ovulation. Hypophysation is presently the most commonly used technique for the artificial propagation of fish. It is employed not only in propagation experiment, but also in the commercial production of millions of young fish.

6.0 Tutor-Marked Assignment

1. What is the mechanism of breeding in fish
2. Explain in detail the approaches to induced breeding in fish.
3. Give a concise account of induced spawning by hormonal approach

7.0 Reference/Further Reading

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UNIT 2: METHODS OF HORMONE ADMINISTRATION

Content

1.0 Introduction
2.0 Objectives
3.0 Main Body
3.1 Methods of hormone administration
3.2 Preparation of Pituitary Gland Solution
3.3 Environmental Conditions for Culturing Breeders
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

There are several variations in hormone administration methods. Each method may have some justification, but may not be universally applicable. The technique is adopted generally dependent on the species of the fish, local conditions and working methods developed by the local scientist and techniques.However, none can be proclaimed as the only definitive technique.

As a rule, the females generally require higher doses of hormones than males, with split doses producing better results than a single large dose.

2.0 Objectives

At the end of this module, students should be able to

1) State the different method of hormones administration
2) describe the process of preparation of pituitary gland solution
3) enumerate the environmental conditions for culturing breeders

3.0 Main Body

3.1 Methods of hormone administration

The different methods of hormone administration, as generally practiced, are detailed below

- **Single injection method**

The calculated 100% dose is, also called the knock-out dose, is given in a single injection. It will be successful if only the female fish is fully ready for spawning as those that are captured in their spawning ground or those in spawning migration. Suitably fed fishes achieve this condition during the second half of the breeding season. In majority of fish species, males are better prepared for spawning than females, and therefore a single dose suffices. If the hormone administered to them amounts to an overdose, or is not synchronized with the gonadal maturation of the female, it may result in wild discharge of milt before the females are ready.

- **Preparatory and Decisive those Method**

The preparatory dose (which is 10% of the decisive dose) advances the gonad development up to the pre-ovulation stage. It is generally given about 18-24 hours prior to the decisive dose (100% of the calculated dose. This is a generally successful sequence of hormone administration in the temperate and subtropical regions. This method also holds for nervous and difficult-to-handle fish. Sometimes the interval between preparatory and decisive doses can be shorter than that indicated above. About 14-18 hours suffice during the latter half of the spawning season given that the water temperature is higher than normal spawning temperature. If the female are less than 1 kg in weight and are in ripe condition for hormone treatment, an interval of only 6 hours is sufficient.

- **One preparatory and two decisive doses**

In tropical regions, where metabolism in fish is more rapid, the decisive dose is given in two equal instalments or two instalments of 40% and 60% within intervals of 6-8hours between them. A preparatory dose of (5-10%) should precede the first decisive dose by 18-24hours.

- **Several preparatory and two decisive doses**

It is employed in cases of fish where the eggs are already in the dormant stage but the ovary has not yet descended into the lower part of the body cavity. In such cases, a series of several preparatory are required before the decisive dose can be successful

- **Distributed doses method:** In this method the injections are given in many doses and the time span between the doses is generally short about6-8hrs. The sequence and quantity of doses may vary as follows:

a. 50 & 50% with an interval of 6-8hrs
b. 40 & 60% with an interval of 6-8hrs
c. 10, 30 % and 60% with an interval of 6hrs each
d. $33^{1}/3$, $33^{1}/3$ & $33^{1}/3$% with an interval of 6hrs

e. 20, 30 and 50 % with intervals of 6 hrs each

These sequences have proved very successful in the cases of tropical fishes and those spawning confined waters.

There is usually 24hours between doses when the decisive dose is given in two or three parts. The time lapse between injections should not be more than 6-8hrs.As a rule, the males are only given one dose of hormones but usually at the time when the females are given the last decisive dose. It is important that males are not administered the hormones earlier; that may result inducing the sperm before the females are ready to ovulate. The recommended single decisive dose for male is 0.5 gland (1.0 – 1.5 mg)/kg of body weight regardless of their length. A little excess hormones in the decisive dose does not harm the fish, therefore, fishermen are advised to increase the required dosage by 1.0 – 1.5g to be on the safe side.

As a rule, the female generally require higher doses of hormones than the males, with split doses producing better results than a single large dose. It has been found that more hormones are needed for ovulation when the ovary is bulky. The bulkiness of the ovary can be expressed by them

3.2 Preparation of Pituitary Gland Solution

Based on the weight, number and sex of the breeders, the dose is determined after which the requisite number or quantity of pituitary gland is counted or weighed. If the glands are not already in pulverized condition, they are thoroughly pulverized in a small porcelain mortar or a homogenizer. The mortal has to be totally dry, as otherwise the gland would become pasty while pulverizing and would not easily dissolve. A measured quantity of solvent is then added immediately. The solvent is usually measured in a graduated syringe. It is necessary to ensure thorough mixing of the solvent and the hypophysis powder. About 10-30 minutes would be required to dissolve the hormone. The tissue residue can be removed from the solution by using a centrifuge or by simply allowing the residue to settle down and then sucking the clear supernatant solution with a syringe.

The solvent is first prepared by dissolving 7g of common salt, free of iodine, in 1l of boiled and already cooled drinking water. There is no need to use distilled water. The solvent can be stored for long periods in sealed bottles.

The solvent used for GTH is 0.9% NaCl (physiological common salt). 1ml solvent is used for the preparatory injection regardless of the dosage (ranging from 0.25-1 gland). The quantity of solvent for the decisive dose is calculated at the rate of 0.5ml for each gland (2.5-3.0 mg) but the maximum amount of solvent should not exceed 5ml. It is not advisable to use too little solvent because the loss of solvent would mean the loss of considerable quantity of hormones neither is it advisable to use much solvent because the administration of a large volume of solution would pose a difficult problem. In general, the quantity of solvents should be between 1-5ml.

Choice of Body Part to Inject

The most commonly adopted procedure is to inject the hormone into the dorsal muscles above the lateral line and below the anterior part of the dorsal. In Indian, fishes are generally injected at the dorsal part of the caudal peduncle (also intramuscularly). This procedure appears to be best for sensitive fishes. In some fishes, the injection are administered into the body cavity (from under the pectoral or pelvic fins) i.e. intraperitonial administration. This method generally yields poor results.

- **Limitation of Hypophysation**

Like other technique, this technique too has its limitations. Some of the sensitive fish such as pike-perch cannot tolerate the treatment, while other may ovulate only irregularly. Then again, the breeders whose ovaries have not yet reached breeders whose ovaries have not reached the appropriate ripe stage will fail to response to hypophysation. It is a fundamental that hypophysation is only effective when the eggs in the ovaries have reached the resting or dormant phase after completion of vitellogenesis. The eggs are then materially ready for further development to be triggered by gonadotropin(s)

3.3 Environmental Conditions for Culturing Breeders

When culturing breeders, the following environmental conditions should be ensured considering the specifics demands of the respective species:

- suitable water and pond
- tempetature
- oxygen
- feed light and photoperiod

During culturing of breeders, the water quality should meet the same requirement as during routine fish culture.

For species with preference for still water (e.g. cyprinids, catfish, and tilapia) earthen or concrete walled fish ponds should be constructed. For rheophyl species (e.g. trout) flow-through systems, canal, or tanks with circulating water should be provided.

