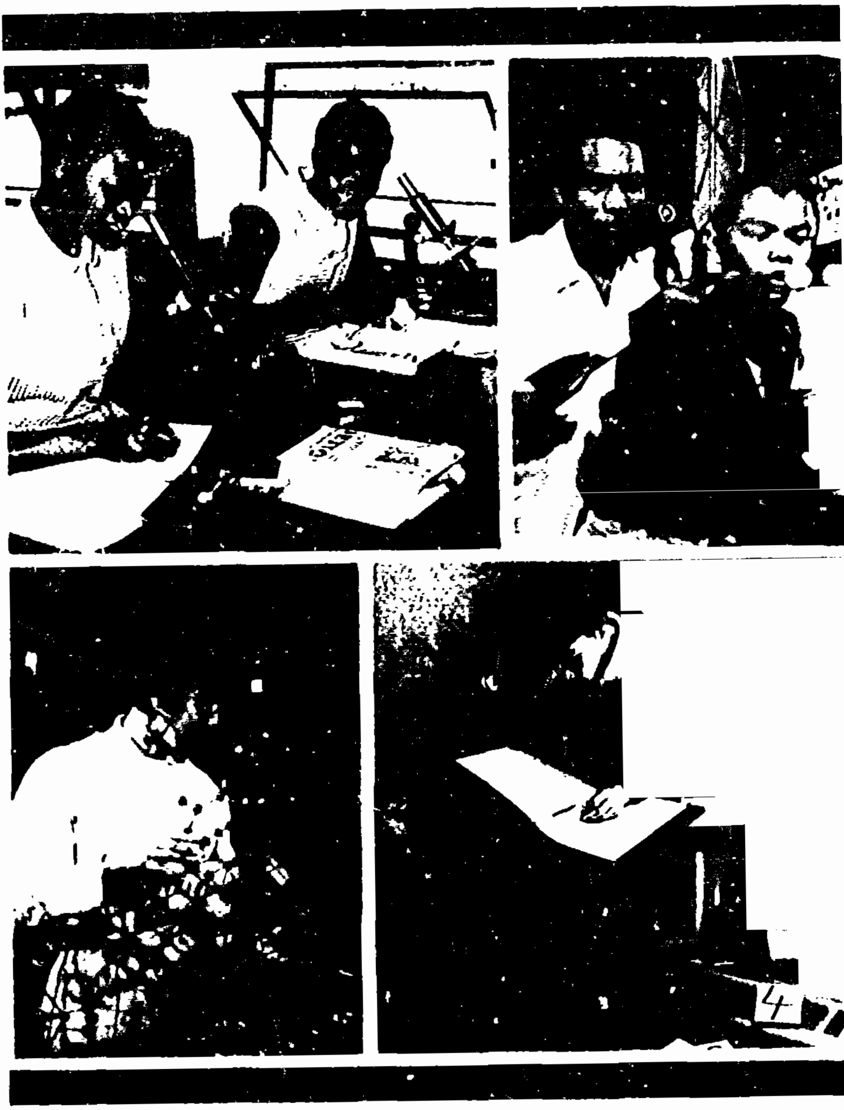
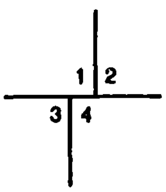
Use of the Sea and its Organisms





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Use of the Sea and its Organisms

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PREFACE

The document series has been initiated as part of Unesco's Science and Technology Education Programme to encourage an international exchange of ideas and information on science and technology education. This is further intended to develop greater awareness and better understanding of the nature of science and technology and their role in a changing society by improving and extending their teaching to in and out-of-school education. The present volume as part of the "Biology and Human Welfare" theme was produced jointly by Dr. Abul K.M. Bashirullah and Dr. Molla Fazlul Huq under contract with Unesco. Both the authors are from the Departments de Biologia Pesquera, Instituto Oceanografico, Universidad de Oriente, Cumana, 6101, Venezuela. The opinions expressed in the following pages are those of the authors and not necessarily those of Unesco.

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INTRODUCTION

This book is addressed to school level students, and at the same time to teachers and some non-professionals interested in marine sciences. The book is oriented to find the use and applications of the sea and its inhabitants for economic development.

Our knowledge of the oceans has grown a lot in recent years, but is still very incomplete. The oceans of the world hold great promise to provide future generations with minerals, food, energy, salt, freshwater, etc. We must turn our attention for finding more appropiate ways of transforming this promise into accomplishment. The oceans cover almost 71% of the surface of the globe. The greatest importance of the sea lies in the possibility that its living resources can supply a large portion of protein to the ever increasing population of the world. Of over 25,000 species of fish in the sea, we capture only 1% for our consumption. Some of these species are over exploited, and have become endangered, therefore consciousness must be applied, otherwise those may be extinct in the near future.

Products of seaweeds are now employed in food processing, cosmetics and other industries. Mineral resources are of potencial interest, but their exploitation are out of reach of developing countries due to lack of high technologies and shortage of money. Desalination of sea-water is expensive but some countries in the Middle East are trying to compensate the dearth of freshwater through it. Extraction of salt from the sea is common, some improvise ways and others use advanced technologies. Certain sea organisms are used for decorative purposes and some people have developed a profession out of it. We must use the sea and its inhabitants very realistically, neither by harming the population nor by deteriorating the habitat. A clean environment should be recognized as one of the rights of mankind, not only because of the food resources of the sea but also for the recreational benifit. We must develop consciousness and ability to preserve our environment.

Within the broad scope of marine sciences, we have selected topics to give general ideas of the sea and its functioning. Economic exploitation of any natural resource implies a thorough knowledge of its origin, development and limitations. A better understanding of the sea and its environment may help tho mankind to put into for its greater use for a long time to come. The instructors are expected to select and mold the materials to match their teaching styles and their availability of facilities.

Both authors accept the responsability for all the materials in the book.

1. THE SCIENCE OF OCEANOGRAPHY

Oceanography can simply be defined as the study of oceans and seas, and can also de defined in various ways depending on the concern of the definer.

The aim of the oceanography is to understand all aspects of the oceans: the properties and behaviour of the ocean waters, the nature of living organisms in the marine environment; the interaction between the waters and their boundaries; the shape and structure of the ocean basins; the air above them; the economic and technical potentialities of the oceans and their roles as a part of the earth's outer covering. Oceanography is basically an interdisciplinary science and it consists of the application of physics, chemistry, biology, mathematics and astronomy. It is a typical environmental science which shares with other environmental sciences, the peculiarity that the present condition of its objects of study has been largely determined by events in the past.

The science of oceanography can be divided into seven main branches: Physical Ocoanography, Chemical Oceanography, Biological Oceanography, Meteorolgical Oceanography, Geological Oceanography, Military Oceanography, and Ocean Engineering.

Physical Oceanography is concerned with the physical properties of the ocean waters and with the transport of energy, momentum and matter.The major activities of physical oceanography consists of 1) direct observation of the oceans and preparation of synoptic charts of oceanographic elements and properties, which is a descriptive oceanography; 2) theoretical study of the physical processes that might be expected to explain the observed behaviour of the oceans, which is a branch of theoretical physics.

Chemical Oceanography is concerned with the chemical analysis of the seawater. It also contrubutes to the indirect determination of the density of seawater,dissolved organic and inorganic materials of the seawater. The role of a chemical oceanographer is indispensable to the physical as well as biological oceanographer.

Biological Oceanography is concerned with the biological environment, that is, with marine organisms, as part of the total oceanic system, and with the ocean as a habitat for life. It aims to understand the interaction of organisms with their environment and with each other.

Meteorological Oceanography is concerned with the possibility of predicting large scale atmospheric behaviour for periods longer than 24 hours, which depends on successful measurements of vertical fluxes of heat, water vapor and momentum, both on land and sea. The behaviour of the air-sea boundary constitutes the central problem in meteorological oceanography.

Geological Oceanography constitute the study of the geological character of the sea bottom, their constituents rocks and sediments, and fossil biota of the sediments that carpet the ocean floor provides the tools to understand present and past condition. It also assists in the understanding of the geochemical cycles and processes of organic evolution.

Military Oceanography is often difficult to distinguish between oceanography which is military and that which is not, since much of what is of interest to a navy is also of interest to civilian investigators.Nevertheless, there are a number of majors areas of interest to the world's navies which may be grouped together as military oceanography. These are the following:

a) Anti-submarine warfare: The nuclear submarine equipped with different nuclear missiles, can remain submerged for extended period of time, is extremely difficult to detect with present methods. Therefore antisubmarine warfare, which is involved with methods of detection and destruction of submerged submarines, is of prime interest to the Navy. Anti-submarine warfare includes such topics as underwater acoustics, underwater visibility,and properties involved with submarines which might lead to detection and identification.

b)Sea ice: The navy is interested in the ice situation for its own purposes and consequently does a great deal of work involved with ice prediction.

c) Mine warfare:The mine, when placed in a harbour by an enemy, is a very dangerous and highly destructive device. The proper amount of noise,the proper magnetic field and a proper pressure field are needed to know to detonate a typical mine.

d)Wave forecasting:The knowledge of accurate forecast of the waves is essential for an efficient and successful maneuvering of warships,aircraft-carrier,etc.

Ocean Engineering, a relatively new field of study of the oceans.It requires the knowledge of all the branches of the oceanography for effective use of sea and the exploitation of its potentials. Ocean engineering needs to apply the classic engineering principles and accordingly modify them to the different environmental factors and forces of the ocean, and to develop the means for carrying on the tasks man wants to accomplish in the sea.

The first scientific expedition to study the ocean were carried out in the 19th century, but people went out to the sea long before this for commerce. In open boats and without the aid of compass, the Viking sailed from Scandinavia to Greenland and Iceland. Othar, in 870 A.D., rounded the North Cape and sailed into the Arctic Ocean.Lief Erikson discovered the America in 1000 A.D, establishing the first-temporary settlement in Labrador, Newfoundland. It is doubtful that Columbus knew about it when rediscovered America in 1492.Vasco da Gama sailed around Africa, reaching India in 1497.Ferdinand Magellan sailed in 1519 from Spain and reached Philippines in 1521. Sebastian del Caño continued his vouyage after the death of Magellan reaching Spain in 1522. Captain James Cook, in his vouyages from 1769 to 1799 surveyed the Pacific from the Bering Straights to the Antarctic Circle.

With the exception of Captain Cook, most of the deepsea vouyages and expeditions prior to 1800 were undertaken for the purposes of commerce, exploitation or colonization. In 1831 a young naturalist graducte from Cambridge University named Charles Darwin sailed in Her Majesty's ship Beagle, under the command of Captain Fritz Roy on the 27th day of December,1831, with the intention to complete the survey of the coast of Patagonia and Tirra del Fuego, and to carry on a chain of chronometrical measurements around the world.Charles Darwin spent the next five years aboard the Beagle, studying animals and plants of the world. This studies led to his famous theory that animals change slowly from one form to another. Later after studying his rich and enormous collection of five years, led to the publication of his famous controversial book ~~Origin of Species~~ in 1857.

In 1845, nine years after the return of the Beagle, the names Atlantic, Pacific, Indian were finally settled upon for the major water bodies. The names were established but the deep basins and the water in them still lay virtually unexplored. No one knew how deep the oceans really were. Between 1840 and 1870, various scientists initiated the studies to find out how deep was the ocean and whether or not there was life on the floor of the deep ocean. The informations available were too few and too widely scattered to give a clear picture of what the oceans were really like.

The Royal Society of England conceived the idea of a great Scientific Expedition that would investigate all the deep oceans of the world from the surface to the profound abyss. On December 7,1872 H.M.S.Challenger sailed out of the Thames river for the vast unknown water bodies of the world. The Challenger took 362 stations evenly spaced around the world. She cruised 3.5 years, from December 1872 to May 1876, covering almost 69.000 miles and collected many new plants and animals from different depths and trawled off the bottom. The scientists located the deepest part of sea known as Marianas Trench, is believed to be the deepest part of the ocean, which the Russian research vessel Vityoz recorded 36,056 ft. This is 7028 ft deeper than Mount Everest's height.On January 23,1960, the bathyscroph Trieste reached the bottom of the Challenger deep and recorded the depth as 35.805 ft. At the determination of the voyage on the May 24,1876, systematic sounding had been taken in every area except the Arctic, and 140 million square miles of ocean floor had-been charted. In 1895, the last of 50 volumes contai-ning the complete scientific results of the expedition was published. The expedition Challenger and the results obtained placed the science of Oceanography on a firm foudation.

2: THE OCEAN AS A HABITAT

Despite its ceaseless activity, the ocean is the most constant environment of earth and this is home for tremendous variety of plants and animals. This ocean environment is characterized by very narrow ranges of change in chemical and physical properties, in seasonal and horizontal fluctuation, in temperature and in salinity. Due to mixing processes, the upper lighted (photic) zone is one of vertical and horizontal constancy, favouring maximum level of photosynthesis. It is this zone of active plant- animal growth that determine oceanic productivity. This chapter deals with the brief geography of the world ocean and their environments, and followed by a discussion of the properties of sea water.

2.1: Ocean and seas

Oceans and seas cover 71.6% of the earth's surface. Most of this area is covered by five great oceans: the Atlantic, Pacific and Indian oceans, the Arctic and the Antarctic oceans which surround the North and South poles. Part of the deep oceans have been called seas, such as, Arabian sea and the Sargasso sea. Other seas are just as deep (atleast 2000m or 6562ft) but are separated from from the oceans and are surrounded by land, such as the Mediterranean sea, the Black sea, the Red sea, the Malay sea, the Bering sea and the Caribbean sea. Shallow seas (less than 200m or 656 ft), such as the North sea and the Baltic sea represent the flooded edges of the continent.

The relative amount of land and water appearing in the Northern and Southern Hemispheres is asymmetric. Of the total surface area in the Northern Hemisphere, about 61% is sea, while in the Southern Hemisphere, about 81% of the total surface area is covered with water. The earth as a whole contains some 365,000,000 square kilometers of sea surface, amounting to 71.6% of the total world surface area. The distribution of areas, volume, etc of the largest oceans are given in table-I(A & B).

Bathymetric features:

The ocean may be divided into three bathymetric areas: the first of these id the Continental shelf, which is arbitrarily defined as a broad shallow strip of seabed that extends from the coast to depths of 100-200 meters. The average slope is about one-tenth of a degre near shore it normally is slightly steeper. The continental shelf varies greatly in width and slope. In some cases, as off mountainous coasts, the shelf may be virtually

Ocean	Area X $10^6 Km^2$	%	Volume X $10^6 Km^2$	%	Average depths (in m.)	Maximum depth (in m.)
Pacific	165.2	32.4	707.6	51.6	4282	11,022
Atlantic	82.4	16.2	323.6	23.6	3926	9,200
Indian	73.4	14.4	291.0	21.2	3963	7,460
Arctic	14.1	2.8	17.0	1.2	1205	4,300

Table-IA : Distribution of areas, volumes, depths of four major oceans.

SEAS	AREAS		
Malay sea	8.142.960	square	kilometers
Caribbean sea	2.753.170	"	"
Mediterranean sea	2.503.882	"	"
Bering sea	2.268.192	"	"
North sea	575.304	"	"
Black sea	461.991	"	"
Red sea	437.710		
Baltic sea	422.170	"	"

Table-I B: Distribution of areas of major seas absent, whereas, off glaciated coasts and off the mouth of large rivers and areas with broad lowlands, the shelf may be very wide. The average width is 75 km. The continental shelf, comprising about 7.5% of the oceanic area, is the most productive due to rich floras and faunas. Most of the larger fisheries are located in this area.

The Continental slope is the next major bathymetric feature.Starting at the sea end of the shelf, the oceanic drop increases very rapidly, extending out from the end of the shelf to a depth of 3000 meters(or 9843 ft) and comprising about 12% of the oceanic area.The average gradient is just over 4° for the first 2000 meters. Most striking feature of the continental slope is the prevalence of large numbers of submarine canyons. The total length of continental slope is about 300.000 kms, almost eight times the circumference of the Earth.

The final bathymetric area is the ocean basins, where the depth is roughly the same throughout. About 80% of the oceanic area falls within the depth range of 3000 to 6000 meters. Ocean basins are large expanse of the deep sea floor that are separated from one another by oceanic ridges and from the continents by the continental shelf and slope. The ocean basins covers three-fifth of the Earth.Water actually covers 71.6% of the Earth, but only 60% of this overlies the deep ocean basins, which occur below the 2000 meters contour line. The average depth of the sea is 3800 meters whereas average heights of the continents is 840 m.

The distribution of ocean basins and continents is asymmetrical. Continents are generally antipodal(diametrically opposed) to ocean basins.The ocean basin lie principally in the Southern Hemisphere, and the Antarctic basin encircles the Earth. There are three major ocean basins(Pacific, Atlantic and Indian) and they are all interconnected, so that there is really only one world-wide ocean basin.

The major features within the ocean basins are the Midocean ridges(rise), Trenches and Fractured zones. Midocean ridge system actually forms a continous swell throughout the world ocean.It is a broad arch one to three kilometers high which may either exceedingly rough or quite smooth. It is by far the most extensive mountain range on the face of the Earth.It is the greatest topographic feature of the sea bottom and extend continously through the Atlantic, Indian, Antarctic and South Pacific oceans and has a length of 60.000 kilometers.The midocean ridge shows seismic activity along the axis.

Trenches constitute the deepest part of the oceans. Oceanic trenches are long, narrow, arcuate depressions in the ocean floor. Typically trenches have an asymmetrical V-shaped with steeper slope towards land and a gentle slope toward the ocean basin. The greatest depth are found in the trenches. The deepest depression is the 10.850 m(35.600 ft) in the Mariana Trench near Guam in the Pacific.

Fractured zones are long, narrow ridges and depression that usually separate oceanic ridges of different depth. The fractured zones may be as much as 100 kms.wide and 2000 kms long. Earthquake activity indicates that the fractured zones are actively moving today only where they connect segments of actively spreading ridges or where they connect a rift to a trench.