The temperature as an environmental factor,has an important role in fish breeding. Fish are poikilothermic animal, which means that their body temperature follows the surrounding temperature, but in case of increased muscular work and metabolism it can be somewhat higher

The duration of sexual maturation also depends, first of all, on the environmental temperature, with most fish species, thus there is a characteristic total temperature value for each species which is necessary for gametogenesis.

Optimal oxygen content of water is very important especially inactive cytogenetic processes. Development of gametes and complete conversion of feeds are all oxygen consuming processes. In case of oxygen deficiency, the gametogenesis slows down;development is inhibited and if it is prolongs the resorption of gametes start. Therefore, proper oxygen supply is a crucial point of brood stock culture.

Feeding of the brooders, especially in the nutrient accumulating phase of oogenesis requires feed of specific composition. Amino acids, carbohydrate, fats, vitamins, and minerals are available for the fish via natural feeding. But at high stocking density under controlled culturing conditions these must be provided through artificial feeds. It is also important that the breeders can get the type of feed characteristic of their species i.e. herbivorous fish should get nutrient of plant origin, and carnivorous should get nutriment of animal origin.

Light/photoperiod has a significant role in the reproductive processes of several fish species.

Stress factors, and the sensitivity of the cultured breeders to these factor should also be kept in mind. Handling, transportation, enclosure which all differs from their normal lives, are stress inducing factors, and may affect their condition. This may hinder the last phase of maturation and ovulation. Therefore, conditions should be established for the breeders where all these stress factors can be minimized.

4.0 Conclusion:

Artificial propagation involves human intervention in the process of natural propagation and has the advantages of (a) better rates of fertilization and hatching, (b) protection against enemies and unfavorable environmental conditions and (c) better conditions for growth and survival.

5.0 Summary

The different methods of hormone administration, as generally practiced include single injection method, a preparatory and decisive dose, one preparatory and two decisive doses, Several preparatory and two decisive doses and the distributed doses. Based on the weight, number and sex of the breeders, the dose is determined after which the requisite number or quantity of pituitary gland is counted or weighed; the solvent used for GTH is 0.9% NaCl (physiological common salt). 1ml solvent is used for the preparatory injection regardless of the dosage (ranging from 0.25-1 gland).The most commonly adopted procedure is to inject the hormone into the dorsal muscles above the lateral line and below the anterior part of the dorsal.When culturing breeders, the following environmental conditions should be ensured considering the specifics demands of the respective species:

- suitable water and pond
- tempetature
- oxygen
- feed light and photoperiod

Induced breeding basically involves the induction of final oocyte maturation and spermiation in male and female fish respectively, followed by stripping and artificial fertilization or natural spawning; the former being preferable for complete control of fertilization.

6.0 Tutor-Marked Assignment

1. What is the role of environmental parameters on induced breeding?
2. How would you prepare a pituitary gland solution?

7.0 Reference/ Tutor-Marked Assignment

Huet, M.V. & D.E. Canfeid Jr. (1972) Textbook of fish culture. Fishing News Books. Survey, England 436pp.

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MODULE 11: MAJOR FISH PROCESSING TECHNIQUE

Unit 1: Fish preservation and processing

Content

1.0 Introduction
2.0 Objectives
3.0 Main Body
3.1 Value addition
3.2 Characteristic of Fish in the Fresh State
3.3 Post-mortem changes in fish
3. 4: Methods of Fish Preservation
3.5:Fish Processing
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 Introduction

Fish is a major source of protein and its harvesting, handling, processing and distributionprovide livelihood for millions of people as well as providing foreign exchange earning to manycountries. Appropriate processing of fish enables maximal use of raw material and production ofvalue-added products which is obviously the basis of processing profitability. Fish processing, like the processing of the other food raw materials should: assure best possible market quality, provide a proper form of semi-processed final product, assure health safety of products, apply the most appropriate processing method and reduce wastes to the barest possible extent.The development of appropriate fishing machinery and techniques that employed effective production, handling, harvesting, processing and storage, cannot be over-emphasized especially in the age when aquaculture development is fast gathering momentum in Nigeria.

Fish processing is the processing of fish and other seafoods delivered by fisheries, which are the supplier of the fish products industry. Although the term refers specifically to *fish*, in practice it is extended to cover all aquatic organisms harvested for commercial purposes, whether harvested from cultured or wild stocks.

Fish processing may be subdivided into two major categories: fish handling (which is initial processing of raw fish) and fish products manufacturing.Another natural subdivision is into primary processing involved in the filleting and freezing of fresh fish for onward distribution to fresh fish retail and catering outlets, and the secondary processing that produces chilled, frozen and canned products for the retail and catering trades.Fish processing can take place aboard fishing and fish processing vessels, and at fish processing plantsfish.

2.0 Objectives:

At the end of this unit, student should be able to

(1) statethe characteristic of fresh fish

(2) identify the post-mortem changes fish associated with spoilage and

(3) explain the basics of fish preservation and processing

3.0 Main Body

3.1 Value addition

In general, value addition means “any additional activity that in one way or the other change the nature of a product thus adding to its value at the time of sale.” Value addition is an expanding sector in the fish processing industry, especially in export markets. Value is added to fish and fishery products depending on the requirement of different markets. Globally a transition period is taking place where cooked products are replacing traditional raw products in consumer preference. For example, there is a demand in urban centers for “ready to eat” and “ready to cook” convenience products in a frozen condition. There is also a need to divert low value fish to human consumption which can be facilitated by diversifying fishery products to value added products, such as minced meat from low priced fishes.

3. 2: Characteristic of Fish in the Fresh State

It is very important to know the quality of fresh fish so as to know when spoilage sets in

- **Colour**: in the fresh state, fish colour is bright, shiny and irridiscent or lustrous (capable of reflecting different colour). When spoilage sets in, the colour is dull, dirty yellow or brown.
- **Skin texture**: the skin of a fresh fish is firm and elastic. Under spoilage , the skin becomes dry, slack, swollen and inelastic.
- **Eyes:** the eyes of a fish are bright, clear with bulging eye balls. The pupils are black brilliant and the cornea is white and bright. When spoilt, the eye is dull, shrinks and sinks in to the eye socket and the pupil becomes cloudy and milky; the cornea becomes opaque.
- **Gills:** the gills of a fresh fish are bright red or pink in colour; the colour changes to dark red or brownish when spoilt.
- **Flesh:** in the fresh state, the flesh of a fish is “firm”. As spoilage sets in, the flesh becomes gradually soften and when completely spoilt, it can strip of the backbone and exude juice when slightly pressed. It may even leave finger impressions.
- Mucous coating on the sin of fresh fish is transparent, free floating and is like a lubricant. In a spoilt fish, the mucous is slimy, becomes thick. Sometimes the colour becomes whitish or creamy in colour and it is no longer transparent.
- **Smell/odour**: Fresh fish is said to have a fresh sea-weedy smell. The colour of spoilt fish is sour, bad and offensive. Spoilt fish is said to have “Off odour/flavour”.

3.3 Post-mortem changes in fish

The quality of the freshly caught fish and its usefulness for further utilization in processing is affected by the fish capture method. Unsuitable fishing method does not only cause mechanical damage to the fish, but also creates stress and the conditions which accelerate fish deterioration after death. Fish is highly susceptible to deterioration without any *preservative* or *processing* measures. It has been reported that immediately the fish dies, a number of physiological and microbial deterioration set in and thereby degrade the fish.

Spoilage proceeds as a series of complex enzymatic bacterial and chemical changes that begin when the fish is netted or hooked. This process begins as soon as the fish dies. The rate of spoilage is accelerated in warm climates. The fish's gut is a rich source of enzymes that allow the

living fish to digest its food .Once the fish is dead; these enzymes begin digesting the stomach itself. Eventually the enzymes migrate into the fish flesh and digest it too. This is why the fish becomes soft and the smell of the fish becomes more noticeable.
There are countless bacteria naturally present on the skin of the fish, in the gills, and in the intestines. Normally, these bacteria are not harmful to a living fish. Shortly after death, however, they begin to multiply, and after two to four days they ingest the flesh of even a well-iced fish as enzymatic digestion begins to soften it. The bacterial load carried by a fish depends on its health, its environment, and on the way it was caught. Healthy fish, from clean water, will keep better than fish dragged along the bottom of a dirty pond in a trawl net.
Both enzymatic digestion and bacterial decomposition involve chemical changes that cause the familiar odors of spoilage. Oxygen also reacts chemically with oil to cause rancid odors and taste. The aim of fish processing and preservation is to slow down or prevent this enzymatic, bacterial, and chemical deterioration, and to maintain the fish flesh in a condition as near as possible to that of fresh fish.
There are five sequences of events that characterized post-mortem changes in fish and they are listed thus:

- **Biochemical changes:** such as glycolysis which is caused by enzymes action (tissue respiration.
- **Rigor mortis in the muscles:** this is simply the stiffening of the muscles.
- **Muscle tendering:** it results from softening of the muscles cause by proteases
- **Spoilage:** due to the microbial action, once the muscles become tender, micro-organisms attacks it and this is usually followed by the release of mucus.

  The process of spoilage is irreversible; once a fish is spoilt nothing can be done to change it quality back to what it initially was at the fresh stage. Therefore, it is important to preserve fish immediately after capture to prevent deterioration and spoilage as improper preservation significant result into post harvest loss.

3. 4: Methods of Fish Preservation

Fish is a highly nutritious food and it is particularly valued for providing protein of high quality better than those of meat and egg. However, it is one of the most perishable of all the foods because it is a suitable medium for growth of micro-organisms after death. In the tropics at ambient temperature, spoilage is rapid; fish will spoil within 12-20 h depending on species, method of capture. As soon as fish is caught and dried, certain irreversible spoilage begin to take place, leading to spoilage and deterioration and most subsequent processing or preservation operation are intended to prevent these causes or usually reduce the rate at which they proceed.
Fish preservation is the method of extending the shelf life of fish and other fishery products by applying the principles of chemistry, engineering and other branches of science in order to improve the quality of the products.Preservation methods maintain the quality of fish for a longer period of time.

The basic task of every fishery is to get the catch to the consumer in good, usable condition. The first fish caught were probably eaten raw, on the spot. Communities grew up near enough to productive fishing grounds so the fish could be consumed the day it was caught. The earliest preserved fish was probably accidentally overcooked, and some observant fisherman saw that dry cooked fish kept for a period of time without spoiling. Traditionally, air drying, salting, and smoking (or some combination of these three) preserved fish for the short periods required by the fishermen. Fish preserved in these ways is often tough and stringy, the quantities produced are small, and success is uncertain. Few people will eat fish preserved this way, if they have an alternative. Over time, other, better methods of preservation came into being.

Proper steps in handling fresh fish

1. Avoid exposing the fish to sunlight. Keep them in a shaded area.

2. Ice the fish immediately after they are caught to lower their temperature.

3. Remove the gills and internal organs.

4. Avoid soaking the fish too long in the water after death as this easily spoils the fish.

5. Use mechanical refrigeration if there are facilities.

It is imperative to understand that all processing methods are preservation method but all preservation methods are not processing methods. Smoking or drying is the most common method of fish preservation in Nigeria. Traditionally, fish is smoked in mud kiln or halved cut drum with wire netting on top and use of wood as source. Hardwoods are preferred to softwoods for fish smoking because the former yield more acid and may therefore produce products that are more bacteriologically stable. If fish is not sold fresh, preservation methods should be applied to extend shelf-life. These include freezing, smoking, drying and heat treatment (Sterilization, pasteurization, etc). Efficient preparation of fish is important when top quality, maximum yield and highest possible profits are to be achieved.
Whenever fish must be kept for several hours or longer before being consumed, they must be treated in some way to prevent spoiling. These are the basic means for preserving fish:

- Cooling and icing
- Salting and pickling
- Pastes and sauces
- Canning and bottling
- Air drying and smoking
- Kiln drying

- **Cooling and Icing**

The first and simplest method to both preserve and process fish is to keep it cool. Cool fish keeps longer than uncooled fish, although both will spoil in a matter of hours.If the market is only a few hours away, and if the fish will be sold promptly, evaporative cooling might suffice. All that is required is some coarse cloth--enough to completely cover the fish-and enough water to keeps the cloth damp. The movement of air over the water causes it to evaporate, and thus keeps the fish much cooler and fresher than fish directly exposed. Wrap the fish completely in the cloth. Any portion that is exposed to theair will dry and become warm enough to support the rapid growth of bacteria. Splash water on the wrapped fish, keeping the cloth wet but not soaked. How well this will work depends on too many variables to predict, but it is a distinct improvement over uncovered fish.
Most fish caught are preserved with ice at some stage in their processing. Trained taste panels are usually unable to distinguish well-iced fish kept less than six or seven days from fresh fish, and storage life can be extended somewhat if antibiotics are added to the ice. Ice works in two ways: it reduces the growth rate of bacteria by reducing the temperature of the fish; and it also washes the bacteria and slime away as it melts.
Because of this, it is important to keep melt water drained away from the fish. Fish are usually

gutted and stowed mixed with ice. Small flat fish are stowed without gutting. An active fish like salmon is gutted and the belly cavity is packed with ice as it is stowed. Fish can be iced in bulk, in large quantities, or they can be boxed. Boxing produces a better quality product for several reasons: the bottom fish are not crushed by the weight of the fish on top; and the melt water is better able to drain away. In addition, it seems to be human nature to take better care of a small box than of a pile of fish.

Ice is expensive and begins to melt immediately, so the fishermen are faced with a loss before they even begin. The temptation to get away with as little ice as possible must be avoided. Within limits, the more ice the better. The box should be lined with ice so the fish does not touch sides or bottom of the box. Layer the fish, avoiding overlaps, and ice each layer as it is boxed. If the catch is large enough that the boxes must be stacked, try to channel the melt water away from the bottom boxes. Keeping the boxes covered with wet cloth will dramatically increase the life of the ice.

There is a wide range of icemakers on the market, ranging from small flake ice machines that produce a couple of tons a day to huge machines that make many tons. They all require electricity and a certain level of technical expertise to operate. The newer machines are built with the small operator in mind, however, and are practically unbreakable. With these machines, it is possible for small operators to make their own ice.

- **Salting and Pickling**

Salting and pickling, along with various kinds of drying, are the traditional methods for preserving fish. Indeed, Egyptian tomb paintings illustrate fish being prepared for salting and drying, and the process must be many years older than that. The bacteria that spoil fish need moisture to grow. If the moisture in the fish can be reduced to about 25 percent of its normal level, bacterial activity will cease. Some bacteria are killed at these levels, while others simply go dormant. The fish will keep for several years as long as the moisture level is not allowed to increase beyond 25 percent. Salt replaces a portion of the water naturally present in the fish, and so reduces the moisture content below the point where bacterial spoilage can occur.