2.2: Ocean Circulation

The great water masses that cover nearly 71% of the Earth's surface are interconnected by a rather orderly system of water currents. The driving forces for this water motion are wind friction at the sea surface and horizontal and vertical differences in the density of sea water.This can be explained by analyzing the two important modes of large scale motion: advective circulation, commonly known as wind-driven circulation; and the convective circulation, known as thermohaline circulation. The former is representative of the major global systems of surface and sub-surface currents found in the world ocean. The later is related to the abyssal circulation.

The wind driven circulation is principally in the upper few hundreds of meters and therefore is primarily a horizontal circulation. The Gulf stream current is an example of wind driven circulation which is described later in this section.

The thermohaline circulation is used to refer to the movement of water that takes place when its density is changed by a change of temperature or of salinity in a suitable parts of its bulk. A standard laboratory demonstration of thermal circulation is to take a large beaker of water and heat it at the bottom by means of a Bunsen burner. The water which is heated expands and rises(convection) in accordance with Archimedes' principle. The water rises over the sources of heat and sinks elsewhere. The sinking in this case is simply the consequence of continuity of volume. In the case of the atmosphere,the sun's energy is absorbed by the land, this heat the air near to it and a similar circulation to that in the beaker takes place. Since there is no significant source of heat at the bottom of the oceans, a thermal circulation like that in the beaker and the atmosphere, plays a little part in the ocean circulation. However, it is known that there is a net heat loss from the oceans at high latitudes. The result of cooling of the water is an increase in density which may be sufficient to cause it to sink and so displace the deeper water. The laboratory experiment to illustrate this is float an ice cube in a beaker of water, the water cooled by the ice will sink. The density of bottom layer of the water can be increased by dissolving salt at the bottom, and stop sinking the surface water.

The thermohaline circulation of the oceans is due to an increase of density at the upper surface, either directly by coolong or indirectly when ice freezes out, ejecting salt and thus increasing the density of the remaining water. In the North Atlantic the cooling effect in the winter is considered to be responsible for the sinking of water to considerable depths. In the Antarctic, the freezing effect is important.

The inclination of the axis of rotation of the earth with respect to the plane of the earth's orbit around the sun is responsible for the bulk of solar radiation falling near the earth's equator and creating a differential heating on the surface of the earth. The rotation of the earth distributes this energy zonlly(east- west).The earth radiates long wave radiation back into space and the processes are such that in equatorial regions there is a surplus of radiation received by the sun while in higher latitudes there is a deficit. The temperature differences so generated require such an amount of heat to be transported towards the polar regions that no conductive processes can provide it.This task is taken by winds and ocean currents.

High temperatures at the equator cause the air at the surface to expand and so become lighter. The air to both north and south being cooler and therefore heavier, presses upon the lighter equatorial air and forces it upwards. The trade winds(i.e. the regular steady winds which blow from the neighbouhood of the tropics towards the equator) are simply this heavier air moving over the surface. It might be expected that they would be north or south winds. This wind keep pushing the surface water of the oceans always in the same direction and thus are the main cause of the ocean current.

The direction of the ocean currents, like those of the winds, tend to be influenced by the effect of the Earth's rotation which act so as to cause freely moving objects to curve to the right in the northern hemisphere and to the left in the southern hemisphere. However, it is mainly the clockwise circulation of winds in North Atlantic and North Pacific that produces a clockwise swirl, or one curving to the right. In the South Atlantic, South Pacific and Indian oceans, the main movement is an anti-clockwise swirl.

The wind driven circulation is well studied, and the Gulf Stream circulation explain the general pictures and some of its peculiarities, which described below:

The Gulf Stream is one of the most important ocean currents and forms part of the great clockwise movement of surface water around the north Atlantic Ocean.

Helped by the trade winds, a broad drift of warm water near the equator moves into the Caribbean sea and then into the Gulf of Mexico. This warm water comes out through the Strait south of Florida as the Gulf Stream.

At this point the current is of deep blue colour, about 65 kms wide and 600 meters deep, flowing at about 6kms an hour and with a surface temperature of 26°C to 29°C. It then follows the east coast of the United States of America to Cape Hatteras, gradually becoming broader, shallower and slower. It next turns northeast, helped by the westerly winds and by the earth's rotation, and flows to a position some hundreds of kilometers east of Newfoundland. On the way it passes the cold Labrador current flowing southwards near the coast. The current do not mix, and the difference in temperature of the water may be 10 degrees within a few meters, but when warm, moist air from over the Gulf stream is chilled by the cold water nearby, dense fogs are caused. In this way dangerous fogs are caused over the fishing grounds known as the Grand Banks of Newfoundland.

East of Newfoundland the Gulf Stream becomes broad slow drift moving towards Europe which is known as the North Atlantic drift. Part of its turns southward as the Canaries current and flows past north west Africa to rejoin the westbound equatorial current, but another part washes the shores of France, British Isles, Norway and Iceland. Although it has lost much of its heat by this time, it is still warm enough to make the winter in this countries much milder than that of other places just as far north. For example, Souther Labrador and the Gulf of St.Lawrence in Canada are icebound in winter while Great Britain, equally far north is ice free. All the coasts of Norway are ice free in winter whereas the Swedish coast in the same latitudes are frozen for three months or more.If it were not for the influence of the Drift, Icleland would probably be too cold for men to live in at all.

2.3: Seawater and Salinitv

Seawater is the accumulated product of millions of years of solvent action by water on rocks, soil, organisms, and the atmosphere. About 3.5% of seawater is composed of dissolved compounds from these sources.The other 96.5% is pure water. The composition of sea-water in its natural environment is constantly changing the concentration of the different solutes, due to the addition or removal of water through the sea surface by processes of evaporation, precipitation, run-off from rivers, and the freezing and melting of sea ice, which not only changes the salinity but also the ratio of the mayor ions. The greatest variation in the concentration of elements take place in the upper 100 meters or so, where the intense biological activity produces large scale fragmentations of certain materials (e.g. iron and silicon). There are in all 73 elements (including 13 of the rare earth groups), apart from hydrogen and oxygen that have now been detected in sea water; which may be separated into three general groups: a) inorganic substances, usually salts and nutrients necessary for plant growth; b) dissolved gases; c) organic compounds usually derived from living organisms.

Many properties of sea-water are crucial for the survival and well-being of the organisms of the sea. Water provides buoyancy and body support for many swimming and floating organisms, thereby reducing the need for heavy skeletal structures. Water accounts for about 80-90% of the bulk of most marine organisms. It is also a medium within which the chemical reactions that sustain life take place. As a result, marine plants and animals are integral part of the total marine environment. Sea-water is a complete medium for life for it provides all chemical substances necessary for the growth and maintenance of plant and animal tissues. Magnesium , calcium, bicarbonate, and silicate are important components of the hard skeletal parts of marine organisms. Nitrate and phosphate are required by plants for the syntesis of organic material.

The average concentration of dissolved salts in the oceans is about 3.5% by weight. Salinity values are expressed in parts per thousand, $^{o}/oo$ (sometimes called parts per mil). The H.M.S. Challenger took on her first worldwide oceanographic cruise, 77 samples of sea-water of the world's oceans. They were analysed and their average salinity was close to 35 $^{o}/oo$, with a normal variation of only $\pm 2^{o}/oo$. There is evidence that the salinity of the ocean has not changed greatly since the ocean was formed; in any events the salinity has been nearly constant for the past 200 million years.

The salinity is calcuted on the basis of negative ions (anions) and positive ions (cations) of the following 11 mayor ions which make up 99.1% of the dissolved constituents of sea-water.

Ions			
Chloride	Cl^-	18.980	
Sulphate	$SO_4^=$	2.649	
Bicarbonate	HCO_3^-	0.140	Negative ions
Bromide	Br^-	0.065	totals=21.861/oo
Borate	$H_2BO_3^-$	0.026	
Flouride	F^-	0.001	
Sodium	Na^+	10.556	
Magnesium	Mg^{++}	1.272	Positive ions
Calcium	Ca^{++}	0.400	totals=12.621/oo
Potassium	K^+	0.380	
Strontium	Sr^{++}	0.013	
Total Salinity		$34.482^{o}/oo$	

Concentrations of the most abundant dissolved substances in sea-water vary somewhat across the oceans, but their relative proportions remain almost constant because of the highly effective mixing processes in the oceans. It is therefore not necessary to measure all the 11 constituents mentioned earlier to arrive at the salinity; only one constituent need to be determined, the salinity being derived using a simple numerical factor. The chloride contents (the chlorinity) is the most conventionally measured parameter. The factor is obtained by $\frac{\text{Salinity}}{\text{Chlorinity}}$. We have from the above table -$\frac{34.482}{18.980}$ = 1.817 . The numerical factor that we are looking for is 1.817 . Therefore the salinity can be expressed as: Salinity= Chlorinity x 1.817 .

Salinity may be classified for biological purposes as follows:

Hypersaline	=	Salinity	>40‰
Saline	=	.....	30-40‰
Brackishwater	=	.....	0.5-30‰
Freshwater	=	.....	<0.5‰

2.4: Classification of Marine Environment

In order to facilitate a study of marine environment, it can be conveniently divided broadly into two primary divisions of the sea: Benthic and Pelagic. The former includes all the ocean floor, while the later includes the whole mass of water. The pelagic division can be sub-divided into two provinces: Neritic province and Oceanic province; while the Benthic can be sub-divided into Littoral and Deep-sea. The benthic division includes all the bottom terrain from the wave-washed shore line to the greatest deeps. The pelagic division includes all of the ocean waters covering the benthic division. Horizontally, the pelagic division is sub-divided into an open-sea (oceanic) province and an in-shore (neritic) province. The vertical border separating the neritic province from the oceanic is set at the edge of the continental shelf; hence all water of depths shallower than 200 meters would fall within the neritic province. Vertically, the oceanic province has an upper lighted zone (or Photic) and a lower dark zone (or Aphotic) with no well-marked boundary between the two (Fig.1). The photic or lighted zone extends much deeper in clear tropical waters than in murky, coastal waters of temperate areas. An average depht of photic zone is 50-150 meters. Photosyntetic process occur only in the photic zone and there is insufficient light for any biological process in aphotic zone.

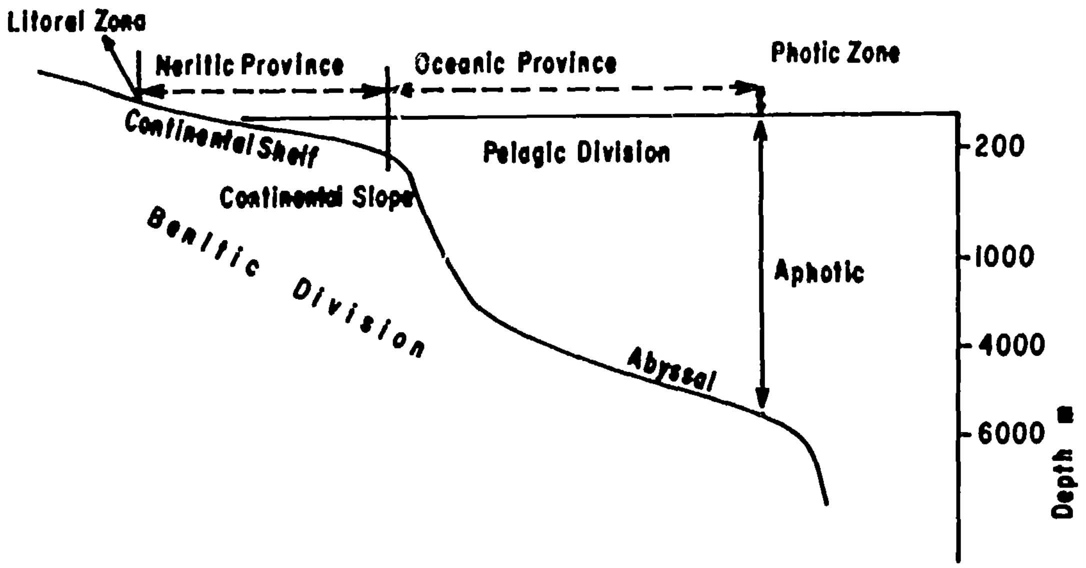


Fig 1 Main division of marine environment. (Adapted from J.L. Sumich, 1976).

EXERCISES:

1. a) What is chlorinity? Determine the salinity corresponding to the following chlorinity values: 3 ‰, 7‰, 15‰, 19‰, 25‰, 29‰ and 40‰.
   b) Using these values, draw a graph of salinity vs. Chlorinity;
   c) From this graph, differentiate the brackish water and hyperhaline zone from the sea water.

2. Assuming that you live on the coastal region, specially on a small gulf coast, whose geographic and bathymetric features are not known. Using the marked leadline, draw a bathymetric map of the gulf and think of some systems to measure the length and width of the gulf.

3: OCEAN NUTRITION

The primary nutrients phosphorus,nitrogen and for some organisms, silicon,are present in inorganic form in sea water, mostly as phosphate, nitrate and silicate ions respectively. The major exogenous source of phosphorus and silicon is land drainage. Nitrogen compounds are also introduced into the sea by land runoff, but the larger proportion comes from the atmosphere and is result of evaporation of ammonia from land surface and in situ fixation. Nutrients are removed from the sea water by the phytoplankton in the photic zone, resulting in a thin nutrient-depleted layer at the surface over large regions of the world ocean.The surface nutrient contents is replaced by mixing nutrient bearing deepeer water and by local regeneration processes.Phosphate and nitrate occur relatively constant proportion in deep water.

3.1: The nitrogen cycle

The sea contains about 450mg of nitrogen per cubic meter of water. Nitrogen exists in the sea in combination with other elements, for example, in ammonia(NH_3) , and as oxides of nitrogen in nitrite ion(NO_2) and nitrate ion (NO_3). Nitrogen enters into the composition of all living organisms. It is the most important nutrients that used by plants in forming the complex protein molecules of their bodies from which animals derive their nitrogen. Not all forms of nitrigen can be used by the plants and therefore decomposition by bacteria is needed for breaking into simpler compound utilizable by the plants. The nitrogen compounds ammonia, nitrites and nitrates are a part of these processes(Fig: 2) and these inorganic compounds can be used directly by the plants for their supply of nitrogen.

Nitrogen compounds are carried to the sea by rivers and by precipitation. The greater part of these are supposed to have been fixed by electrical discharges in the atmosphere. A certain amount of the fixed nitrogen in the sea is liberated as free nitrogen and returned to the atmosphere.

3.2: The phosphorus cycle

The average concentration of phosphorus in sea water is about 73μgP per liter. Phosphorus is another important plant nutrient which has a biologically activated cycle involving alternation of organic and inorganic phases. Carbondioxide is always present in sufficient quantity for the need of marine plants, the phosphorus like the nitrogen, may be depleted from the environment, but is believed to be regenerated quickly by bacteria and other agencies following the death of plants and animals, which is represented schematically (Fig: 3).The processes of

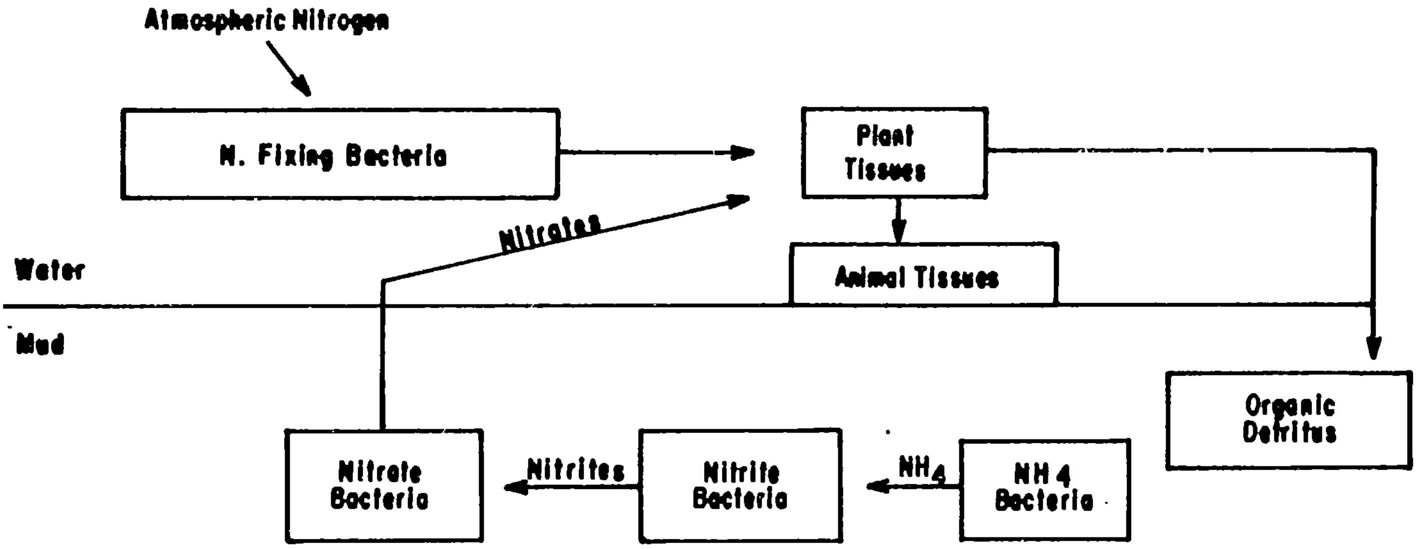


Fig 2 The nitrogen cycle of a soft bottom marine community. (After Sumich, 1976).

the cycle fall into three categories: A, addition of phosphorus to the active system by input, regeneration, decomposition or turbulent action; B, removal of phosphorus from the active system by precipitation or physical removal; and C, uptake or concentration of phosphorus by living organisms. The processes of the phosphorus cycle in Fig. 3 can be explained in the following way:
The annual delivery of phosphorus to the sea because of erosion and agricultural fertilization(1A) and a small amount of phosphorus are returned to land(1B) mostly as guano from marine birds.
The reserve of dissolved phosphorus in the sea is about 120.000.000 million metric tons. The amount is maintain by dissolution of particulate inorganic phosphate(2A), precipitation of insoluble phosphate(2B) or the uptake by plants(2C). The annual phytoplankton requirements are about 1,200 million metric tons of phosphorus. Plants are consumed by higher organisms(3C) or upon death become particulate phosphorus(3B) and phosphorus are removed temporarily; ultimately dissolved phosphorus is produced(2A). Organisms other than plants may excrete soluble organic phosphorus compound(4A). Bacteria take up these compounds(4C) and release other phosphoric compounds(4A). Finally, the death of these organisms produces particulate phosphorus as organic detritus(4B). Dissolved organic phosphorus compounds may also be formed by the decomposition of the organic detritus(5A) or may be removed by burial in muds(5B). Finally, particulate phosphorus settles to the bottom(6B) or is brought from the bottom layer by turbulance(6A). In addition, inorganic phosphate may be released(2A) as part of sulfur cycle or by dissolution of particulate phosphorus. This completes the phosphorus cycle.