The several salting methods vary mainly in the amount of salt the fish are allowed to take up. "Dry salting" is used to preserve non-fatty fish such as cod. The split fish are completely buried in salt, and the brine liquid that emerges is allowed to drain away. The fish are finally dried. In the "pickling" process, used for fattier fish such as herring, the fish are packed in salt in airtight containers. Bacterial decay is reduced or prevented when the salt has replaced enough of the moisture in the fish to inhibit the growth of fish spoilage bacteria.

A combination of coarse grained salt (like rock salt) and a fine grained salt is used. The coarse grains keep the fish separated so as to drain, and the fine grains dissolve quickly into the flesh ofthe fish. Salt may be mined from prehistoric deposits, manufactured from partly concentrated brines, or "manufactured" by solar evaporation of shallow ponds of salt water. Any of these may be available to you, as well as salt that is produced expressly for use in salting fish.

Some of the flavor of the finished product depends on the kind of salt used. Impurities in the salt, such as magnesium or calcium, if present at too high a level, impart a bitter taste to the final product;these impurities also interfere with the absorption of salt into the fish. Some common impurities readily reabsorb moisture from the air, so if the curing salt contains enough of these compounds the fish will become damp again and grow bacteria. On the other hand, small amounts of these same impurities give the salted fish a whiter appearance that is more attractive to some consumers. For all these reasons, it is important to know what kinds of salt you are

using, and what their effects will be.
The fish to be salted are cleaned, and the guts and gills and sometimes heads are removed. Larger fish must be split so they can be opened up and laid flat in the salt. In general, a layer of salt is placed in the bottom of a container and a single layer of fish is placed on it, flesh side down. The first layer of fish is then covered with more salt and another layer of fish is added. The layers of smaller fish like herring are crisscrossed. The process is continued until the container is full.
The same cautions as to cleanliness and care in handling apply. Avoid reintroducing a bacterial load. Use clean processing equipment and keep the work area clean. Keep guts and offal away from the processed fish and dispose of it in an area removed from the cleaning area and water supply. If drying is the ultimate goal, the water that is withdrawn from the fish by the action of the salt is allowed to run off, and the fish are restacked at frequent intervals, rotating the fish from the top to the bottom of the pile to equalize the cure. The fish can remain stacked for several months in a cool climate before being dried, but this is not possible in temperate countries.
Fish can be air dried in Norway or Iceland, but in most areas some sort of dryer is generally required. If the fish is to be pickled, it is packed in the same way, in a container that can be sealed. As the fish shrink, the barrels are consolidated, putting fish from the same day's catch together. After about ten days, half of the replaced water is drained off, the container is packed full again with fish from the same batch, and the spaces between the fish are filled with the water that was drained off earlier. The container is then sealed and stored.
Salting is a simple process. It does not require much equipment or manpower, but the product has a limited life unless it receives some sort of additional processing such as canning or freezing. Drying, which is explained in the following section, is an alternative to freezing.

- **Air Drying and Smoking**

Even the most heavily salted fish will begin to spoil after a few weeks at warm temperatures. Some additional processing is required to preserve fish in any but the coldest climates. Moreover, although salt alone will protect against the growth of some bacteria, salt-loving bacteria continue to flourish. A combination of salt and reduced moisture, or salt and no air, will allow fish to be kept for several years. Bacterial activity ceases when the moisture content is reduced below about 25 percent. Mold will no longer grow at a moisture level of about 15 percent. Fish dried to this level will last several years if not subsequently moistened.
Air drying and kiln drying reduce the moisture content of fish to the point where bacterial action ceases. Smoking dries the fish, and also adds bacteriacides that are present in the smoke. The process varies from a mild cure that will keep several weeks if chilled, to a hard smoke that will keep indefinitely if not moistened.
Fish preserved by air drying tends to be tough and stringy. Most people will not eat fish preserved this way unless they must. If the weather is dry, fish may be air dried. Take care to keep the fish in shade, exposed to breeze. Keep flies and insects away! Air drying of fish is an uncertain undertaking. Since it requiresa low relative humidity to achieve the necessary degree of dryness, the fish will keep only so long as it is kept dry. On the other hand, it requires a minimum of equipment and no technology. It is primarily suitable for small quantities for personal use. With a minimum of investment solar dryers can be constructed for the drying of fish. Solar dryers made from plastic on a wooden frame eliminate contamination by insects and can increase ambient temperature to accelerate drying. They also reduce storage of fish when rain storms interfere with sun drying.

Kiln or tunnel drying of fish is a more complex process, and the final product is much more palatable than natural air dried fish. It requires careful control of many variables, such as relative humidity, air temperature and velocity, and rate of drying. The product will have to be stored in some sort of cold storage because it also will draw moisture and putrify. In kiln drying, the fish is hung on racks in a tunnel. Dry inlet air is heated, circulated through the tunnel, reheated, and recirculated. A portion of the moisture laden air is vented off and replaced with outside air. Control of the humidity inside the kiln can be accomplished by venting off more or less of the moisture laden air from the kiln. Midway through the process the kiln is unloaded and the position of the fish is reversed to equalize the drying rate.

- **Fish Sauces and Pastes**

In areas where a rice diet predominates, a number of fermented fish products have been developed. If a fairly fixed procedure is followed, the product has a more or less consistent flavor and texture. In areas in which dried or salted fish is impractical because of the high humidity and temperature, fermented sauces or pastes may be an acceptable or preferable alternative.

Small, ungutted fish are mixed with salt (four to five parts salt to six parts fish) and sealed in vats or pots. In a process that requires several months, the fish dissolves and ferments. The result is a clear "pickle" with good keeping properties that is used as a condiment for flavoring rice dishes. Fresh or salt water fish can be used, as well as shrimp. The processes vary as widely as the kinds of fish used.

Fish paste is made from cleaned fish, which is mixed with salt (one part salt to three parts fish) and allowed to digest. Sometimes fermented rice, roasted grains, or bran are added. The manufacturing methods are complicated and vary considerably from area to area. As a result, the product is seldom standardized. Tastes vary from area to area, so local knowledge is imperative.

- **Bottling and Canning**

The bottling and canning of fish requires more precision and expense than the aforementioned methods of preservation. Many nations during their lean fishing seasons import large amounts of canned fish to supply a source of protein. In such a case, perhaps domestic canning is a viable option. The canning or bottling of fish requires a high quality product at the onset. It should not be employed as a last resort for unsold fish. Consumption of such fish may cause severe illness. Bottled fish is usually prepared for personal consumption. The bottled fish is usually cooked, boned, and put in a pickling solution, then stored in sterilized jars with rubber sealed lids. Canning, on the other hand, entails placing the fish in a tin can with a lid, removing the air within the can through heat treatment, sealing the lid entirely, and then heating a second time to a specified degree. The two most important considerations of this method are the availability and expense of the cans or bottles and strict quality control of the product.

3.5:Fish Processing

Fish Processing is a way of preserving fish and at the same time improving their quality. In the process, the properties of the fish change.There are many ways to process fish. Some methods such as salting and drying have been used since the ancient times, long before modern technology was introduced. Others involved the use of chemicals and electrical devices. But whatever process is used, the fish to be processed should always be fresh.The methods employ in fish processing include the following:

- **Salting**

Salting is the process that lowers the moisture or water content of fish and other fishery products to a point where microorganisms cannot live and grow. Sodium chloride, or salt, improves fish texture because it firms up the fish. Salt partially dehydrates the fish and kills the bacteria.