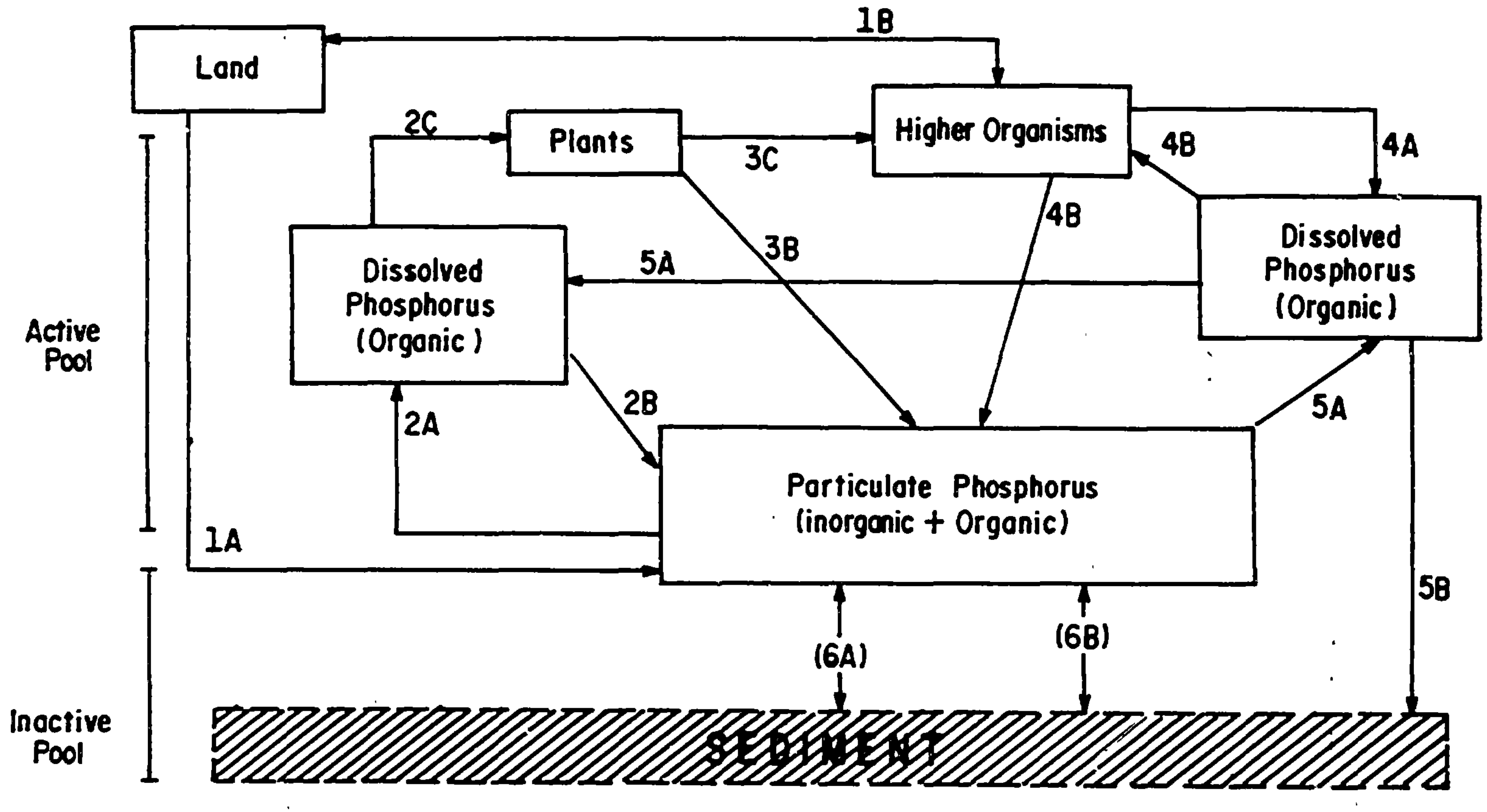


Fig 3 The phosphorus cycle.(After Martin, 1970)

3.3: Carbon and Sulfur in the biological system

The carbon compounds built by marine plants and animals are decomposed through bacterial action with the formation of carbon dioxide. Carbon dioxide is added to the system through the processes of respiration, activity of bacteria, chemical oxidation, temperature decrease, and pressure increase. Carbon dioxide is removed through photosynthetic uptake, turbulance, temperature increase, and pressure decrease.

Carbon is possibly the most important element of the sea for being the basic element of all living matter. Carbon dioxide is a gaseous substance which is used in primary production and it can be replaced immediately through gaseous diffusion. The utilization of inorganic carbon compounds in primary production is of supreme importance bacause it forms the basis of the whole marine food chain and energy flow in the marine ecosystem.

Sulfur is one of the essential constituents of living matter and its compounds, like those of other elements of protoplasm, are acted upon by bacteria. Plants utilize a small amounts of sulfur in metabolism; the compound used is sulfate, produced by chemical or biological oxidation. The decomposition of organic compounds containing sulfur, hydrogen sulfide is produced as a disintegration product. The odour of hydrogen sulfide is frequently noticeable at low tide in the organically rich muds of protected bays.

3.4: Productivity and Trophic levels

The term production is frequently applied to denote the product, that is, the amount produced, of any group of organism in the sea.The term phytoplankton(plant) production, Zooplankton(animal) production and fish production are thus applied. Productivity of the sea can be defined as the capacity to produce, and is commonly used as qualitative term for indicating the fertility of any ocean region. The total amount of organic material produced in the sea by photosynthesis represents the Gross Primary Production of the marine ecosystem. Plants possessing the green pigments,chlorophyll can utilize solar energy to create from simple inorganic substances to new organic materials involving high energy bonds, which chemically expressed as:

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2.$$

This process is termed as photosynthesis. A portion of the organic material produced by photosynthesis is utilized directly by the plants themselves for respiration. Any excess product is applied to growth, reproduction, and losses due to death, and is referred to as the Net Primary Production. Net marine primary production represents the amount of organic material that is available to support the animals and decomposers of the sea. Rates of gross and Net Primary Production can be expressed as gram of carbon per cubic meter per day or year($gC/m^3/day$ or $gC/m^3/year$).

Most of the primary production is accomplished by phytoplankton, which is composed of as much as 98% of the total marine production. Secondary, tertiary and higher levels of productivity refer to the rates at the carbon or energy fixed by primary production is incorporated by herbivores (plant eating organisms) and carnivores (flesh-eating organisms) into different types of biological production at higher levels in the food-chain. Because of variations in the efficiency of conversion to higher level of production, there is no direct correlation between primary, secondary and higher levels of productivity.

Biological productivity in the oceans is usually measured in terms of primary productivity. Primary productivity is normally determined by measuring either the rate of uptake of C^{14} by phytoplankton in samples of surface water, or the amount of chlorophyll, per unit volume of surface water. The total oceanic phytoplankton is estimated to 'fix' annually 1.9 x 10^{16} tonnes of carbon by photosynthesis, and this is estimated to represent about 10 percent of the live weight.

Living organisms require two fundamental things from their nourishment. Matter is necessary for individual growth and reproduction. Energy is required also to perform work, like, respiration, egestion, locomotion, etc. The transfer of matter and energy used for metabolic processes within the marine environment has resulted in a close interdependence of the three major kinds of marine organisms: Producers, Consumers and Decomposers. Plants are autotrophic or self nourishing. Plants are the producers capable of absorbing readily available solar energy through the process of photosynthesis building high energy organic substances, such as carbohydrate. Plants are referred to as the Primary producers of the marine ecosystems and are placed in the first trophic level. The consumers and decomposers are unable to synthetize their own food from inorganic substances and thereby depend on plants for nourishment.

These are heterotrophs. Animals adapted to feed on plants are herbivores and occupy the second trophic level, while those that prey on other animals are carnivores. The carnivores occupy the third and higher trophic levels depending on what they consume(Fig: 4).

The animals at the base of food chain are the most numerous, and there is a progressive decrease in numbers at each successive trophic level. In other words, weight or numbers produced per year of all predators at the fourth or fifth trophic level must always be much lower than that added annually at the third, which in turn must be less than that for the herbivorous animals of the second trophic level, whose weight production in turn must be much lower than the weight of plant production in the community.This occur in the food chain as the living organisms, like most other energy consuming systems, are not highly efficient in their use of energy. Much of the solar energy available at the surface of the sea is absorbed by the marine plants. Another portion of the energy that is captured by the photosynthetic process is used by the plants for cellular maintaenance, growth and reproduction. Only a fraction of the energy fixed by the plants is available to the herbivores. A similar decrease in available energy occurs between herbivores and carnivores. At each trophic level, energy is lost due to egestion, locomotion, reproduction,etc. In addition, some fraction of energy is involved in growth of tissues,such as, chitinous exo-skeleton, bones, teeth,etc, which has no nutritive value to the next trophic level, and so only a fraction of this is in turn available as a potential food supply for the predator of the next trophic level.Laboratory and field studies

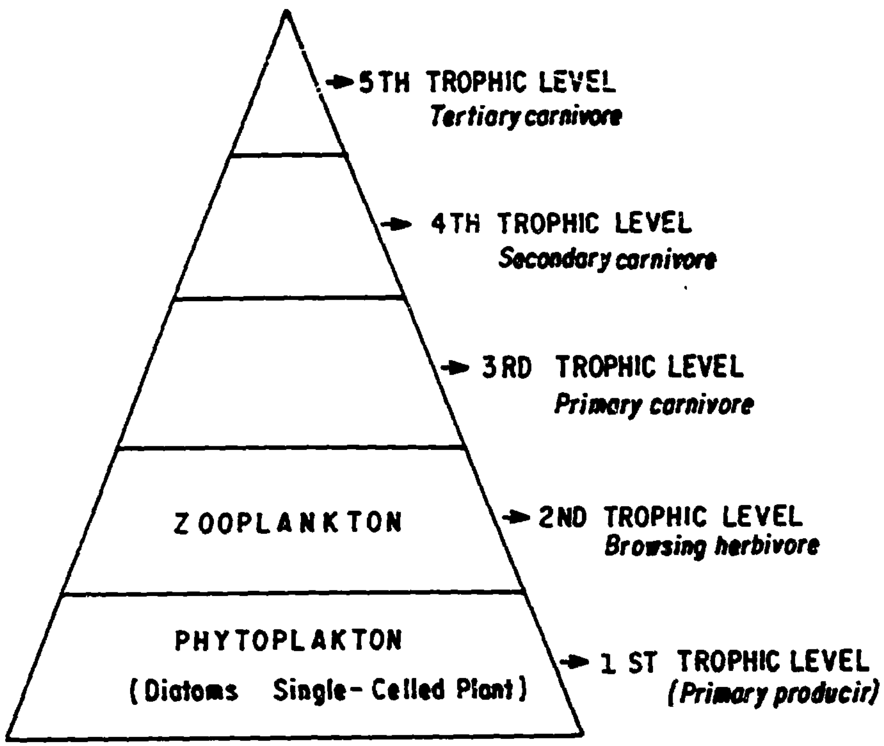


Fig 4 Five level food pyramid.

of marine organisms place the efficiency of energy transfer from one trophic level to the next, in most cases 10 percent or less. In other words, only 10 percent or less of the energy available to any trophic level is usually passed on the the next.

EXERCISES:

1. Oxygen, Nitrogen, Carbon dioxide, Argon, Helium, Neon and Xenon are the atmospheric gases found in the sea water. These gases can be grouped into three categories according to their characteristics.
   a) What are these three groups?
   b) What are the only two sources of oxygen in the sea?
   c) What is the major source of CO_2 in the ocean?
   d) Set up an experiment to prove that Oxygen is released through the process of photosynthesis.

2. Draw and discuss a four level marine food pyramid leading to carnivorous fish (e.g. cod). How do you identify a herbivorous fish from a carnivorous fish?

3. Phytoplankton population is capable of dividing once each day. Maintain a phytoplankton for 12 days in a suitable environment, where it divides once a day. What will be the total population in 12 days? Draw a histigram showing the growth against time in days.

4. The net photosynthetic rate of any phytoplankton population can be estimated by measuring the rate of oxygen production or CO_2 consumption by the phytoplankton. The following is the method to study the primary production:
   Collect sea water samples from two different depths of study area. Divide the samples into three equal parts and place into three bottles. A light bottle (LB) is transparent to light, an opaque dark bottle (DB) covered with alumium foil or black tape or painted black to exclude light and the third is initial bottle (IB).

The oxygen concentration of water is determined immediately to find out the initial concentration of O_2 of light and dark bottles. Each pair of light and dark bottles are lowered back to the depth at which they were collected. The phytoplankton cells within the bottles are allowed to incubate under normal environmental conditions. After a period of few hours(4 to24), the light and dark bottles are hauled to the surface and O_2concentration of each bottle is measured quickly.

Dark bottle: The phytoplankton are unable to photosynthetize due to lack of light, but must respire and therefore, dissolved oxygen must decrease due to respiration. Threfore, O_2 consumption= IB- DB

Light bottle: Phytoplankton in the bottles recieve the light intensity equal to that of the surroundings and therefore, photosynthetic process functions normally. The O_2 produced in the bottle, after reuse by the plants thenselves, is the net primary production=LB-DB.

The total amount of organic material produced in the sea by photosynthesis is the gross primary production, which in the experiment is, LB - DB.

Following the above method, calculate the gross primary production of two lagoons that you want to use for fish culture. Can you estimate the production of mullets in those lagoons?

4: ECONOMIC OCEANOGRAPHY

The origin of life is believed to have begun in sea. Without the sea, life as it is known today could not exist. The oceans provide the least expensive form of transportation known to man, and the margins of the sea serve as a mayor site of recreation as well as a vast production of food through mariculture. The sea is a mayor source of food and a dumping ground for many wastes; and also a mayor source of protein, minerals including oil, and power. All these economic aspects of the sea is included in the economic oceanography.

4.1: Resources of the Sea

The oceans contain a great number of minerals in solution, of which 11 mayor ion make up 99.9 % of the total dissolved constituents. Most of these appear in dilution too great to make commercial extraction economically feasible. At present about five mayor items are obtained from sea-water, e.g. sodium chloride, bromine, magnesium metal, magnesium compounds and fresh water. In addition the sea floor possesses varieties of minerals, such as petroleum, sulfur, sand, heavy minerals, light minerals, and even iron and coal. To obtain all these minerals requires advanced technologies and economical resources which developing countries cannot afford. Therefore, exploitation of resources from sea is restricted to developed countries only.

Three mayor types of mining occurs now-a-days:

a) Mining seawater: principally five items are extracted by processing large volumes of sea-water, e.g. sodium chloride, bromine, magnesium metal, magnesium compounds, and fresh-water.

b) On-bottom mining: it mainly involves conventional dredging operation for sand, gravel, oyster shells and tin.

c) Offshore mining: this includes gas,oil, and sulfur mining. The only offshore production of sulfur is that to be found off the coast of Louisiana, U.S.A. The sulfur deposits are roughly 2000 feet below the sea level. Mining offshore resources of sulfur is economically feasible because of the rapidly growing shortage of immediately available sulfur.

An explosive increase of interest in seeking petroleum offshore has occured after the price hike of petroleum in the seventies and also as the result of success in exploratory work. Approximately 30 countries are producing or are ready to produce sub-surface oil and gas. The offshore oil reserves is estimated to about 20 % of the world total reserve. The estimated world potentials of offshore petroleum liquids and petroleum gas is 2,700 and 350 millions of barrels respectively, against 1,500 and 800 millions of barrels on land.

Construction of platforms for drilling offshore is costly and requires advanced technologies. The cost and technology requirements varies with the increase of the depth of operation in the sea. The drilling of offshore oil is to date economically feasible due to higher price of oil. The prediction is that the oil price will go down to 20 dollars a barrel, during the next few years. The British and Norwegian drilling in the North Sea will be economically unproductive if the price goes down to that level, because their production cost is extremely high.

4.2: Energy from the Oceans

Desalination of sea-water is only one of many new energy demanding endeavors connected with man's increasing mastery over nature. Many scientists have planned to harness the gigantic forces of the waves and tides for the production of energy, but many abandoned considering the enormous investment it involves.

Rance Project in the coast of Brittany in France, produced energy by using tidal waves. The entry of the tides into the estuary of the Rance produces a large mass of water that is carried up river to a height of 20 feet or more, and reaches out again with tremendous force. A dam across the Rance houses special turbines, which funtions by means of a small pressure differential between incoming and outgoing tides that are retained by the dam, inaugurated in November 1966.

The Bay of Fundy in the Canadian east coast is famous for its fast runnig tides that rises as great as 70 feet, the highest in the world. The bay has become into prominence as a mayor potencial source of hydroelectricity, but due to great engineering difficulties, enormous costs involved, and possible environment damage,has impeded the development of another tidal power plant in the world.