Three basic methods of applying salt to preserve fish:

- **Pickle Salting -** cover the fish with salt and pack them in layers in watertight containers. This forms the pickle that serves as the saturated brine solution that covers the fish completely.
- **Brine Salting-** immerse the fish in a saturated solution made up of 25 parts of salt and 100 parts of water. Brine salting is done only as a temporary way to preserve fish before they are dried, smoked, or processed.
- **Dry Salting-**run granular salt on the fish. The proportion of salt to fish varies from 10% to 35% of the fish weight.

Steps in Salting

1. Place the fish either in crushed ice or frozen brine.
2. Remove the fins
3. Remove the head (optional).
4. Split the fish along the dorsal section. Spread it open.
5. Remove the internal organs such as the intestines.
6. Take out the black membrane of the fish.
7. Wash the fish thoroughly and drain it a little.
8. Rub the fish well with salt.
9. Arrange the fish in a container. Place the container inside a refrigerator.

- **Smoking**

This method combines with salting, precooking, and drying. The final process is smoking, which dehydrates the fish further. The smokes give color and flavor to the fish.

Steps in Smoking

1. Clean the fish by removing the gills and make 1/2 inch slit in the fish belly. Wash the fish thoroughly with clean water.
2. Soak the fish in a brine solution (1 part of salt to 10 parts of water) for 20 or more minutes, depending on the size of the fish.
3. Place the fish in the immersion basket made of woven bamboo strips or wire netting. The basket will be suspended during the immersion in boiling brine. Cook for 2-4 minutes or more, depending on the size of the fish.
4. Drain the fish. Allow them to cool after being cooked in brine solution. Place it in a layer of wire screen (rattan or bamboo) and have it dried in a cool and shady place.

5. Smoke the fish in tin cans for 1 to 2 hours until it gets golden brown. The length ofsmoking actually differs, depending on the size of the fish and the smokeproduced.
6. Packed the smoked fish in coarsely woven bamboo baskets. Line the sides and bottom of the baskets with old newspaper. Cool the fish completely before packing them to allow moisture to escape and prevent the attack of mold and bacteria.

- **Drying**

This method is also known as natural dehydration. Like the salting method, it lowers the water content of the fish to a point where microorganisms, bacteria, enzymes, and yeasts cannot grow and multiply. The most popular fish preservation method is solar drying. It is done in combination with salting. Fish dried under the sun look and taste better.

Steps in Drying

1. Wash the fish thoroughly.
2. Soak the fish in 10% brine solution for 1/2 hour to draw out the blood.
3. Squeeze or open the belly cavity. Remove the visceral or internal organs.
4. Soak the fish for 3-6 hours in a concentrated brine solution to partially draw out the moisture or water content of the fish.
5. Place the salted fish in drying trays and dry it under the sun.
6. When the fish are thoroughly dried, pack them and store them in a clean, dry place.

- **Curing**
  This method uses chemical preservatives (including vinegar and salt), smoke, and other physical factors to reduce the moisture or water content of the fish. Cured fish or fishery products possess flavor and texture completely from those of the fresh fish.
- **Dehydration**
  Dehydration is an artificial process of drying because it is done with the use of mechanical devices, such as an oven, that produce artificial heat for drying.
- **Pickling**
  Pickling is a method of preserving food in brine or vinegar. It can be done with or without bacterial fermentation.
- **Cooking**
  Cooking is the best way to prevent wastage or spoilage of fish. Cooking fish with vinegar, like in paksiw, prolonged the period of preservation.
- **Canning**
  Canning is the packing of fish in airtight containers such as tin cans and glass jars, which prevent air and microorganisms from entering. Through the heat processing, microbes inside the can are destroyed, thus preventing spoilage under normal condition and allowing the fish to be stored for longer periods. Sardines and salmon are the most commonly canned fish in the market.

Steps in Canning

1. Remove the scales of the fish.
2. Remove the internal organs. Cut off the head and the tail of the fish.
3. Cut the cleaned fish to fit the size of the can to be used.
4. For 30 minutes, soak the fish in 20% brine solution.
5. Half-fry the fish in oil.
6. Fill each can with half-fried fish. Leave about 1/4 inch space. Add a tablespoonful of corn oil and tomato sauce. Do not add salt because the fish has been brined.
7. Sealed the filled cans temporarily. Use the first roll operation of the can sealer.
8. For 10 minutes, stem the clinched cans without pressure to exhaust the air inside the cans. Then, seal the can completely.
9. For 45 minutes, process the sealed cans at a 15 lb. pressure using the can sealer.
10. Immediately, coll the processed cans in running water.

- **Fermentation**
  Fermentation is a fish preservation method in which fish in brine solution undergo chemical reaction. Bagoong is the most popular fermented product in the Philippines.
- Steps in Fermentation

1. Clean the fresh alamang well. Remove sticks, shells, seaweeds, and other materials.
2. Wash the alamang in a weak brine solution (1 part of salt to 9 parts of water). Drain it well. Cover the container while draining the alamang to keep flies away.
3. Mixalamang thoroughly with salt (1 part of salt to 3 parts of alamang).
4. Place the alamang-salt mixture in a clean container.
5. Store the bagoong in a clean, warm place

4.0 Conclusion

Fish is a very important foodstuff in developing countries, due to its high protein content and nutritional value. However, it is a greatly perishable product, especially in hot climates and tropical areas where cold preservation techniques are often missing. Quality losses can occur very rapidly after catch. Fish salting/brining, drying or smoking, are traditional techniques for improving preservation and storage, which increase availability to consumers.

5.0 Summary

Fish that are not taken to the market fresh must be preserved in some way after harvesting. All fish have bacteria in their intestines; as soon as they die, these bacteria begin to multiply, and the process of decay begins. So the first thing which must be done – as soon as possible – is to remove the intestine. After this is done, go on to preserve the fish in the way chosen. Fresh fish are characterized by certain properties of their colour, skin texture, eyes, gills, flesh and odour; the same way there are some changes that characterized fish spoilage (biochemical change, rigor motif in muscles, muscle tendering and spoilage).It is imperative to understand that all processing methods are preservation method but all preservation methods are not processing methods. There are a number of way to preserve fish (-cooling and icing, salting and pickling, paste and sauces, air drying and smoking/kiln drying). Fish Processing is a way of preserving fish and at the same time improving their quality. In the process, the properties of the fish change.There are many ways to process fish. Some methods such as salting and drying have been used since the ancient times, long before modern technology was introduced. Others involved the use of chemicals and electrical devices. Basically, the fish processing methods include canning, fermentation, pickling, dehydration, curing e.t.c.

6.0 Tutor-Marred Assignment

1. What does the term “Value addition” denotes in Fisheries”.
2. Elucidate on the mechanism of fish spoilage
3. Write an essay on fish preservation and processing

7.0 References/ Further Reading

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UNIT 2 ADVANCED FISH PROCESSING METHODS

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1.0 Introduction

Approximately 75% of world fish production is used for human consumption and the remaining 25% is used to produce fish meal and oil. Fish meal is a commodity used as feed for livestock such as poultry,pigs and farmed fish and fish oil is used as an ingredient in paints and margarine.