In Great Britain the Severn River Estuary has been studied as a possible power station. In the world there are nearly 100 estuarine sites that could harness for tidal hydroelectric power.

A group in the U.S. has developed a system whereby the energy can be extracted by a floating power plant that eliminates the pumping problem. Propane,or some similar fluid that will boil at the temperature of the surface layer water is used, the gaseous phase then being released to a turbogenerator to manufacture the power. After the gas is condensed to liquid in the cooler, lower layers of water is pumped to a surface boiler to be recycled.

Some techniquines have been developed in the 1970s for handling liquid hydrogen and liquid oxygen on a large scale. If power, generated in remote areas of the ocean were used to reduce sea-water to hydrogen and oxygen, these gases might be utilized economically in shoreside thermal power plants.

In the tropics, sunstruck surface water may be 40'F or warmer than water 3000 feet below. In a process named Ocean Thermal Energy Conversion (OTEC), huge power plants would use this temperature differential to drive turbines. Inside one OTEC system, warm water vaporizes a low-boiling point fluid, such as ammonia. The vapor drives a turbine that generates electricity. Cold water pumped from 3000 feet below condenses the vapour back to liquid. The electricity generated could be transmitted ashore by cables or used to extract hydrogen as fuel from sea-water.

French engineers did try to install such a turbine on the Ivory Coast, near Abidjan; but tropicalstorms played havoc with the laying of the pipes, and their scheme was abandoned. In the United States, a mini-OTEC project off the coast of Hawaii has worked on a small scale. By one estimates in U.S., OTEC could replace 400,000 barrels of oil a day by the year 2000. Most of the proyects to tap the power of trade winds, waves, and current in the open seas are costly and vulnerable to tropical storms; and thereby face cancellation or long delay.

Another energy source of great potential is the oil bearing sediments on the continental shelves. There are approximately $3x10^7$ cubic miles of known oil bearing sediment, representing about one third of the total known remaining oil reserves of the world. This figure may change frequently due to finding of new oil reserves in the seas.

4.3: The Sea for Transportation

The ocean is the mayor coastal and intercontinental highway for the transport of heavy and bulky materials. The movement of goods and persons by water-dates back to the earliest times. The Egyptians used water-crafts during the 4th millenium b.c.; early seafarers from Crete and Aegean sailed westward to the Mediterranean islands and Spain and penetrated to Ireland, Wales, and Brittany. Over the centuries this mode of transport developed to meet the differing needs of fighting and trading. Whereas early war vessels were galleys carrying sails and propelled by oars, trading vessels generally took more time to sail.

Romans fought many wars in the Mediterraneans and the Atlantic. In China, Kublai Khan fought one of the largest wars in the sea in 1274 and in 1281, to conquer the island of Japan. In 1281, Kublai Khan prepared a vast armada that would consist of 4,400 ships and 142,000 Mongol, Chinese and Korean troops; on the other hand, three centuries later Spanish armada numbered only 130 ships and 27,500 men.

Considerable trades were carried over water by the Romans between the Mediterranean and their northern territories. In the middle ages Viking trading vessels were venturing far from their Scandinavian homelands to pioneer sea routes to Greenland and Iceland. In the 10th and 11th century the Venetians expanded their trades to the Middle East. The Portuguese established trading posts in India, South China, and East Africa, during the 15th century.

The sea route to India and to the Far East was established, America was discovered, and the Pacific was reached. People started enjoing fruits out of the sea. By then the seas were infested with pirates. Larger vessels able to carry bigger cargoes were also needed to make the long voyages worthwile. To cope with the expantion of trade, the British East India company built ships of heavy construction between the 16th and 18th century.

Sailing cargo fleet survived well through the 20th century. World War I gave the final blow to sail. The use of sail is a recreational sport in the west, but it is still a common means of transport in many areas of the Arabian Sea, South Seas, Indian Ocean and of the Bay of Bengal.

Technological advances in the late 18th and 19th centuries, particularly the coming of steam and the building of ships of iron and, later of steel, brought changes in the design and size of ships. The steam ship combined with the industrial revolution, vastly extended world comerce and at the same time the development of steam-power caused a worldwide demand for coal.

With changes in the types and quantities of goods carried, there arose a need for ships specially adapted to different purposes, of which the chief types were refrigerated vessels for perishable food staffs and bulk carriers for oil and grain. Oil had previously been transported in barrels aboard ships, but it became advantageous to carry it in bulk as demands grew. This initiated the introduction of giant-oil tankers to transports oil from producing countries to industrialized countries. Over the years a comprehensive pattern of worldwide liner services has been built for both passengers and freight, linking all continents and countries.

Since World War II, a great deal of interest has been evidenced in the sea by the various navies of the world, specially the Russians and the Americans. They have been spending large sums of money in an effort to understand the environment better; and at the same time developing to improve the capabilities of its undersea strategic forces, as well as to increase its ability to perform undersea search and recovery. In the future we can expect greater and more effitient use of the oceans for transportation of civil and military purposes.

Since the laying of the trans-Atlantic cables in the 19th century, the oceans have served as a mayor means of communication between continents and island. Hundreds of sea-floor cables connect all mayor population centers of the world. With the development of satellite communications, ocean floor cables as a means of communication may tend to decrease in importance, but they will continue to carry to informations for many decades to come.

In addition to communication cables, pipes on the ocean floor carry electrical energy, oil, and other commodities to many parts of the world.

4.4: Salt from Sea-Water

The common table salt or sodium chloride is a white solid formed of cube-shaped crystals. It is one of the most abundant minerals in nature. The Greek and the Roman obtained their first salts by evaporating sea-water and natural brines. Similarly they found rock salt in some zones of their conquered lands.

Salt was known since antient times because of its medicinal and nutritional values to man and because of its use as a seasoning. The use of salt began in Spain with the Fenicians and the Greek who made salted fish and a fish sauce which they sold in Athens, Greece. Now-a-days salt also has many industrial uses (as a preservative, as a prome material for the production of baking soda, caustic soda, hydrochloric acid, etc).

Sea-water is a natural deposit of salt, it contains almost 30 kilograms of salt per cubic meter. It has been estimated that if the oceans of the world were dryed-up, they would yield at least 4,500,000 cubic miles of rock salt. The ocean salt concentration varies from 3 percent (in the polar regions) to 5 percent. The Mediterranean Sea, the Red Sea, and other enclosed seas contain a higher proportion of salt than does the open sea at the same latitude.

Natural brines have an even higher concentration of salt; the Dead Sea, for example, covers an area of only 1,020 square kilometers, but has a concentration of 27 to 33 percent - it contains 12,650,000,000 tons of salt. Other natural brines of commercial importance are found in Austria, France, Germany, India, the United States, and Great Britain.

Another important source of salt is rock salt— a crystalline sodium chloride. All mayor rock salt deposits originated from the evaporation of sea-water some time in the geological past. This type of salt is present in the United States, Austria, Poland, Germany, the Soviet Uninion, and other countries.

Most commercial salt is manufactured from rock salt. The beds of rock salt are mined or quarried by the usual excavation methods and then treated by diverse methods to purify it.

Salt manufacture from natural and artificial brines are done by evaporation . In many countries natural and artificial brines are evaporated by different artificial methods (fire, steam-jacketed vessels, multiple efect vacuum evaporators, etc). In maritime countries where the evaporation rate is negative— i.e. more water evaporation than rainfall— salt is produced by solar evaporation from sea-water.

Sea-water with a salt concentration of 3.5°Baumé is extracted by means of pumps and taken to pools of little depht and great extention, where, with the combination of wind and solar evaporation, salt concentrates upto 25.5° Baumé.

During the concentration proeess, the sea-water looses iron salts and calcium carbonate, similarly it looses calcium sulfate totally.

From the pools, the water goes to other reservoirs called crystallizers, where the salt precipitates. The deposit or sediment is collected by appropiate mechanical devices and accumulated in piles of 20 to 25 meters high. These piles are transported to the refinery for purification before selling it to the public for consumption(plate-I).

4.5: Freshwater from Saltwater

The total ammount of water on the earth is fixed and has a volume of some 326,000,000 cubic miles. Of this, it is estimated that 97.2 percent occurs in oceans and inland seas, 2.2 percent in ice caps and glaciers, and 0.6 percent is liquid freshwater. Most of the liquid freshwater occurs as ground water.

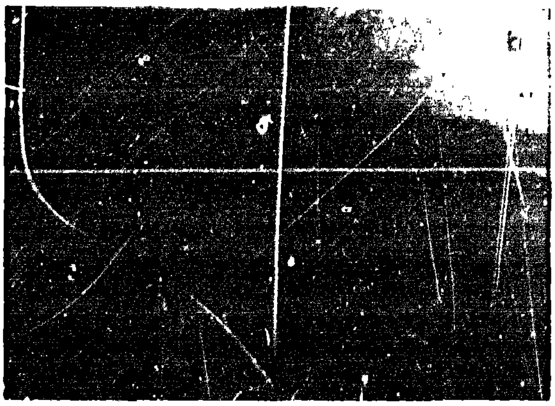
Terrestrial water is in continuous circulation. Great quantities evaporate from the oceans and lands surfaces each year. The water vapuors are held temporarily in the earth's atmosphere until it returns to the earth as precipitation. Much of it falls directly back to the oceans but lesser quantity falls annually back onto the continental land masses in the form of rain or snow. Most of the precipitation goes into ground water storage or re-evaporates from the land surfaces.

But in todays world the need for water has become acute in many areas because the water is not available at the time and places where it is needed-most. Many of the world's rivers discharge a large part of their runoff as flood

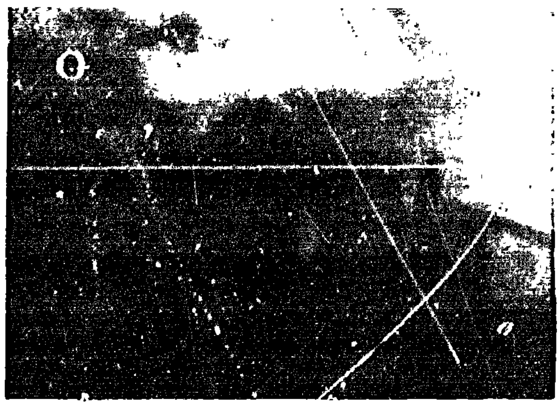
Plate I: Salt production from a natural lagoon.
Arya, Cumana, Venezuela.

a) Mechanical extraction of salt from the laguna Madre.

d) Transporting salt by elevator to the tower of bagging.



b) Transporting salt in a chalan.



e) Salt mountain, it is trucked to the refinery.

c) Washing salt and carried by elevator.

f) Bagged salt for industrial use.

flews that-cannot be conserved or economically used. Many countries in the Middle East do not have enough storage of surface or ground water to meet the demand of the population. There two mayor steps one can take. The first is to reduce lavish waste of water and the second is to increase the water supply. There's one way the later can be achieved on a very large scale— by converting sea-water into freshwater. There is plenty of water in the oceans and the modern technologies can be applied for converting sea-water and other saline waters into freshwater at a reasonable cost.

The salinity of waters available for conversion varies greatly. The oceans are fairly uniform, averaging about 35,000 parts per million of dissolved salts. Brackish water contains more than 1000 parts per million. Common salt, sodium chloride, accounts for most of the saltiness of sea-water. However, sea-water contains small amounts of many other salts— some 73 dissolved elements in all.

What is required to desalt water? The basic facts are simple. A salt dissolved in water is separated into ions (e.g. in the case of sodium chloride: the positively charged sodium ions and the negatively charged chlorine ions). The ions are bound to water molecules by their electrical charges. The problem is to pull the water molecules and the ions apart. This is presently achieved mainly by distillation processes, membrane processes, or crystallization processes, but may also be accomplished by ion-exchange or solvent demineralization methods.

Commercial desalting is most commonly based on evaporation and susequent condensation of water. Large distillation plants are in regular operation in areas where freshwater sources are not economically available. Distillation processes currently in use include multi-stage-flash evaporation, vertical-tube evaporation, vapour compression, and solar distillation. The largest desalting plants in commercial operation, use the multi-stage-flash evaporation process or the vertical-tube evaporation process. In the multi-stage-flash evaporation process the latent heat released by the condensation of the evaporated water at each stage is used for the next stage, providing a chain effect. For example, in the first stage sea-water is evaporated to steam at atmospheric pressure or higher; the steam passes through the coils in a second evaporator, condenses there and is collected as distilled water; in condensing it releases its latent heat to evaporate sea-water in that container, and so on through a number of stages. Vacuum pumps keep each successive evaporator under low pressure, so that its water boils at a lower temperature. Such a system could operate on the exhaust steam from electricity generating plants.

The first large land based sea-water desalting plant was built in Kuwait in 1949, with a capacity of 1.2 million gallons a day; this was increased to 5 million gallons a day in 1958. There is a large desalting plant at Rosario Beach, near Tijuan, Baja California, México which has a capacity of 7.5 million gallons a day. One of the largest desalting plant is under construction in Jeddah, Saudi Arabia. The cost of desalting has been substantially lowered as a result of larger plant construction and use of improved materials and processes developed from operating experiences and research.

EXERCISES:

1. What are the important minerals that are extracted from the sea floor? Why the extracting in the off-shores requires high technologies?

2. What is desalt water? Why desalting is essential in some parts of the world and not in the other?

3. The average concentration of dissolved salts in sea water is about 3.5% by weight. How much salt you expect to collect if you evaporate one kilogram of sea water with a salinity of 34%? Do you expect to collect same amount of salt from a kg. of water of a hyperhaline lagoon which has a salinity of 85% .

4. What is common salt? Is there any differences between table salts and the salts used for salting fish?

5. How rain forms? The total amount of water on Earth is 326×10^6 cubic miles. What is the total amount of fresh water available on Earth?

5: LAGOONS AND ESTUARIES

Lagoons are areas of relatively shallow waters, situated in a coastal environment and having access to the sea; but separated from the open marine condition by a barrier. The barrier may be either sandy or shingle-built structures. Generally, lagoons exchange their water with the larger adjascent water mass through a channel or a series of channels. Lagoons are rarely completely isolated from sea and their water are marine or at least brackish.

Thereeare two main types of lagoons:firstly, elongated or irregular stretches of water that lie between coastal barrier islands and the shore line, and secondly, a circular or irregular stretches of water surrounded by coral atoll reefs or protected by barrier coral reefs from direct wave action. The first typeeis characterized by quiet water conditions, fine grained sedimentation and, frequently, brackish salt marshes. Water movements are related to discharge of river flow through the lagoon and to the regular influx and egress of tidal waters through the entrance channel. Wind is often the only effective force to drive circulation, both in the process of mixing and inducing currents. The second type of lagoons are best exemplified by the roughly circular quiet waters that are surrounded by coral atoll reefs. Lagoon's depht are maintained at a moderate level by sedimentation. Because the reef is an organic structure, the lagoonal sediments contain much calcareous material. This type of lagoons will not be discussed in this section.

Coastal lagoons are widely distributed throughout the world, and have been estimated to constitute approximately 13 percent of the world's coastline. Of this 13 percent, 34 percent is in North America, 22 percent in Asia, 18 percent in Africa, 10 percent in South America, and 6.8 percent in Australia.

Lagoons are generally associated with low coasts and rarely occur where the high cliffs form the coast. They can form only where there is abundant sediment for the construction of the barrier. Too much sediment from the mainland, however, can lead to delta formation rather than lagoons.

5.1: Lagoon Formation and their Fate

The essencial feature that causes the lagoon to exist is the barrier that separates it from the sea. Barriers are normally produced by wave action on shallow gentle-shelving sand and pebbles. They are normally found on low coasts. They may occur in areas of subsidence, stability, or emergence, wherever sufficient sand exists. The length of the barriers are variable and depends on the shore line and subtidal topography. The sediments of the lagoon are usually finer, as conditions are quieter. The source of fine sediments is on land areas, transported to the lagoons by rivers. The detail of the lagoon sedimentation vary with the nature of the river load.

The barrier islands are formed by the waves by deposition on a gradient that is too flat. The level of the growing accumulation of sand or shingle may be raised by the wind, forming dunes. When the land behind the growing barrier is low, it will become flooded if the sea level rises slowly— thereby forming a lagoon. As long as the barrier island can maintain its level above the sea as sea level rises, the lagoon will exist; otherwise, it will be filled with sediment and the lagoon will disappear.

Storms and tidal waves exert an effect on lagoons when they breach or overtop the barriers around the lagoon. Mayor changes in configuration can occur in a short time on the coast line, forming shallow, flat-bottomed lagoons, or may move masses of sand and shingle to fill small lagoons.

Once formed, lagoons do not persist for long periods of geological time— normally for less than 1000 years. All-though their life span is generally correlated with their size, several processes can destroy them:

a) high water levels during storms, hurricanes, or tidal waves,that overtop the barrier and wash away with tremendous force the water, converting the shallow lagoons into swamps, marshes, or beaches.

b) in comparatively exposed areas, particularly heavy wave action can break through and erode an enclosing barrier, forming a coastal bay. Onshore gales, may, through wind and wave action, gradually but relentlessly move sediment from the windward face of a barrier, up over its coast, and redeposit it on or behind its leeward face. Eventually, the barriers may become erode and obliterate a lagoon.

c) man can affect the lagoons by reclamation works, by changing the entrances, and by modificating hydrografic regimes.

5.2: Lagoonal Habitat

The environments of lagoons are variable and diversified. They can be classified into four general environmental types charecterized by the salinity of the water: a) freshwater influenced zone, with minimum of salinity; b) brackish zone; c) sea-water dominated zone, normally near the mouth of the entrance channel; and d) hyperhaline zone, farthest from the coast, containing the highest salinity of the four habitats(Fig.5).

Salinity:

Salinity is the most important feature of lagoons. Longitudinal salinity gradients in lagoons are stable and do not fluctuate on diurnal basis in relation to tides due to the relatively small size of the channel. They may vary seasonally, specially in areas subject to wet and dry periods, because the controlling factors responsible for the nature of gradients are, volume of freshwater and volume of evaporation from the surface. In rainy seasons, lagoons may be greatly diluted by rain and by freshwater flowing from rivers. In contrast, in the dry season salinity may rise to hyperhiline levels due to high evaporation. Lagoons are shallow and therefore lack vertical stratification of water in respect of salinity, but certain stratification exists in lagoons with a relatively deep basin near the entrance of sea- water.

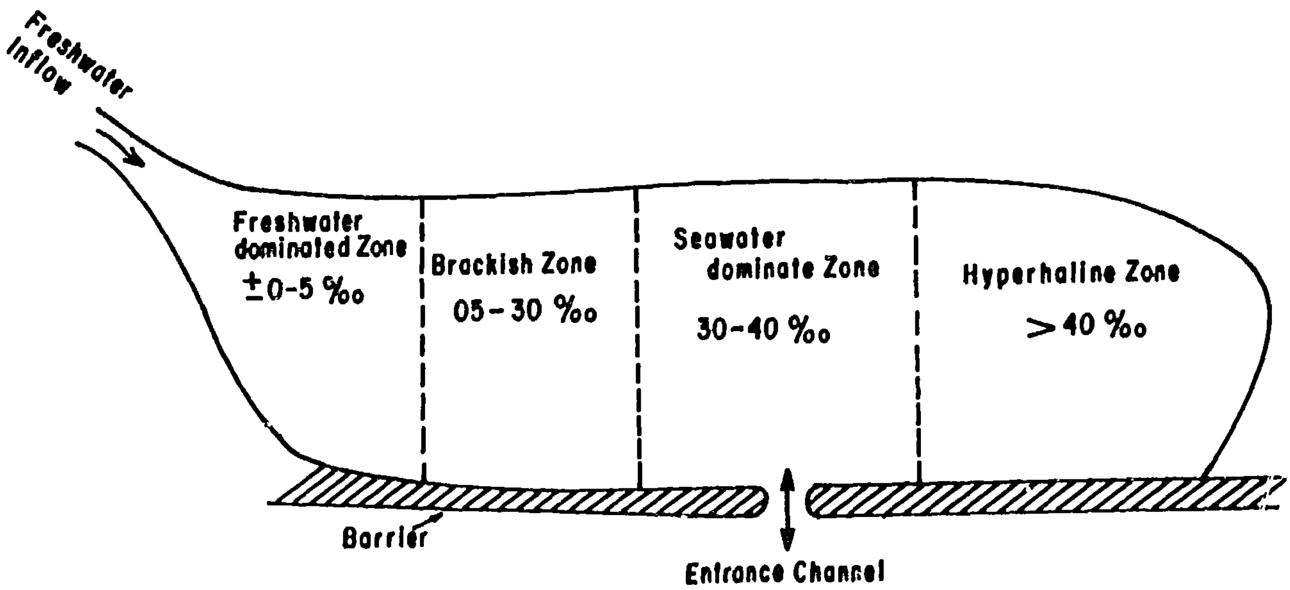


Fig 5 Arbitrary classification of lagoon on the basis of salinity of water. (Adapted from Barnes, 1980)

5.3: Estuaries

An estuary is a partly enclosed body of water, with an open connection to the sea where river water is mixed and diluted with sea-water. Generally, the estuary's environment is defined by salinity boundaries rather than geographic boundaries.

The lower reaches of river such as the Amazonas, Orinoco, Hudson, Thames, and Ganges are estuaries. Estuarine waters are consequence of river water discharging and mixing with tidal influxes of sea-water. Within an estuary, complex gradients of salinity, water temperature, turbidity, and current action occur. Salinity normally decrease inland from the mouth of an estuary, as sea-water experiences increasing dilution by the river from the upstream end. Vertical salinity gradients are also established, for less dense freshwater usually flows out along the surface, and only partially mixes with more saline wedge of sea-water, beneath. This dynamic system, with the inflow of freshwater from the rivers which push out the sea-water on the surface and tidal changes pushes the sea-water in from the bottom wedge, produces salinity gradients in an estuary(Fig.6).

As a general rule marine animals and plants penetrate estuaries to their limit of tolerance to low and rapidly changing salinity conditions. Some have only poorly developed osmoregulation capabilities and avoid osmotic problems by not venturing to far into the estuaries. On the other hand, some organisms can easily venture into the estuaries.

The most successful and abundant groups of estuarine animals have evolved mechanisms to regulate and stabilize the water and ion concentrations of their body fluids

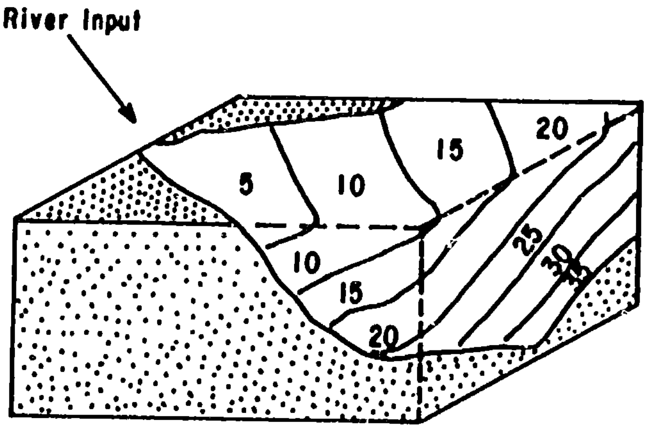
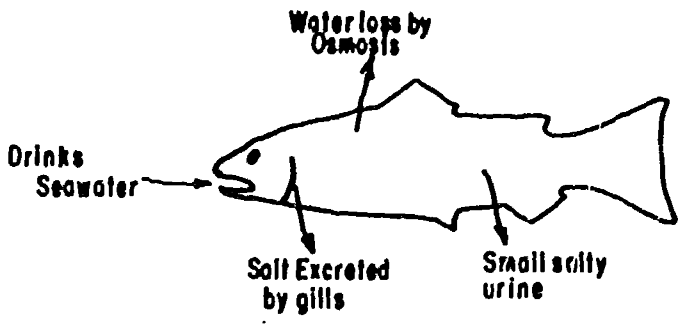


Fig 6 Diagram of horizontal and vertical salinity gradients in a hypothetical estuary of the Northern Hemisphere. Numbers refer to salinity in °/oo. (From Sumich, 1976).

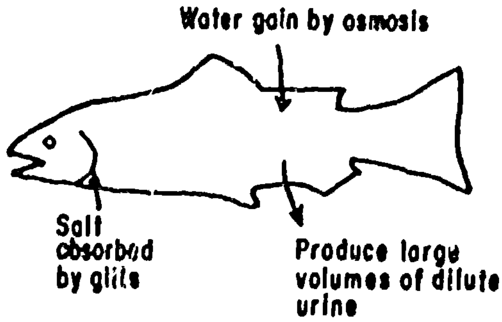
independently of external variations. These mechanisms are as varied as the organisms themselves. Some fish adapt to these changing environments successfully; salmon is cited as an example(Fig.7).

- The salt concentration of a salmon's body fluids,is intermediate between freshwater and seawater(about 18 ‰). As such body fluids are hypertonic to freshwater and hypotonic to seawater. These fish never achieve an osmotic balance with their external environments, Instead, they must constantly expend energy to maintain a stable internal osmotic condition. In seawater, salmon lose body water by osmosis and are constantly plagued by problems of dehydration, even though surrounded by ocean water. To counter this, salmon drinks large amount of sea water, which is absorbed by the digestive tract. The water is retained in the body tissues, and excess salts are actively excreted by special chloride cells located in the gills. Since the kidney of fish are unable to produce urine with a salt concentration higher than that of its body fluids; they excrete very small quantity of salty urine.

When in freshwater river and lakes, the osmotic problems of salmon are completely reversed. Salmon drink very little freshwater, besides swallowed with food. To balance the inflow of water, the kidneys produce sufficient amount of diluted urine, after recovering the salts from that urine. Needed salts are obtained from food and also are actively absorbed from the surrounding water through specialized cells in the gills. Thus, migratory fish maintain a homeostatic internal fluid environment in either river or ocean water at a considerable expense of energy.



In Seawater



In Freshwater

Fig. 7 Mechanism of osmoregulation in a migratory fish.

5.4 Productivity

Lagoons and estuaries are the most productive area of the marine waters. According to Whittaker, the average primary productivity of open sea is 125 g dry wt/m^2/year; lake,etc. 250gdw/m^2/yr;coastal seas,360 gdw/m^2/yr; and algal beds, reefs, estuaries,swamps and marshes,1800 to 2000 gdw/m^2/yr. The productivities of salt marshes, man-groove swamps lie in the range of 1000-4000 gdw/m^2/yr, and will place lagoons amongst the most productive of ecosystems. I general, it can be said that lagoons are characterised by an exceptionally high productivity. Basically, potential food sources in lagoons are: phytoplankton, benthic and epiphytic algae, and detritus derived from the macrophytes. Excluding the top carniv--ores and the consumers of living phytoplankton, most-lagoonal animals consume detritus, benthic algae and epiphytes, and even living plant material(grey mullet is a prime example).The vertebrate members of the lagoon-al fauna contain some detritus feeders(grey mullet) and some planktivorous(anchovies), but majority are oportu-nistic omnivores or carnivores.

Estuaries are important coastal environments by virtue of their very high productivity, effect of which extend well into coastal seas-detritus is exported from estuaries and the young of several species of fish migrate into estuaries to feed, migrating out again to sea as young adults.

The estuarine fauna and flora are basically organisms of the intertidal zone, able to live on or in muddy sub-strate and able to withstand fluctuating salinity. Typi-cally, there are large numbers of individuals of some of the species but t number of species is generally low.

The small number of species is probably related to the uniformity of the environment(the mud), as well as to the environmental stresses(changing salinity). The animal species increases where there are rocks or stones on the surface of the mud, because solid surfaces can support many sessile organisms.
The high productivity of estuaries result from several factors. Probably the four most important ones are: their high levels of nutrients, derived from land drainage; their shallowness, so that benthic productivity is high; their lack of strong wave action, and therefore, their ability to accumulate detritus and inorganic matter; and their tidal nature, which results in a continual replenishment of nutrients for the attached benthic plants.

5.5: Economic Exploitation

Coastal areas, including estuaries and lagoons have long been important to man for economic exploitation and recreation. Man uses these areas for harbour sites, centers for commerce and food production. Man's influence on all coastal system is increasing year by year. Here we will divide man's utilization of lagoons and estuaries into four aspects, e.g. utilization for food, recreation, land reclamation, and pollution.

Sources of Food:

The use of lagoons as naturally occuring fish ponds has a long pedigree. From prehistoric time through the present day, man used coastal lagoons for raising fish of selected species (specially mullet and shrimps). Lagoons have been used by closing the entrance channel with metalic or plastic net, permitting young fish to enter. Many coastal lagoons in South America and Asia are in use for intensive fish cultures.in the form of mono- and poly-cultures to use efficiently the different food chain of the lagoon. The potential of lagoon based fisheries is enormous, specially in the tropics. In addition, many lagoons serve as nursery groundfor larval stages of shrimps and fishes.

Like lagoons, estuaries are also very productive and very rich in flora and fauna. The world's fishing industries is somewhat dependant on the estuarine environment, either directly as an area of fishing or indirectly as a region where the species spend a portion of their life cycle. Pacific salmon, anadromous trout and shrimp are all estuarine dependent species for part of their life cycle.

Rational exploitation of fishing reserves provides a continuous and much needed, source of protein. It is estimated that lagoonal and estuarine habitats of tropical coastline are suitable for intensive culture, with potential yields of upto 1000 kilograms per hectare, but in reality,the production is much less.

Estuarine shore provides ideal feeding grounds for vast numbers of birds. Some birds occur in flocks of thousands. Many lagoons serve as the sanctuary of many resident and migrating birds.

Recreation:

Lagoons and estuaries can accomodate considerable re-creational usé, for example, boating, sport fishing, swimming, and teaching as a model of ecosystems.

Many boaters prefer the estuaries and lagoons for both sailing and motor boating, for its relatively calmer waters than the open sea.

Fishing is an important form of recreation. The great abundance of food sources for fish in lagoons and estuarine waters make them relatovely productive fishing grounds for recreational anglers.

Lagoons and estuaries are less important as swimming areas due to soft sediment but many artificial beaches have been developed on estuarine shore. Swimming is a good exercise and an important pastime.

Lagoon and estuarine habitat can serve as a teaching model for biological productivity and functioning ecosystems. The smaller sizes, high productivity, rich flora and fauna, are conducive to scientific study aimed at the understanding of the whole ecological and biological system. This scientific and educational trips to lagoons and estuaries may have served as recreations.

Land Reclamation:

Dating back to the Romans, land reclamation was done for the purpose of either or both flood protection and the production of agriculturally valueble land. In recent years, Bangladesh has built high embankment along the coast to protect agricultural land and coastal villages from the recurring cyclones and high tides.

Land reclamation was in full swing in the Netherlands in the 12th century and it has increased in scale since then with all modern technologies, and 18% of the area in the Netherlands is reclaimed land. The largest land reclamation project was the conversion of the Zuiderzee into the freshwater lake IJsselmeer by the construction of a great barrier dam between the Wadden Zee and the IJsselmeer. The barrier dam was completed in 1932 and

isolated approximately 2700 km^2 of shallow estuarine waters.
The Florida region of the United States of America has long been used for reclamation sites primarily for real estate developments in coastal regions. Land reclamation has also been used to create land for residential housing, industry(electricity-generating stations, oil refinery, etc.),port, dock and airport facilities, as well as to yield empoundments suitable as freshwater storage reservoirs.

Pollution:

Many of the world's largest metropolitan areas border estuarine environment, e.g. Buenos Aires,Osaka, Los Angeles, Tokyo, London, New York,Shanghai,SanFranscisco. These cities are highly industrialized, and all make use of the estuarine as a waste disposal sites to a greater or lesser extent. Some of the cities have improved their environmental conditions tremendously due to anti-pollution regulation.
There are many ways man can pollute estuaries. An wide range of objects and substances are discharged intentionally or accidentally into the estuaries: oil and petroleum products, mining spoils, industrial solvents, heavy metals, domestic wastes, sewage and other organic materials, automobile bodies, industrial cooling water, etc.
Pesticides that man has been using to control insect-population both on inland crops and around marshes will eventually wash off the land into the rivers, then into the estuaries and finally into the sea. The high organic contents of human and animal wastes can use up oxygen in estuarine waters as the waste decay and thus cause the estuary to become anoxic and essentially devoid of life.

Thermal pollution can change the ecology of the estuary. The discharges from the power plant might alter primary and secondary production in coastal receiving waters. Most of the Pulp and Paper industry discharge their wastes to the marine environment, creating pollution in the estuaries. These wastes affect the fish and macro-fauna, as well as water.
The present annual production of crude oil is about 3×10^9 tons, of which it is estimated that about 6 million tons i.e. about 0.2%, escapes into the sea as pollution. The effect of oil pollution on the marine environment is treated in the last section of this book.
Estuarine pollution is one of man's more serious problems, there is indication that he is taking steps to combat it. Marine pollution may expect to decrease considerably, because of the implementation of pollution control legislation. Effect of pollution can be reversed if people sincerely want to. San Diego Bay, off the coast of California,U.S.A. and the Thames river estuary in England are now free of pollution, and fish and other forms of wildlife are beginning to return. Developing countries should take lessons from the experiences of the industrialized countries in implementing anti-pollution legislation to avoid contaminating the marine environments.

EXERCISES:

1. Why estuary is important to marine fish? why the estuaries are to be maintained in reasonably natural condition?

2. How agricultural pesticides pollute sea water? How estuary become anoxic? What are the measures you should think to take to avoid anoxic condition of the estuaries?

3. Lagoons are very rich in benthic fauna. To know, it is necessary to take a series of samples of the sediments together with its organisms, samples are needed to analyse to quantify the organisms present. You can extract samples by pushing a P.V.C tube(diameter of 4-10 cm.) into the the floor of a selected lagoon. Analyse the samples and find out the following:

   a) Nature of the sediments,
   b) Different types of organisms, their numbers and their depth of occurrence,
   c) Draw a distributional pattern of different organisms in a profile of the lagoon

4. What is osmo-regulation? How a migratory fish adjust its osmoregulatory problem in freshwater or sea water? Would you able to transfer a freshwater Tilapia to salt water? If so, demonstrate through a set of experments.

6: MARICULTURE

The production of suitable aquatic organisms at a given site is aquaculture. When the aquaculture or farming is done in brackish or marine environments is called Mariculture. Each year more and more efforts are made in Mariculture. Estimated world production through aquaculture was approximately 6 million tons in 1975 and is expected to rise to 12 million tons in 1985 and by the end of the century will be 50 million tons. This means that man is changing his habit of fish hunter to fish farmer. Fish farming is reaching a stage comparable to agriculture and animal husbandry. Important factors contributing to this spectacular development are increased world demand for fishery products, increased cost of fishing, depletion of many commercialy exploited stocks, change in the laws of the seas and added costs of finding job for excess fishermen. These problems forced many to seriously look into the possibility of using aquaculture as an alternative route, this was helped by research results and some technological developments. Another important factor is the involvement of developing countries in aquaculture because with moderate investment it offers jobs to a large number of people and in some cases gives exportable products.

Japan is well advanced in mariculture, followed by Korea, Taiwan, Indonesia and Thailand. Recently many developing countries are stepping into the area. Bivalve production is dominated by Spain, Italy, the Netherlands and France. Sea weeds, (mainly from Japan, Korea, Taiwan and China), account for approximately 17.5% of total aquacultural products. In recent years shrimp farming has become more and more popular in a number of developing countries. Shrimp farming techniques are well understood. Added to this, the almost ipsatiable world market of these costly food species has triggered the culture of shrimp in countries like Ecuador, Taiwan, Korea, Philippines and India.