Currently, only about 30% of fish produced for human consumption are marketed fresh. The supply of frozen fish fillets and fish, in the form of ready-to-eat meals and other convenience food products is growing in both developed and developing countries.The end products from fish processing may be fresh, frozen or marinated fillets, canned fish, fish meal, fish oil or fish protein products, such as surimi. Surimi is an important fish product, with the majority of catches for some species used solely for its production.

Fish processing most commonly takes place at on-shore processing facilities. However some processing can take place at sea, on board fishing vessels—for example the gutting of oily fish. In some regions of the world, where large sea fleets operate, processing can also take place on board fishing vessels. For some sea fleets, 100% utilization of the catch may be required by legislation. This means that the entire processing operation, including fish meal and oil production for offal and fish waste, takes place on board the fishing vessels.

2.0 Objectives

At the end of this unit, you should be able to

(i) explain production of fish meal and fish oil

(ii) state fish preservation and processing in Nigeria

3.0 Main Body

3.1Advanced fish processing methods

- **Filleting of white fish**

Filleting involves a number of unit operations: pretreatment, fish filleting,trimming of fillets, packing and storage. These processes generally takeplace within separate departments of the fish processing plant.White fish species have low oil content and, unlike their oily fishcounterparts, are generally gutted, cleaned and sometimes de-headed onboard the fishing vessel. The fish are kept on ice in boxes before beingdelivered to the fish processing plant. On arrival at the plant, fish may bere-iced and placed in chilled storage until required for further processing.

- **Pretreatment**

Pretreatment of the fish involves the removal of ice, washing, gradingaccording to size and de-heading, if this has not been done previously.Large fish may also scaled be before further processing.

- **Filleting**

The next step in the process is filleting, which is generally done bymechanical filletingmachines. The filleting department is generallyseparated from the pretreatment area by a wall, to prevent workers andgoods passing from the non-sterile pretreatment area to the sterilefilleting area. The filleting machines comprise pairs of mechanicallyoperated knives which cut the fillets from the backbone and remove thecollarbone. Some fish fillets may also be skinned at this stage.

- **Trimming**

In the trimming department, pin bones are removed and operatorsinspect the fillets, removing defects and any parts that are of inferiorquality. Off-cuts are collected and minced. Depending on the finalproduct, the fillets may be cut into portions according to weight ordivided into parts such as loin, tail and belly flap. As a final step beforepackaging, the fillets are inspected to ensure they meet productstandard.

- **Packaging and storage**

Fresh products are packaged in boxes with ice, the ice being separatedfrom the products by a layer of plastic. Frozen products can be packedin a number of ways. Fillets or pieces can be individually frozen andwrapped in plastic, but the most common method is for them to bepacked as 6–11 kg blocks in waxed cartons. The blocks are typicallyfrozen and then kept in cold storage.

3.2 Fish meal and fish oil production

Fish meal and fish oil are produced from fish that are caught specificallyfor this market, by-catch from fishing activities and solid waste fromfilleting and canning.Fish meal and fish oil products have a high nutritional value. Fish meal isused as feed for livestock and farmed fish, and the oil is used as aningredient in paints and margarine.Fish meal is derived from the dry components of the fish, and the oilfrom the oily component. Water, which makes up the rest of the fishmatter, is evaporated during the process.Most fish meal and fish oil production processes are automated andcontinuous, and comprise several process lines, each with a certainprocessing capacity. Production rates vary considerably, according tothe season and types of fish being processed.
The steps involved in fish meal in fish oil production are summarized in figure1.

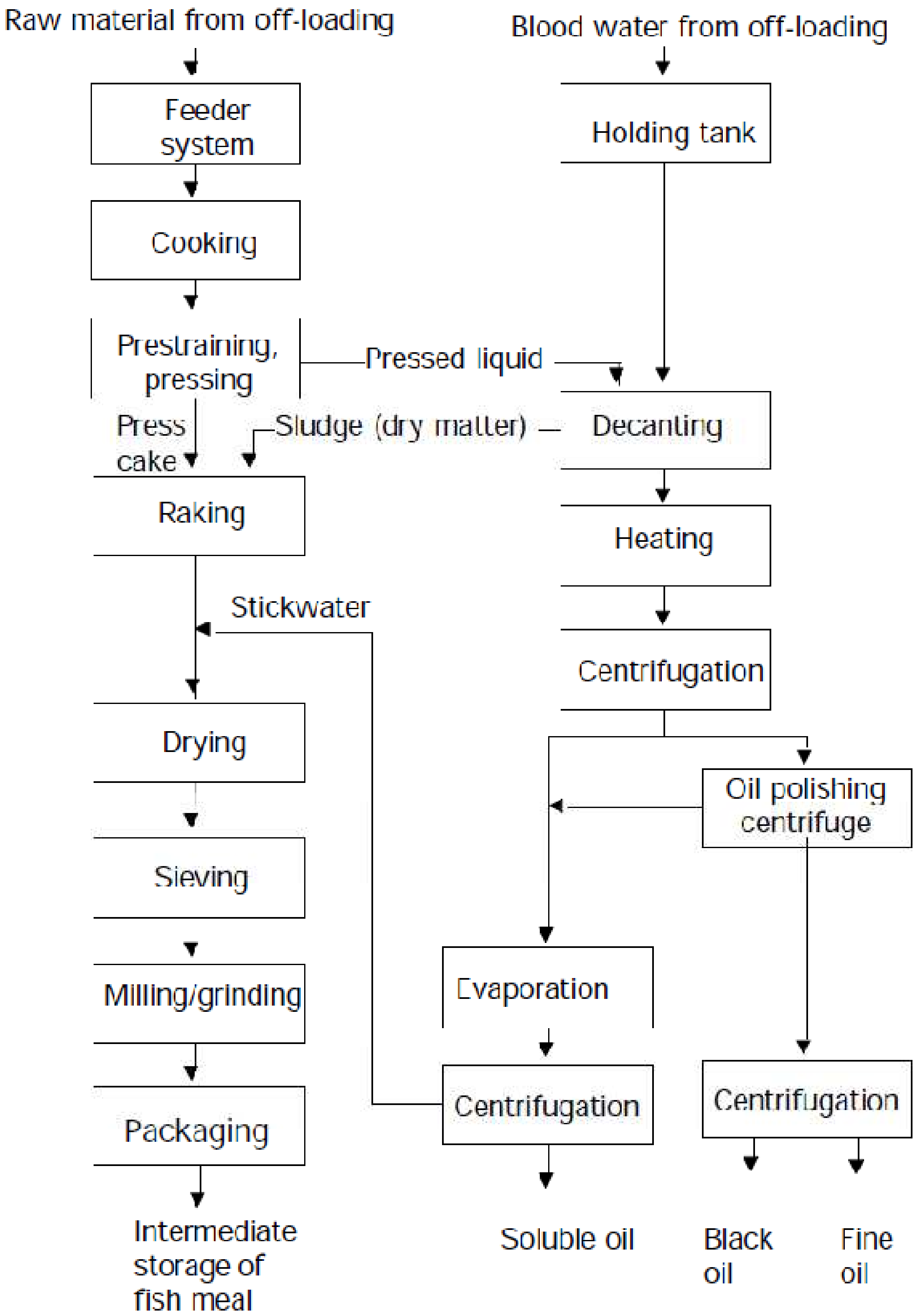

Figure1: Process flow diagram of fish meal and fish oil production

Off-loading

On board the fishing vessels, the catch is normally stored in tanks ofwater. Upon arriving at the processing plant the fish are pumped toholding bins, where they are stored until required for processing. Extrasea water may need to be added to pump the fish.