"Sea ranching" is another domain of mariculture which, although started initially as governmental efforts, is now being taken up by private operators. Species such as salmon are used in sea ranching. Juveniles reared in hatcheries, when strong enough to care for themselves are released in the environment. They then undertake their normal routes of migration and within two to five years return to the place of release as adults. It is estimated that in North America, the economic return for sea ranching of coho salmon (Oncorhyncus kisutch) is 1:7 for dollar spent : dollar earned. Sea ranching practices are used in Japan to increase production of shrimp in inland seas.

Bait fish farming originated in the US as minnow farming in fresh-waters is now applied in mariculture. In some of the Pacific islands, production of live bait for skipjack tuna (Katsuwonus pelamis) fishing is being seriously considered. If successful bait farming could save considerable fishing time in the tuna fishing industry in those areas where there is shortage of live bait.

Prospect

Mariculture practices, in the world, are expected to increase in the foreseable future. It is estimated that there are approximately 440 million hectares of coastal wetlands in the world; most of these wetlands are tropical mangrove swamps. If 10% of those are brought into production and if they produce at the subsistance level of production then the world will have 100 million tons of produced aquatic organisms. The quality of these produced organisms will, however, depend on national policies of those countries. Because species and their culture systems are known, it will be up to the policy makers to decide whether the aquafood to be produced will be for the common man or for the luxury market.

Mariculture is basically a rural activity. This will provide jobs to the rural populations. In developing countries this will help arrest the drift of population to urban areas and help solve part of the problems cities face. On the other hand those coastal wetlands which otherwise will be low priced will gain value through maricultural uses.

Problems

Mariculture is very sensitive to many forms of water pollution. In many countries this is already causing problems. For example, in Japan oyster production remained more or less stagnant for the period 1965 - 1975 because of coastal water pollution. Known or unknown causes related to water pollution caused a decline in bivalve production of France. On the other hand mariculture can also be a polluter. Culture of dense populations contributes to water pollution through addition of excess feed and fish excrement. Over sensitive environmental awareness for the protection of aquatic environments from pollution also has in some cases slowed down the progress of mariculture. Thus mariculture has suffered from the presence of polluted water or polluting the water by its activities or through lack of protective actions against pollution.

In many developing countries in order to control the cost of living, food prices are regulated, thus influencing income of primary industry such as agriculture. In developed countries increased suply created by productivity improvements influence price and farm income. Small shifts in quantities produced generate large price fluctuactions.

The absence of a legal framework under which maricultural enterprises could be established and operated is also a problem. There are many institutional and legal constraints in working with water, such as the littoral region at the edge of the sea that are generally thought to be public property, and usually under a water resources management system of the region. To do anything with the water will require permission of the public regulatory authority. The area under "Maritime mile" i.e. a strip of land a few miles inshore from the mean high tide mark is in many countries under defense department control. Besides, present day ecological awareness has created considerable interest among government authorities to protect coastal wet lands because these are natural nursaries for many commercial and sport fisheries. Thus governmental control of these lands are more strict and their use for private purpose is becoming more and more difficult. Finance is another problem. Mariculture is a highly risky business. Many financers therefore do not like to finance it. The nature of work in mariculture requires adequate long term investment for land development and construction so that the enterprise has a chance to gain enough experience to make sound decisions. Under capitalized conditions have ruined many maricultural endeavors in the past.

The feed cost is the largest single item in mariculture operations ware prepared feed is administered. Feed formulation in aquafarming is based an the experience of a few species only. Optimization of cost efficient, nutritionally sound feed for each species under mariculture needs to be found. The aquaculture industry is also sensitive to fluctuations of price of the ingredients for feed formulations. For example, fish meal which is the main ingredient of feed comes from peruvian-Chilean anchovies. When for some reason there is short supply of these anchovies, fish meal prices shoot up. Feed availability at a site might influence the decision to use it for mariculture. Meanwhile systems could be designed in such a way that mariculture organisms could obtain their nutritional requirements from natural productivity in their growout environment. To have a self sustaining natural productivity system in a limited volume of water with high density of crop animal will require additional knowledge of the system. Recycling of aquafarm wastes through careful selection of species is a domain yet to be fully utilized and understood. The biological problems that are most serious and need attention are i. seed production, ii. disease and parasite control and iii. inventory control. Dearth of seed supply is still a problem in many of the species used in mariculture. An assured seed supply must be achieved. It would be ideal to have the situation so controlled as to have abundant quantities of healthy young of known genetic composition. Disease and predators are still taking a good percentage of crop species. It is necessary to learn how to control and prevent disease in a high-density culture environment. Precise measurements of the number of crop animal in the production system at any one time is a must for making correct decisions about rate of feeding, disease control and water management. But at the present state of knowledge this is not possible.

Lack of adequate manpower is another problem facing the mariculture business. There are of course college trained biologists and engineers available but a dearth of sufficient on the job experienced persons in all levels of the aqua-farming business is and will be a problem for some time to come.. Inspite of all these problems, however, mariculture is going to advance, solving some of its existing problems and facing more to be solved by future generations.

6.1.1: Species selection

Large scale mariculture requires detailed evaluation of a species before it is chosen for culture. The important area for consideration are (i) economics, (ii) marketing including consumer acceptability and (iii) biological characteristics. The crop species should be such that it can bring good profit. The product should be such that the consumer must want to buy it. And the biological characteristics should be such that it can be easily raised and preferably bred in captivity.

Economics. A high selling price for a species obviously brings higher return on the investment. Species having very high rate of production but less market value can also bring high return. Quick generation of cash is certaing preferred. This is possible for species with short grow out periods. Among species that have similar market value those which require less initial investment for their culture are preferred.

Marketing. The consumer acceptance of a crop species depend on the traditional food habits of people together with individual taste and food preferences the latter is probably the reflection of the availability, durability in storage and ease of preparation. The marketing criteria of a species should satisfy human needs and preferences and at the same time should command sufficient selling price to make a decent profit.

The following are some of the important points considerated for market acceptability of a given aquaproduct.

Flavour. In food technology the term flavour includes both taste and odor of a food. The flavours of a product should be such that it is accepted by the majority of the consumers. Because of the available food or water quality of the grow out facility, an aquatic animal of accepted flavour may aquire off-flavour or unusual-flavour.

Appearance. The form, color and external characteristics of a candidate for culture must also be considered. Frequently fish of strange color or apparance are rejected by the consumer. Besides the color, lustre and texture of the flesh are of importance. For example pink color is preferred more than dark color and white flesh is preferred over yellow. Flaky and firm texture have wide acceptance although sometimes soft textures are also preferred.

Processing. The manufacturing efficiency which ultimately influence the economics is also important. The relation between total weight and dress out weight influences the price For example a bony fish with big head will give fewer filets than a fish of similar weight with smaller head. The same relation applies to other organisms. For example the ratio between the weight of exoskeleton to the meat of crustaceans; or meat to shell-weight ratio of oyster or the recoverable and marketable component of squid-like invertebrates. In other words how much of the marketable product can be had from the whole organism will determine the price of the product and thereby will influence the choice of the organism to be cultured. Other processing consideration concern the ease and cost of handling from harvesting to packaging. The tissue of the animal should less susceptible to rapid decomposition. It should have a long shelf life such that for a reasonable period of storage time it should retain wholesomeness, flavour and texture. And then there are such factors as the ease of control of size, uniformity for portioning, amenability of processing the carcass should also be considered.

Market behavior. Major determinants for the candidate species are the size and structure of the market and the elasticity of demand and price of the grown product. The size of the market is different for different species. For example penaeid shrimps have a very big market. The price depends on the supply. The price fluctuation due to increased or decreased supply is more often seen in most aquatic animals the cultured organisms are always in competition with the wild variety; the supply of the latter is always seasonal. As such there is possibility of taking advantage of seasonal market price fluctuation by trying to orientate the harvesting time of the cultured organisms to the season when the price is highest. Another variable that effects the price is the size of the animal. A culture system can control the size of the product and can produce the most profitable size.

Biological characteristics. It is the biological characteristics of the species which mainly governs the production cost. The indispensible parameters of the biological characteristics should include the environmental requirement of the species,its behaviour, its nutritional requirement, its reproductive requirement and above all its rate of growth. The rates of growth of different organisms vary some grow much faster than the others. Fast growing crop species should have preference over the slow growing ones. Many of the most desirable species such as crabs and lobsters, takes several years to grow to marketable size in their native habitat. It is this slow growing characteristic alone that may put them at a disadvantage as candidates for culture. On the other hand there are some fast growing species that can produce marketable crop within three months; for example the penaeid shrimps.

Size at harvest. For many commercial species there are approved minimum size or age for a fish to be marketed. For such fish, unless the law is modified there is no flexibility for the grower for marketing time of its crop. But for quite a number of species there exist no law for minimun marketable size. For these species the farmer has a choice. The of maintaining high density populations in confinement over long period of time is expensive as well as risky. The danger comes from the theat of death of the population due to disease, predation and environmental change. Since per kilo price of a species does not always increase with increased size the farmer should make the decision as to the size of the organism to be marketed for maximum economic gain. As such some crop animals could be harvested when juveniles or young adults however, for some species it would be profitable to harvest at a larger adult size than the legal minimum size. The decision of the size at harvest will depend on the conversion rate and the age at which the inflection in the curve of the conversion rate with age occurs. The point of diminishing return on feed costs and conversion usually determine the appropriate age or size.

Feed convertion efficiency. Growth rate alone should not be the criteria for selecting a species for culture. The cost to achieve desirable growth rate must also be given consideration. Generally as an animal increases in weight it requires a greater portion of the ingested food to maintain itself. Therefore the conversion efficiency decreases when the cost per increment increases. As such the conversion of feed energy into marketable product is of merit.

The feed cost can be reduced if the crop organism utilizes food from the natural environment; in which case a sound management of the ecosystem is required. The natural food capacity of a water body can be increased by fertilization. In this case choice of the crop species should be aimed at utilization of various ecological niches.

Species which live in a school and take food together without disturbing each other are preferred because this behavior allows a high stocking density. Whereas those species that are territorial or have agonistic or antagonistic behavior among the members of a confined population are always difficult to culture.

Seed production. The sucess of culture depends on an abundant and reliable supply of seeds. For many species seeds come from their natural habitat. For only a few limited species seeds are produced in hatcheries. The candidate species should be such that its breeding can be easily done in captivity. The candidate species should have high fecundity and fertility. Newertheless, a species even if can not be bred in captivity, may be chosen for culture if other qualifications are favourable.

Hardiness. In nature the motile organism usually respond to changed environmental conditions by moving to another suitable one within its home range. In the culture environment this may not be possible. Yet at times the environmental conditions might change quckly. In such cases only those species that have wide range of tolerance will survive. The environmental tolerance may include oxygen tension, temperature, sunlight intensity, salinity, pH, heavy metals, ammonia, nitrite, pesticides, industrial wastes and other harmful solutes.

It would be rather difficult to find a species that has wide tolerance for all environmental factors but certainly there are species, tolerant to important environmental factors; such species should be considered first.

6.1.2 : Feeding

In mariculture practices feeding is done to get the desired growth of crop animals. From an economic standpoint the cost involved in feeding must pay off through increased growth of the cultured animal. To get more growth, more feed is supplied untill a situation shown in Fig. 8 is reached and the fish farmer gets his profit at a point A. With proper care feeding rate can be checked at a point to get maximum profit (point B). It is therefore necessary to determine the amount of feed to be given to the crop animal. Feed requirements vary with species. Active species may require more feed for a given amount of growth than sedentary organisms. Similarly, high rates of feeding will be needed for those species that waste significant amounts of feed while eating and also for those animals that are inefficient in locating feed. Examination of food conversion ratio (FCR) is required to determine the optimum rate of feeding. FCR is obtained by dividing the dry weight of feed offered by the wet weight gain by the organism. The lowest FCR values are obtained at highest food conversion efficiency (Fig.9). Optimum feeding rate will therefore be at the lowest FCR value. Daily feeding rate is calculated on the basis of percentage of biomass or on the basis of unlimited food supply. The latter method, in most cases, become very costly due to wastage of feed. For most mariculture practices feeding rate at certain percentage of biomass is generally practiced. Since during the growing

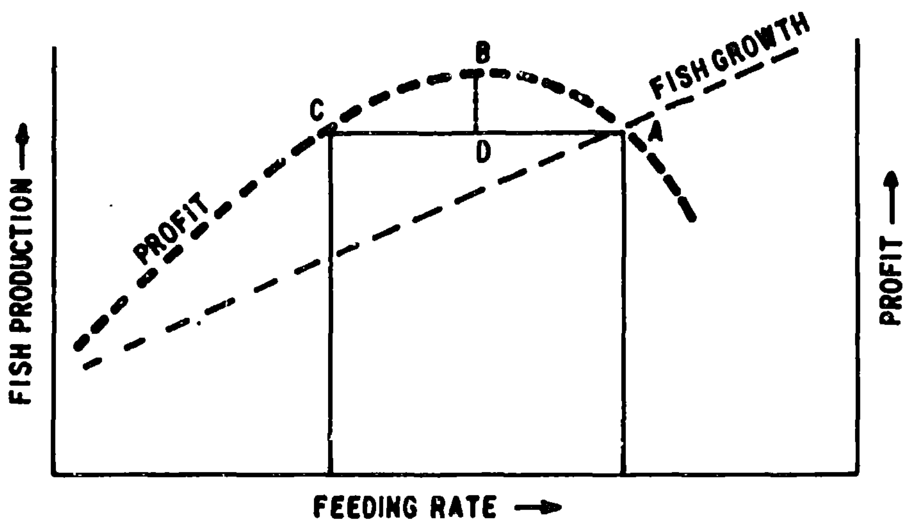


Fig 8 Relationship among feeding rates, fish production and profits.

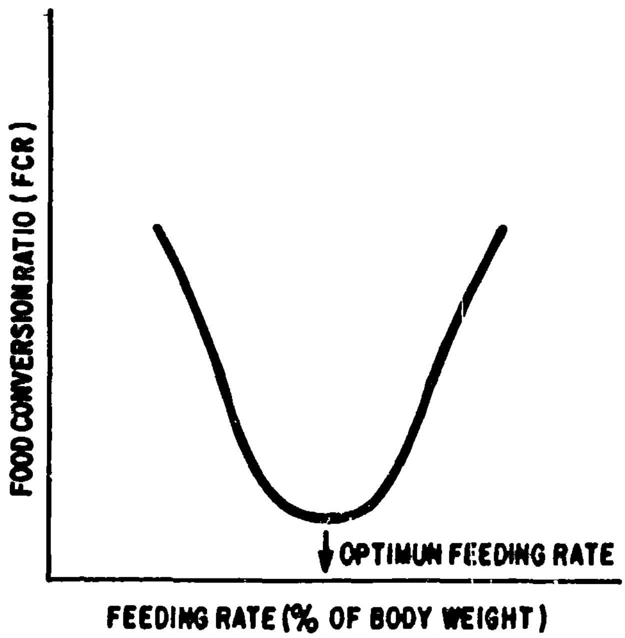


Fig 9 Theoretical plot of change of Food Conversion Ratio (FCR) with changing feeding rate. (Under experimental condition).

season, organisms grow rapidly, the amount of feed needed is adjusted daily for the added biomass. If the FCR of a species is known and remains constant, then the daily growth in biomass may be calculated through the following formula. However, FCR varies considerably for a variety of reasons, including environmental changes within the grow out facility. On getting the estimation of biomass it is possible to calculate the amount of feed required for a given percentage rate of feeding. Formula for the calculation of biomass:

Wt = WO + WO x FR / FCR where

Wt = weight of crop organism on day t

WO = weight of crop organism on day 0

FR = feeding rate expressed as percentage of body weight

FCR = food conversion ratio. For example on day 0 crop organisms weighed 1000 kg; were fed @ 5% of body weight and had a food conversion ratio of 1.5. On day t the weight of the crop species is expected to be :

Wt = 1000 + 1000 x 0.05/1.5 = 1000 + 33.3 = 1033.3 Kg. Now if they are fed @ 5% of body weight then the stimated feed required is 1033.3 x 0.05 Kg = 51.6 Kg.

Indirect feeding is also practiced in mariculture. For example in the case of milk fish and shrimp indirect feeding is through the growth of food organisms by means of fertilizers (inorganic compound) and manure (organic compounds). Inorganic nutrients stimulate growth of phytoplakton or algae which in turn stimulate the growth of microinvertebrates and other organisms in the food chain. Greater fish growth results through the availability of an abundant natural food supply. Organic fertilizers or manure decompose in the water, releasing inorganic plant nutrients resulting in the same process as inorganic fertilizers. In some cases the culture organisms use the organic matter directly.

A mixture of nitrogen, phosphorus and potassium is generally used for pond fertilization but at times along with the above named primary nutrients other plant nutrients are also used. Nutrients in chemical fertilizers occur in simple inorganic compounds which, when dissolved in water ionize to release NO_3, NO_4, H_2PO_4 or K. The nutrient content of fertilizers is expressed as percentage equivalent of N, P_2O_5 and K_2O. For example a fertilizer graded as 10-10-5 actualy contain 10% N, 10% P_2O_5 and 5% K_2O. The fertilizer ratio is obtained by dividing the fertilizer grade by a common denominator. For example a 10-10-5 fertilizer has a ratio of 2:2:1, The nutrient content of fertilizer is also expressed as percentage of N, P and K and is calculated as follows:

$$\% P_2O_5 = \% P/0.437 \text{ where } \% P = \% P_2O_5/2.29$$

$$\% K_2O = \% K/0.83 \text{ where } \% K = \% K_2O/1.2$$

Secondary nutrients are calcium, magnesium and sulfur; trace elements are copper, zinc, boron, manganese, iron, molybdenum etc. The secondary nutrients as well as trace elements also aid phytoplankton growth but these are normally not used in pond fertilization except in freshwater ponds where liming is done. There are different kinds of solid fertilizers; the common ones are urea, calcium, nitrate, sodium nitrate, ammonium nitrate, ammonium sulfate, superphosphate, triple superphosphate, monoammonium phosphate, diammonium phosphate and muriate of potash. Liquid fertilizers are also available and are used i.e. liquified ammonia and urea, ammonium phosphate and phosphoric acid.

Most fertilizers absorb moisture and should be stored in a cool dry place to prevent caking. Ammonium nitrate is extremely explosive if exposed to sparks or open flame. Most solid commercial fertilizers are corrosive, some liquid fertilizers like phosphoric acid are highly corrosive. Appropriate care should therefore be taken for their storage and handling.

Fertilizers with specific grades are made by mixing appropriate quantities of nitrogen, phosphorus and potassium sources, mixed fertilizers usually contain the primary nutrients and a filler. The latter may be an inert material or neutralizing agent like lime. Different grades mixed fertilizers are usually available. However one can prepare his own mixture through the following calculations:

x = PN/B where

x = Kg of source to be added

PN = desired percentage of hte primary nutrient

B = percentage of primary nutrient in the source expressed in decimal. For example for the preparation of 5-15-5 fertilizer from ammonium nitrate (33.5% N), superphosphate (46% P_2O_5) and muriate of potash (60% K_2O) may be done as follows:

Percentage of N in the desired mixture is 5, which is to be divided by the percentage of N (33.5) in the source ammonium nitrate expresed in decimals i.e. 0.335. Thus the amount of ammonium nitrate to be added is 5/0.335 =14.9 Kg for 100 Kg of desired mixed fertilizer. Similarly percentage of

P_2O_5 in the desired mixture is 15 which when divided by the decimal expression (0.46) of the percentage (46%) of P_2O_5 in the superphosphate gives 5/0.46 = 32.6 kg of superphosphate to be added. The percentage of K_2O in the desired mixture is 5 which is to be divided by the decimal expression (0.6) of the percentage (60%) of K_2O present in the source muriate of potash gives 5/0.6 = 8.3 Kg of muriate of potash to be added. Thus the calculated amount of different ingredients are:

N as ammonium nitrate 14.9 Kg

P_2O_5 as superphosphate 32.6 Kg

K_2O as muriate of potash 8.3 Kg

Total : 55.8 Kg

Filler to be added to get 100 Kg of mixed fertilizer is 100 - 55.8= 44.2 Kg. When the primary nutrient is present in more than one source of fertilizer intended to be used in the mixture the calculations are done in such a way that the total amount added from two sources adds up to the desired percentage. At times it is not possible to make up a particular mixture of fertilizer from a given set of source material. In such case it is advisable to choose an alternate source.

6.1.3. Environmental factors

Environmental factors are extremely important for an aquafarm. The knowledge of the environmental requirement of the crop species is the key to sucess. High concentrations of crop species in grow out facilities make them very sensitive to environmental changes. The aquafarmer therefore should be aware of these and be careful to avoid problems. Salinity, temperature, dissolved oxygen, turbidity are part of the natural aquatic environment. Toxic materials and other pollutants although not part of natural phenomena nevertheless are encountered and strongly effect mariculture productions.

Dissolved oxygen. Dissolved oxygen is a critical factor in intensive fish culture. Fish, like all other animals, need oxygen to oxidize food material to release energy. Without sufficient dissolved oxygen in water physiological processes can not be carried out by fish. Dissolved oxygen requirements of fish vary with species, size activity, temperature and nutritional status. The cold water species generally require more oxygen than the warm water ones. It is generally that a minimum of 6 ppm of dissolved oxygen is enough for most crop species. Many species can withstand a situation of less than 6 ppm dissolved oxygen for a varying period of time. However the longer they live in oxygen deficient water the more susciptible they become to disease, inhibition to growth, decrease fecundity and even to death. Fish respond quickly to dissolved oxygen depletion. The hourly rate of oxygen consumption in pond water help us understand the dissolved oxygen content of culture ponds. The hourly rate of dissolved oxygen consumption in pond water may be estimated from secchi disc visibility by the following equation:

02 consumption in mg/I/h = $-1.133 + 0.003815 + 0.0000145\ S2 + 0.0182\ T - 0.000749\ T2 + 0.000349\ ST$

where S = secchi disc reading and T = Temperature

Dissolved oxygen content of water is dependent on temperature and salinity; the higher the temperature and salinity the lower is the dissolved oxygen content. On the other hand oxygen supersaturation of water can also cause problems by causing gass bubble disease. Gas bubble disease can also be induced by suddenly moving fish from a water of high dissolved oxygen concentration to one of low.

Weather conditions reduce oxygen, warm and cloudy summer days may cause problem through reduced photosynthesis and increased use by respiration and reduced capacity of water to hold oxygen. Several aquacultural practices also cause oxygen depletion. Over feeding of crop species and aquatic weed control activities contribute to the accumulation of excess of decaying organic material in the water. Decaying organic material has a high oxygen demand thus quickly depletes the oxygen supply. Lowering water levels reduces the surface area, concentrates organic material and thus uses up oxygen. A combination of weather and farm management practices may bring the dissolved oxygen concentration below critical level thus endangering the crop.

Salinity. Salinity is an important factor in the coastal ecosystem. Most organisms in the braekish and coastal waters are tolerant to a wide range of salinity changes. Care should be taken to provide water of suitable salinity to the crop animals. Grow out facilities in the tidal zone should be constructed in such a way that seasonal excess freshwater quickly bypasses the ponds whereas during the dry season enough freshwater must be retained to keep the salinity within the most favourable range for optimum growth of crop species.

Temperature. Although fish are cold blooded organisms, they maintain their body temperature approximately o.5° C above that of their environment. In other words the body temperature is governed by the water temperature. Metabolic activities are controled by enzymes, the production and action of these enzymes in turn are controled by temperature. Enzymes are most sensitive to temperature change. Fish can produce different variants of many enzymes for efficient working with in a given temperature regime. For example in cold water they can produce enzymes efficient for a cold environment likewise enzymes can be produced for efficient functioning in warm water. This requires time; slow and gradual change of temperature is conducive to the production of the required variant enzymes. A sudden change of temperature may kill a crop species before it has the chance to make the necessary physiological adjustments. Optimum growth of a crop species is possible under a given temperature range, which is specific for each species. Crop species in a grow-out facility should have that temperature.

Ammonia. Un-ionized ammonia is highly toxic to fish but the ammonia ion is not. The sum of ionized and unionized ammonia is called total ammonia. It is generally believed that only measurable amount of ammonia in water will effect fish growth however in general total ammonia concentrations should not be allowed to exceed 0.1 ppm. Chronic exposure to ammonia will result in reduced growth and stamina, gill hyperplasia and an increased susceptibility to disease. Ammonia problems occurs in culture facilities due to over crowding, over feeding and where the turn over rate of water is too low. Ammonia in water originates through break down of organic material by bacteria and through the excretion of aquatic organisms.

Turbidity. Turbidity caused by plankton is desirable and helpful in fish growth, through increased available natural food for the crop species. Turbidity caused by high humic acid concentrations are not helpful but not harmful either, at least not directly. Turbidity caused by clay particles is undesirable. As a result of erosion and run off from land areas near the culture facility, the amount of suspended silts may be increased in water. This abnormal increase may result in turbid water diminishing the quantity of light transmitted for photosynthetic reactions. Suspended particles carried with water may provide active surface on which photogenic microorganisms may grow before infesting the crop species.

Nitrite. When nitrite is absorbed the haemoglobin become effected and can not carry as much oxygen as it normally would. When appreciable amounts of nitrite are absorbed fish blood becomes brown and the fish is said to have "brown blood disease".

Toxic materials. There are a number of materials that are toxic to fish; some are more so than others. Most harmful materials are synthetic organic insecticides, heavy metals, and polychlorinated biphenyls (PCBs). Organochlorine insecticides interfere with the nervous system in vertebrate, thus these are regarded as neurotoxicants, organophosphate and carbonate insecticides inhibit some enzyme actions disrupting neural functions. Insecticides derived from plant extracts interfere with oxidative metabolism while also affecting neural functions. The toxic substances are taken up by fish through their food or through their gills. Some of the toxic materials can be highly concentrated as then moves up the food chain. Toxic materials that are hard to break down in the natural environment are the ones which accumulate and build up in high concentrations in organisms. Highly fat soluble materials become very much concentrated in aquatic organisms. For example DDT, very soluble in fat, in 1960 in lake Michigan, in some fishes, was found at a concentration 1 million times more than that found in water. Toxic materials at non-lethal levels are also harmful to crop species by effecting the temperature preference, growth, and reproduction. These adverse effects are at times more harmful than highly publicized fish kills.

Oil is another pollutant. Since oil is immiscible with and lighter than water, it forms a film on the surface thus preventing diffusion of oxygen into water. Besides, oil when it come in contact with respiratory organs of crop species, covers the gill surface and thus prevents respiration. The organism suffocates to death. Furthermore there are a number of compounds in oil which when dissolved in water in sufficient quantities, kill aquatic organisms. The susceptibility varies with the concentration of oil, duration of exposure, type of species and its age and physiological condition of the species effected. At sublethal concentration, crop species develop oily taste many times, crop species exposed to oil even if not killed, become unsafe for human consumption.

6.2 MULLET CULTURE

Mullets are cosmopolitan species, distributed all over the world. Among the approximately 77 species, the grey mullet or jumping mullet, Mugil cephalus is well studied and widely used for culture. Oren (1981) gives a good account of mullet culture.

6.2.1 General bilogy

The grey mullet is widely distributed in the world. Perhaps due to their euryhaline and eurythermal characters. They are greyish green in color on the dorsal surface and silver white on the ventral. Juveniles migrate from the high sea spawning area to estuaries where they spend a considerable part of their life. When adult they make a migration towards the open sea. The adults migrate in schools to the spawning areas. Spawning areas are far from shore, out in the open sea over a depth of about 900 to 1500 m. The fecundity ranges from eight hundred thousand to 2.7 million eggs. The mullet egg is round, averaging 0.93 to 0.95 mm in diameter with a yellowish brown oil globule measurung about 0.38 mm in diameter. The fertilized pelagic eggs may drift with the current into deeper water and float at mid depth until hatching.

The diet of the mullet varies according to age and size. The smallest group (15 to 25 mm) use exclusively animal food, mainly crustaceans, the intermediate group (25 to 55 mm) use mixed food, both animal and plant, while the largest group (55 mm) almost exclusively eat plant and detritus (benthic algae and diatom). According to Thomson (1966) the food of the adult Mugil cephalus may be classified into the following categories: (1) Micro algae including epiphytic and benthic forms (2) decaying plant detritus and (3) inorganic sediment particles. This, although, may generally be true with mullets, may in some cases include a portion of animal material. In the laboratory, on hatching, larvae prefer tiny zooplankton, such as fertilized oyster eggs, few days later they prefer rotifers, at 70 mm body length they like Artemia.

Seed Collection

Approximately 99% of the mullet fingerlings come from the sea during the breeding season of the mullets. The habit of the mullet fry to enter lagoons, channels, creeks and brooks are used for their capture during appropriate seasons. Because fry accumulate in small indentations and in quiet spots before heading upstreams, such structures are artificialy created to attract them in a convenient location. A widely practiced method is to use beach seine made of mosquito net or other knotless material net. The softness of the net is very important for the capture of healthy specimens. The fry actively fight to escape capture A rough net will result in lost scales and injuries which later will be a source of infection and cause of death. Using a motor boat along the coast to trawl fingerlings, although time saving, is yet not recommended for, it cause excessive injuries to the delicate fingerlings. The lenght of the net should be only large enough that can be handled by four persons although there reports of use of nets to 700 x 3 m.

Once trapped in the net, fingerlings may be scooped out by using a scoop net. Large dip nets as well as umbrella nets are also used. The latter is advvantageous in that it can be operated from shore, and is efficient. At night a light source (600 - 1400 W) may be used to attract fish and then they may be caught with an umbrella net or dip net.

The survival rate of the fry is very poor, approximately 10%. They are more sensitive to salinity change than to temperature change. The survival rate can be increased by very care ful handling and by supplying preffered food (zooplankton). Sometimes mullet fingerlings obtained at certain time are called "dead fry" because most of them die for unknown reasons.

Induced spawning of stripped mullet is possible in captivity by the use of pituitary hormone injections of ripe females which is done successfully in Hawaii, Taiwan. The initiation of ovarian development may be made by manipulation of temperature and photoperiod but for successful spawning hormone injection is necessary. Several types of hormones (salmon, carp, and mammalian gonadotrophin) give favourable results. By controlling temperature and photoperiod and then injecting hormone mullets can be spawned throughout the year.

6.2.2 Cultivation Methods

Mullets can be cultured in freshwater, in brackish water, in sea water and up to 145% saline water. Freshwater will give a little less growth, whereas brackish water is the ideal environment . Mullet grow much better in eutrophic ponds if oxygen concentration is maintained above the 50% saturation level.

Three different types of cultivation method are in use, i.e. extensive culture, polyculture and intensive culture.

Extensive culture. So far most mullet culture is of the extensive type. Fish ponds are commonly located on the shore, near estuaries Fingerlings enter into these ponds on their own through sluice gate. No food is usually supplied. By the end of second year they will have grown to 500 to 550 g each. The production varies between 200 Kg/ha to 663 Kg/ha. Best results are reported from Japan where individuals grew to 552 g in weight and 29.3 mm in lenght. The survival rate in extensive culture system is very low (5 to 10%). Higher survival rate may be possible by stocking with bigger fingerlings, between 150 - 180 mm or in cold waters stocking with overwintering fry, which grows faster. In warmer areas "overwintering" type fry may be obtained artificially by stocking them at a very dense rate at the begining thus creating stress condition and then stocking with these fry at a lower density, hopefully these will give similar growth rate as those of overwintering fry.

Polycuture. Polyculture best utilizes the natural feed and culturing space. In order to get best results it is necessary to have an optimal stocking ratio of various species combinations so as to achieve a stable ecosystem. Mullets are cultured with other fishes for maximum ecological use. In carp ponds, mullets are introduced as secondary consumers. In Israel, 30 - 70 g mullets are stocked in carp ponds at the rate of 500-800/ha which at the end of 3 - 5 months reach 400 - 700 g. In Japan mixed culture of mullet with carp and eel is done where rice barn @ 57 - 227 g/m^2 is used as feed. Mixed culture with carp and eel or carp and crucian carp, the production of mullet was independent of total production, meaning that the stocking density of mullets could be decided independently of the maximum rate of stocking of the other species. Yet some stocking rates are as follows: Carp-mullet ponds 800 mullet/ha, mullet, tilapia, carp and silver carp, 1200 mullet/ha; of course at the higher rate extreme care has to be taken to maintain water quality. In Taiwan mullets are cultured with milk fish and grass shrimp. The mullets are first separately raised up to 2.5 cm sl, then introduced into polyculture ponds containing milk fish and shrimp 500/ha. These ponds give high survival rate (92.9%). Supplemental feed@ 57- 227 g/m^2 of rice barn or small quantities of flour and rice barn is given.

Intensive Culture. Among the few existing reports of intensive culture of mullet there is the mixed culture of mullet at a density of $2/m^2$ and feeding with worn pupae@ 0.3-2 Kg/m^2. The effort produced 1,290 Kg/ha of mullet.

Pisani (1976) reports intensive culture of various species of mullets at a facility in the lagoons and their inlets at the northern Adriatic in Italy. The salinity of the water usually varied between 28 - 30%, rising during drought to 40%. Careful planning and construction permitted the advantage of adequate water exchange without loss of fish. There were rooms for rea rig fry in controlled environment. There were outdoor rearing facilities. The set up was too big to supervise and thus had problems with poaching.

The system depend on seed supply from fry dealers who used to bring fry from other coasts of Italia. Because of environmental problems which were accompanied by unfavourable weather, sufficient fry from around the culture facility were not availabe. Fry rearing facilities consisted of a series of 4 m diameter circular concrete tanks, housed in a roofed structure to protect the fry from winter conditions. Tanks were stocked from October to November with 10 - 20 mm fry 150,000 specimens per tank. Each tank was constantly flushed and aerated. Every ten days the fry were disinfected with malachite green or Neguvon- Masoten (Bayer). The fry were fed by an automatic feeding machine every two and a half hours@5 - 7% of body weight. The amount of feed given depended on water temperature. As the fish grew they received less and less food. The mortality rate was between 25- 35% which occured within first few days and weeks after their arrival. It was believed that this mortality was due to transportation and capture of the fry. As the fry grew they were thinned out such that a 4 m diameter concrete pond would hold a maximum of 13,000 specimens of 50 - 80 mm TL. On reaching 80 mm the young were transferred to rearing ponds.

Each rearing pond was a rectangular, earthen pond with an area of 100 m^2, with a depth of 1.5 to 2 m. At the head of each rearing pond there was a 20 m^2 concrete trough feeding area. Rearing ponds were stocked @ 2 Kg of fish per m^3 of water. These ponds were flushed @ 15- 60 l/s. The rate of flushing depended on temperature; higher water temperature required more flushing. Peletted feed was supplied; the rate of feeding depended on water temperature and body weight of fish.

To help fish withstand cold weather a series of "hibernation" ponds were constructed. These were rectangular, earthen ponds, measuring 30 -100 m x 3- 6 m with a depth of 4- 5 m. During very cold weather the fish were guided to these ponds so that they could pass the cold-wave safely in deep waters.

During spring, fish were guided to semi-intensive rearing facilities which were rectangular earthen ponds of 40 - 50 m x 20 m with a depth of 50 - 70 cm but along the circumference the depth was 1- 2 m. These ponds were also flushed with water@50 to 60 l/has/s. The fish were fed peletted feed @0.5 to 1% of body weight. A specially designed boat was used to blow air to the bottom of the semi-intensive holding ponds. The air mixed the bottom deposit with the water column, thus helping in the production of more natural food. This natural food compensated for more direct feeding. At the end of a year some of the fish weigh up to 300- 350 g, which was the marketable size. Those which failed to attain marketable size were transferred back to their respective pond for further growth. At the end of third year they weighed 800 g each.