3.2 Fish meal process

From the storage bins, the fish are transported by screw conveyors to acooking process which acts to coagulate the protein. The cookedmixture is then screened, using a strainer conveyor or a vibrating screen,and then pressed to remove most of the water from the mixture.

The pressed cake is shredded and dried, using an indirect steam drier ora direct flame dryer. The meal passes through a vibrating screen and onto a hammer mill, which grinds it to the appropriate size. The groundmeal is automatically weighed and bagged.

Fish oil process

The pressed liquid generated from the previous processes passesthrough a decanter to removemost of the sludge, which is fed back tothe meal dryer. Oil is separated from the liquid by centrifuges, polishedand refined to remove any remaining water and impurities. Theseparated aqueous phases, referred to as stick water, is concentrated inan evaporator and then added to the pressed fish meal prior to beingsent to the dryer.

3.3**: Overview of Fish Preservation Processing in Nigeria**

In Nigeria an abundant fish catch is experience in the dry season. During this period, ponds, lakes and streams experience reduced water level, for easy harvest. Thus, period of fish scarcity is often encountered especially during the flood and raining seasons, during which fish are in short supply. Thus, it is imperative to process and preserve some of the fish caught in the period of abundance, so as to ensure an all year round supply. This will invariably reduce post harvest losses, increase the shelf-life of fish, and guarantee a sustainable supply of fish during off season with concomitant increase in the profit of the fisher folks.

Fish processing is still predominantly undertaken manually in Nigeria. Traditional fish processors adopted open fire or simple smoking oven such as halved cut drum oven, rafters and mud oven to improved technology such as dryer, chorkor kiln and gas oven. The different types of fish preservation techniques practiced are brining/smoking, drying, hot or cold smoking, smoke-drying, smoking with pepper, frying and sun-drying. Most common of all these processing technique was smoke-drying. This could be adduced to the fact that most of the fish communities have no access to electricity to freeze their products. Electricity itself is fast becoming a less reliable source of energy for fish processing and preservation. Despite the rudimentary nature of process of traditional methods, and lack of control over the drying rate, sometimes results to under-drying or over-drying, and expose the fish to unexpected winds, dust, dirt, insect infestation, and contaminants such as flies. These methods still remain predominant in Nigeria. Most of the processing technique favours the use of drum oven and mud oven. For the improved technology, electric dryer, chorkor kiln and gas were not common in the processing centers. Losses during fish processing were significant intraditional processing method compared to improved technology. To reduce post harvest losses and to improve the quality of fish and fishery products, traditional processing technology must be improved upon in Nigeria. This includes upgrading the traditional fish processing technology and adoption of solar dryer. The acceptability of mechanization of fish processing operations are hinged on the following factors based on the fish processors comments; literacy level, cost of the machines, level of awareness, infrastructural facilitiesavailable such as electricity, tap water or borehole water and accessible roads.

Highincidence of fish losses is a major impediment to the realization of government goal towardsincreasing the contribution of the fisheries sector to the overall national economy. The use of appropriatetechnology which is a radical approach to stem up production and processing technique, has become subordinate to social need, and is of paramount importance. The need to mechanize fish processing techniques has drawn the attention of national agricultural research to devote utmost interest and resources to engineering research in operation, to minimize the drudgery, reduce labour operation, and unsanitary and inherent unhygienic handling that are mostly involved in the traditional manual operations.

Artificial dryers such as solar dryer, kiln, oven and so on have long been in existence, some of them are powered electrically, by sun, gas or natural fuel such as firewood, charcoal, wood and saw dust.The drying of fish in oven consists of a period of several hours in which the fish is cookedfollowed by a period drying with low burning fire, producing only a moderate amount of smoke. The length of this latter period varies with the required keeping quality. The moisture of the dried products varies between an estimated 40percent in the higher ranges and 10-20percent in lower. The quality of the product is judged on degree of drying, appearance, damaged and insect infestation is influencing the price. Smoked fish as source of foreign exchange is gradually losing ground. This is adduced to the fact that exportation of processed fish to developed countries is becoming increasingly stringent because of the emerging set of Food Safely and Agricultural Health Standard, along with buyers changing their requirements.

4.0 Conclusion:

Traditional fish products (TFPs) are usually produced by applying old preserving methods such as salting, fermenting, drying and smoking. These products also greatly varies amongst the countries as well as within the same country by using many different applications such as differences in additives, percentage of salt or vinegar and maturing temperatures. Moreover, modifications in these techniques are also known due to food safety issues and changes in customer preference of new generation. Although such processing/preserving methods have been known as old techniques for many years, they have still wide acceptance around the world because of their specific taste and aroma.

Due to their specific characteristics for varying many types, they have both advantages and disadvantages.

Traditional fish processing and preservation were originally developed to preserve fisheries products for a long storage life by either lowering water activity (aw) and/or changing pH of the products. In addition, preservation was also carried out by applying antibacterial activity of salt and/or smoke components or other preservative compounds to increase shelf-life and improve safety of such products. Although new technologies such as canning, high pressure processing (HPP) and modified or controlled atmospheric packaging (MAP, CAP) methods have been developed to improve safety of seafood products, traditional preserving methods of fish products have still wide acceptance around the world due to their accustomed taste and aroma.

Despite the preserving aim of such traditional methods, these products are still under risk of several hazards due to following reasons: (i) these products have long maturation time, (ii) they are generally consumed without further cooking, (iii) changes in the original methodologies over the years such as decreasing salt con

5.0 Summary

The end products from advanced fish processing may be fresh, frozen or marinated fillets, canned fish, fish meal, fish oil or fish protein products, such as surimi. Surimi is an important fish product, with the majority of catches for some species used solely for its production.Fish processing is still predominantly undertaken manually in Nigeria.Traditional fish processors adopted open fire or simple smoking oven such as halved cut drum oven, rafters and mud oven to improved technology such as dryer, chorkor kiln and gas oven.

6.0 Tutor-marked assignment

Account for the preference of fish processed by traditional method to that processed by advanced method in Nigeria.

7.0/ Further Reading/References

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MODULE 12:WATER QUALITY MANAGEMENT IN AQUACULTURE

Unit 1 Water Quality Management

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1.0 Introduction
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3.0 Main Body
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1.0 Introduction

Management of water quality to include colour, pH, dissolved oxygen content, turbidity, total alkalinity and hardness as well as pollutants is important because they affect survival, growth and reproduction of fish. Quality of water must be checked weekly, monthly or bimonthly depending on prevailing conditions. However, colour of water should be checked daily.

2.0 Objectives

At the end of this unit, students should be able to understand the importance of water quality parameters and water quality management of ponds.

3.0 Main Body

3.1 Water quality management

3.1.1 Good water is characterized by the following:

1. It should be greenish or bluish in colour due to phytoplankton. Yellow or brown colour may indicate acid water.
2. It should be about neutral or slightly alkaline. Best pH range for fish production is 6.5-9.0. Acidic and alkaline death point for pond fish is pH 4 and 11 respectively.
3. It must contain enough dissolve oxygen above 4mg/l. At values of 3mg/l or less growth will slow down, fish may become susceptible to diseases.
4. It must not be muddy or turbid. Secchi disc visibility less than 25cm is not desirable (adequate range = 40-90cm). When Secchi disc is unavailable, the palm should be visible when hand is dipped in water except turbidity is caused by plankton bloom.
5. It must not have offensive odour
6. It must be free of pollutants e.g. oil films, detergents, heavy metals e.t.c.

3.2 Control of pH levels in Ponds

When pH level is consistently low agriculture lime should be applied to raise the pH at the rate of 250-500kg/ha. Acidic waters are common in ponds constructed in acid sulphate soils (found in coastal mangrove swamps). Such pond dykes should be limed at the rate of 1-2kg/m (length) and the pond water limed periodically (30kg/ha/month) in addition to the normal one dosage application before stocking. High Ph levels can be controlled by application of filler alum (aluminiumsulphate at dosages of 10-20mg/h).

3.3 Dissolved oxygen (DO): This is probably the most critical factor in fish culture.

(a) Causes of low DO: In ponds
  - Heavy plankton blooms caused by excess manuring of fish ponds.
  - Accumulation of uneaten feeds in ponds caused by over –feeding (high feeding rates) or bad feeding methods.
  - Overcrowding caused by high stocking densities.
  - Reduction in rates of photosynthesis caused by extended periods of cloudy weather or high turbidity of water.

(b) Indicator of low DO in ponds
  = swimming of fish to water surface to gasp for air. It is serous when this involves bottom fishes and it occurs all over the pond especially around midnight.
  - Lack of response to noise i.e. escapes into deeper waters when scared by noise e.g. clapping of hands.

(c) Control of low DO
  - Fertilization should be suspended.
  - Feeding rate should be reduced or feeding stopped

- Water should be changed and fresh oxygenated water added to the pond.
- Water should be aerated either by use of aerators or agitators especially if pond water cannot be changed due to shortage.

3.4 Turbidity-cause

- Suspended silt or clay particles. Clay turbidity restricts light penetration and may limit growth of plankton. It may also clog and block gill systems of fish and affect rate of reproduction by damaging fish eggs and destroying breeding grounds. Habitats of benthic organisms are also damaged.
- High plankton density. Turbidity arising from planktonic organisms is desirable so long as it is not in excess. Excess plankton bloom may limit light penetration due to algal scum on surface and may deplete dissolved oxygen due to respiration

Control of Turbidity

- Simply by soaking dry vegetation in pond.
- By use of chemicals such as lime, filter alum to precipitate suspended solids
- Fertilization should be suspended if turbidity is caused by plankton blooms.

3.5 Alkalinity and Water Hardness

Desirable level of total alkalinity and total hardness in ponds ranges between 20-250mg/l. If these variables are low (less than 20mg/l) formation and growth of plankton may slow due to low supply of carbondioxide. Low levels of total alkalinity and hardness are increased by liming.

(v) Pollutants:

Their presence in ponds can result in extreme mortality of fish. Control of pollution includes:

- Location of fish ponds away from heavy industrial centres, oil fields and chemically treated agricultural farms
- Diverting or re-channelling run-off water from agriculture farms away from ponds
- Ensuring that source of water for fish culture is of high quality
- Each pond should have its own inlet and outlet

Pollution caused by waste products of fish can be controlled by changing the water in the pond

GENERAL WATER MANAGEMENT IN PONDS

Low oxygen can kill fish. The decay of excess feed and organic fertilizer consumes oxygen from pond water. Fish will die of asphyxiation if too much oxygen is consumed. Ponds receiving large applications of fertilizer and/or feed must be closely monitored to determine if oxygen levels in the pond are satisfactory for fish. Low oxygen occurs most frequently just before sunrise. Farmers should visit their ponds early in the morning to see if fish are suffering from low oxygen. Fish will come to the water surface seeking higher oxygen levels from water in contact with the atmosphere. The fish appear to be "drinking" the surface water (Figure 1).

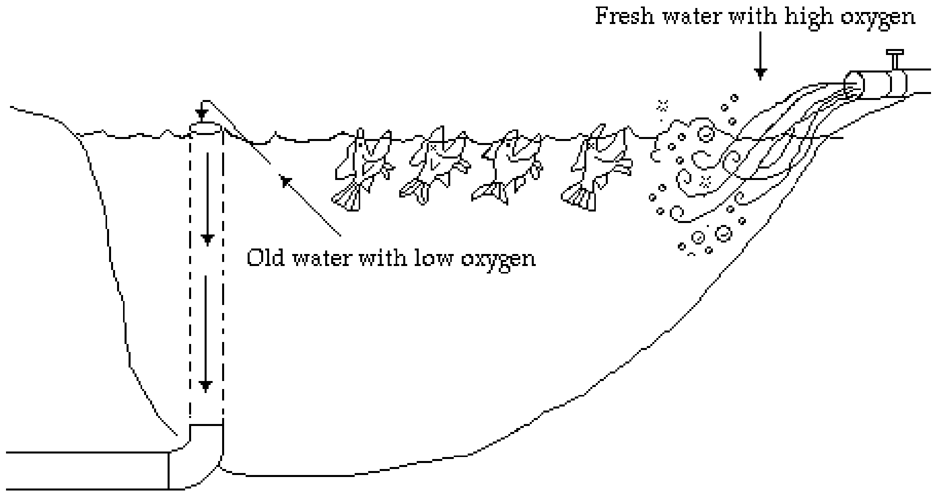

Figure 1: Pond with low oxygen and fish gasping at the surface.

Almost all fish in the pond will be evenly dispersed over the pond surface and gasping for air. When scared, they will make a splash and dive for deeper water, but will quickly return to the surface. This behavior is sometimes confused with feeding. However, feeding fish will not return to the surface quickly if scared. Fish suffering from low oxygen will usually not eat. Take immediate action to remedy low oxygen using the following steps.

<u>How to correct low oxygen in ponds.</u>

1) Add fresh water to the pond to replace water with low oxygen until fish stop gasping at the surface. More oxygen may be added to the fresh water by letting it run over a terraced structure before it enters the pond (Figure 2).
2) Stop fertilization and feeding for several days. Observe fish behavior closely during this time. If low oxygen has been corrected, fish will resume their normal feeding habits. When plankton abundance decreases and a submerged object is visible at a depth of 30 cm, fertilization may be resumed.
3) If low oxygen becomes a chronic problem, reduce the amount of fertilizer and/or feed placed in the pond.

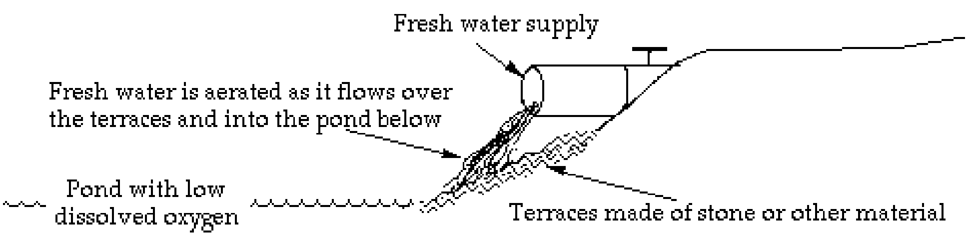

Figure 2: Adding new, aerated water to a pond with low oxygen.

4.0 Conclusion

Good water quality is imperative for the success of a fish culture.

5.0 Summary

Management of water quality to include colour, pH, dissolved oxygen content, turbidity, total alkalinity and hardness as well as pollutants is important because they affect survival, growth and reproduction of fish.

6.0 Tutor-Marked Assignments

Give three water quality parameters and its management in a pond

7.0 References/ Further Reading

Lagler,1956; Williams, 1072; Boyd, 1971.