Using heated water from power plants to maintain optimum water temperature and giving supplemental feeding with commercialy prepared feed, 293- 804 Kg/ha of mullets with 50-85% survival rate was produced.

Roe. Dried mullet eggs or roe is a delicacy at certain parts of the world and are sold at high prices. In pond culture there are usually more females than males. They grow faster in culture environment than in the wild and they mature one and a half months earlier thus giving better prospects of marketing roe earlier, thus making more money.

6.2.3. Parasite and Diseases

Epizootics with bacterial infection can cause mass mortalities of mullets. In crowded conditions mullets are more susceptible to bacterial disease. Maintainance of good environ mental conditions will avoid these problems. In freshwater, injured mullets are infected with fungus, Saprolegnia sp., which may lead to mortalities. Extreme care may be taken during handling so as to avoid injuries, thus avoiding the infection.

Parasitic dinoflagellate, Amylodinium ocellatum and a closely related species occasionaly infests Mugil cephalus in Mississipi and can easily kill most fishes stocked. Most of the flagellate infections are possible in fish ponds with high density. No chemical yet known can save fish in heavily infested conditions. Ciliates also cause problems particularily when environmental conditions are bad and or the fish are in stress. "Ich", Ichthyopthirius multifiliis Fouquent is one of the most harmful parasitic diseases of cultured fish, in both fresh water as well as, in salt water.

Ergasilids, Ergasilus sp. Infect and cling to fish gills. Heavy infections reduce the respiratory function of the gills. Heavy infestations are likely to occur in crowded fish ponds. The disease is controlled by treating with 0.2 ppm Borax solution (Lahav and Sarig,1967). Some cyclopids, such as caligus sp cause die offs in mullet fish farms.The infection causes integumental lesions. Change of salinity and temperature can initiate the infection.

Fish lice, Argulus sp. also attack mullet, especially in heavily stocked, confined waters. Such infections are controlled with periodic use of pesticides. Benedenia sp. a helminth, infections cause death in natural population of mullets. This infection when acute can cause extensive erosion in the gular and opercular region.

Mullets as toxicant to man

Ciguatera poisoning in humans is caused by eating several fishes including mullet. Cooking does not destroy the toxin. More specifically associated with mullet is "hallucinatory poisoning". It primarily effects the central nervous system of man causing loss of equilibrium, hallucination, mental depression and a sensation of constriction around the chest, may develop within a few minutes to two hours after ingestion of mullet and may persist for a day or longer. Eating raw mullet is the cause of Hyuga or Kagami fever.

6.3 SHRIMP CULTURE

Shrimp is the costliest of all the marine food organisms. World demand for shrimp was expected to increase by 26% and that of the USA by 30% by 1985. Shrimp farming is evolving into a new industry for both develop as well as developing countries. Shrimp culture is now a good business in Ecuador, Japan, Taiwan, Panama, Brazil, and the USA. Ecuador exported only 450 metric tons of cultured shrimp in 1977, which was increased to 1,800 tons in 1982, where as in Taiwan it went up from 1,100 tons in 1977 to 8,000 tons in 1982 and the country is foreseeing a production of 50,000 tons in the near future.

Mariculture of shrimp owes its sucess to Dr. Fujinaga, a Japanese scientist, whose tireless efforts in 1933, opened the door to the secrets of the biology of Kuruma shrimps and it is he who discovered a practical system of rearing the larvae to large enough post-larvae to be stocked in open air ponds. Obviously, the detailed procedure for farming shrimp was first develop for Kuruma shrimp, Paeneus japonicus.

Today farming procedure is known for many species and that for several others are in the process of development. It has been observed that grass shrimp, P. monodon, is a more desirable species for culture than Kuruma shrimp, because the former (grass shrimp) tolerates wider temperature and salinity ranges, grows faster, attains larger size, eats almost everything (omnivorous), accepts cheap food, converts more of the food into muscle (food conversion ratio 1.8:1), requires less expensive culture facilities, is hardy, disease resistent and when cooked its muscle becomes a more brilliant red than that of the Kuruma shrimp.

The following description of shrimp culture is primarily that for grass shrimp. With appropriate modification it can be applied to other shrimp. A beginner with limited resources may start with a species locally available. On gaining sufficient experience, he may then switch to exotic species.

6.3.1 Site Selection

Site selection is very important. No site will have all the desired characteristics, the question to be asked is whether farming will be profitable in a given site. To answer thus, the following need to be considered:

1. Salinity. Post-larvae grow better in lower (than that of the sea) salinities. The salinity of the water during high or low tide should be favourable.

In areas of heavy rainfall arrangements is to be made to bypass the excess freshwater. During excess evaporation a source of adequate supply of freshwater is required to keep the salinity at the desired level by dilution of sea water.

2. The pH of the water on or adjacent to the pond site should be within 7.8 to 8.3. Water with good growth of phytoplankton is an indicator of acceptable pH. Also good growth of Avicinia, a mangrove plant, is an indicator of favourable pH. On the other hand such mangrove plant as Rhizophora, Brugiera, Soneratia acida with extensive root systems above ground are indications of acid soils. Trees such as nipa, with high tanin contents cause long lasting low pH in water.

3. In general, places where tidal fluctuation is between 2 to 3 meters are suitable, because ponds can be filled or drained with tidal flow. Tidal fluctuation of over 4 m or under 1 m are unsuitable, because for the former the dike construction and maintainance will be costly and at low tide, maintainance of desired level of water will be difficult. In the later case changing pond water will be difficult.

4. Information about the water current and wind is important for planning erosion control of culture facilities as well as sediment control inside the ponds.

5. The potential pond soils must have a high enough clay content to assure that the pond will hold water. Peaty, sandy and acid soils are unsuitable. Estimate of water loss through pond bottom or dikes are helpful for water management.

6. River water usually brings harmful substances such as pesticides, minning wastes, industrial and urban wastes. Such water may be avoided by selecting sites away from such contaminant sources.

7. Knowlegde of the availability and source of procuring seed is a must. It is necessary to know the species available and their seasonal abundance.

8. The availability of labour, supplies, equipments, marketing outlets and technical assistance should also be considered.

9. Temperature is an important factor as it effects growth as well as survival of shrimp larvae. While each species has its own optimum temperature range, temperatures between 26- 30°C are generally considered suitable. Temperatures above 32°C must avoided.

10. Adequate amounts of dissolved oxygen are very important for shrimp ponds. Oxygen values under 3.5 ppm are considered dangerous. In a shrimp pond, on a daily basis, some 8% of the oxygen is consumed by shrimp, about 7% by fish and some 7% is consumed by microorganisms including phytoplankton. So care should be taken to avoid deposition of food remains, in the pond, which support growth of microorganisms. Frequent water exchange will help ease the situation. Instalation of aerators, like compressed air stones, or paddle-wheel aerators are helpful. The paddle wheel is made from the rear axle of car, driven by a 6 hp, motor and housed on a drum float.

6.3.2 Seed Collection and Transport

Collection

In many areas of the world there are naturally occuring post-larvae available in abundance. Small artisanal farmers may utilize their labour and resource to collect wild post-larva.

A passive method of collecting post-larva is to open the sluice gates at high tide, when along with water and undesirable organisms, post-larva enter the pond. This method is practised in Thailand, Singapore, Indonesia, Malaysia, Philippines and India. The major problem here is that among the undesirable species there could be predators of shrimp. The predators, when grown large enough, will reduce the shrimp population. This problem can be avoided by allowing the passive entrance of organisms in a nursery pond, as frequently as possible. Then after a period of 3 to 4 weeks, treating the pond with an appropriate concentration of saponin or tea seed cake to eliminate the fish but not the shrimp. After fish are eliminated the shrimp may be tranferred to stocking ponds.

Entrance of shrimp larvae may be increased by use of a light source (lantern) in front of sluice gate. Shrimp larvae along with fish larvae are attracted to light. When enough larva accumulate then the water surface is slapped to make a loud sound. This sound scares fish larva away but not shrimp larva. The sluice gate is then opened and rapid flow of water carries the shrimp larva into the pond. Repeating the process several times permits enough shrimp larvae into the pond.

Shrimp have the habit of clinging objects in water. small branches or twigs in bunches can he fixed in shallow waters to attract larvae during high tide. At low tide by placing a soop net under the twig larvae are caught. Also, to attract larvae, twigs or salt water grass are hung little above the bottom from ropes. Several such lines of approximately 20 m lenght each are used. A scoop net is placed under these lines and lifted up to catch the larvae in grassy areas using a scoop net gives good results. Push nets or scissor nets, hand or boat operated along beaches also give good results. There is a practice using baited trays for luring larvae. Any organic matter, like rice barn or even mud high in organic content is used as bait. After a sufficient period in water, the tray is lifted and placed in tanks with water.

Many people prefer to collect post-larvae in fine mesh nets, without wings, placed in tidal passes. In areas of weak tidal flow use of wings is recommended but not in areas of strong tidal flow. Constant attendance of net and regular removal of larvae give best results.

The best time to collect fry is on the rising tide during a new moon. It is claimed that for larvae of P. monodon, P. semisulcatus and P. indicus the third to fifth hour of a rising tide give the best catches and that at times larger numbers of P. indicus are caught at the second hour.

A collection of shrimp fry is usually a mixture of shrimp, fish and other fry. Manual separation is time consuming and tedious. The separation is done by treating the collection with saponin or tea seed cake which kills fish but not shrimp and crab larvae. The crab larvae are then separated manually.

Seed Transport

The most common method of fry trnasport is in polyethylene bags (50 x 70 cm) with water and ox gen. Generally two bags are used, one inside the other with 5-6 l of water. The water is saturated with oxygen by bubbling O_2 gas. Shrimp larvae, not fed for several hours prior to packaging, are introduced into the bag containing water. The rate of stocking is 1500 of post-larvae of 10 mm or 5000 of 17 to 18 mm or 3000 of 20 to 24 mm standard length. Soft and fresh twigs are placed in the bag for the post-larva to attach. While the oxygen is still bubbling the bag is closed and sealed taking care that there remains only water and no free air in the bag. The bag is then placed in an impermeable container for example one of styrofoam. A few pieces of ice are then placed on the side of the bag to keep the temperature of the bag as well as the metabolism of the larvae dowm. Saw dust cooled and mixed in ice, when placed around the box serves the same purpose. The container then should be completely sealed and taped. In this the post-larvae may be kapt no more than 6 hours without change of water and oxygen. After packaging all efforts are made to avoid direct sun light on them and stored in shade, away from heat sources. Post-larvae are shipped at night whenever possible.

6.3.3 Nursery

Stocking larvae directly into rearing ponds usually does not give desired yields because of high mortality of larvae.

If care is taken to hold larvae in nursery ponds untill they reach 2.5 to 3.0 cm and then to stock them in a rearing pond. There will be a better chance of getting a higher yield.

Larvae transported in polyethelene bags are transferred to an well aerated acclimatization tank, where the water temperature and salinity are kept almost equal to that of the shipping bag. The temperature and salinity of the tank is adjusted to that of the nursery tank. It takes about four hours to make that change. In the case of not having the facilities to artificially prepare the required temperature and salinity conditions, the shipping bag water is changed slowly with that of the recipient water while the larva are still in the bag. A change of no more than 15% is recommended at a time. After each change, a period of time is given for the larvae to acclimatize in the new environment. Release of larvae in the nursery pond is done in the evening or during the coolest part of the day. All efforts are made to avoid hot and sunny parts of the day for the release of larvae. Stocking rates in the nursery pond can be up to 25 individuals/m^2.

Nursery Tanks

1.2 x 2.4 x 1.2 m boxes made of marine plywood, aerated by air stones are used. Daily, 25 to 50% water is changed. A stocking rate of 10,000 to 50,000 post-larvae of 5 to 6 mm grow to 25 mm with 70 to 90% survival when fed with ground meat of mussel or of fish or pelleted fish food @ 100% body weight.

Round plastic tanks of 25 m^2 bottom area and 60 cm depth have been successfully used without aeration but with 50% of water changed daily. The bottom is covered with 10 cm of sandy garden soil. At a stocking rate of 2,000 to 4,000 per m^2, fed @ 100% of body weight with a mixture of acetes meàl 40%, coconut oil cake 20%, ricebarn 20% and cassava flour 20%, the larvae grow up to 30 mm within one month with a survival of 60-95%. Lower survival rates were reported for higher densities and in tanks without soil on the bottom.

A sophisticated tank is now available commercially in the USA which is in use in other places too. If none of the above facilities are available, earthen ponds may be used where lower stocking rates may give encouraging results.

Rearing

Pond preparation. It is a common practice to drain out the pond completely and allow it to dry before stocking larvae. However there is no standard procedure, for drying neither for lenght nor for the frequency of drying. Excessive drying seem to be harmful. In areas of high potential acid soil drying ultimately will increase pH. Many a times lime is used to control pH. It may be borne in mind that agricultural lime may control soil pH but is not effective in maintaining pH of salt water. Natural carbonates of organisms such as dolomite, mollusc shell or coral are more soluble at pH of the salt water and will aid in maintaining optimum alkalinity and pH. After drying, the pond bottom is leveled. Organic fertilizer is added on the bottom soil. Chicken manure or other manure may be applied. These manures are dried but not treated with pesticide. Inorganic fertilizers 100 to 150 Kg/ha of 16-20-0 mixture are also used, instead of organic fertilizer after one week, the same amount of fertilizer is applied and the water level is raised to 10 to 15 cm. The fertilizion is repeated and the water level is raised to 20 to 25 cm, additional water is added to cover loss due to evaporation, The pond is drained gradually and checked for the presence of unwanted species and if necessary an appropriate pesticide is used to eliminate them. The pond is refilled and redrained once or twice. Each time water is allowed to enter the pond, a trap net is placed to prevent the entrance of unwanted species. Many farmers fertilize their ponds every seven days or after every change of water.

Rows of twigs and small branches are placed at 6 to 15 m apart, perpendicular to the direction of the prevailing wind, to act as wind breaks.

Stocking Rate and Time

There is no optimum stocking rate. The stocking rate is calculated depeding on the farmers capability, management system adopted and resources available. In Thailand, for monoculture of shrimp, the suggested rate is 0.5- 2.0 juveniles per m of the pond.

The juveniles are stocked at the time of the month when tidal amplitude is the greatest. Transfer of juveniles from nursery to rearing pond is done with utmost care otherwise large number of them may be killed or injured. There are several methods in use. The water level is slightly lowered, 2 to 3 hours before the incoming high tide, late in the afternoon or early evening. Only enough fresh tidal water is admitted into the pond to make them active and ready to move out of the pond. A floating bag net (Fig.10) is attached to the sluice gate and the water is drained out as soon as the tide recedes. This is best done at night and placing a lantern on the sluice gate to attract the shrimp. Juveniles thus caught are carried to the growing pond in suitable containers.

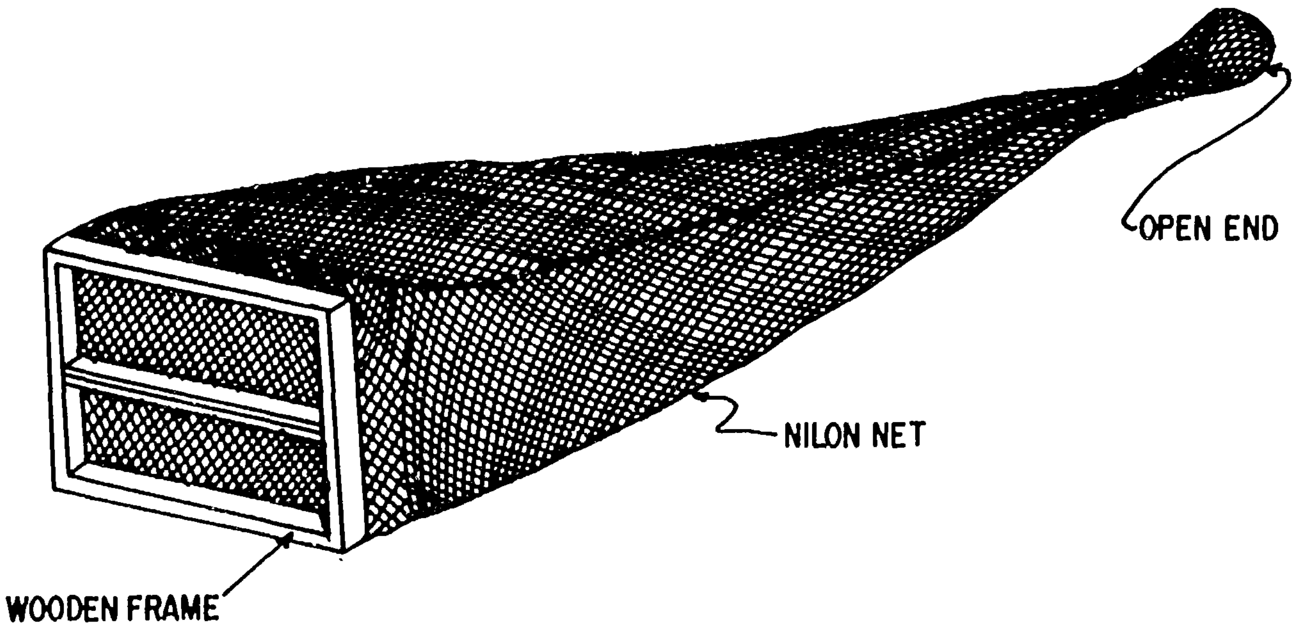


Fig 10 Floating bagnet.

Water Change

Frequent change of water is beneficial to maintain good water quality of rearing ponds; the incoming water brings few natural food organism. In extensive culture system, 1/3 of the water is changed every week or every two weeks. After each change fertilizer is added. But in feeding type management 1/3 of the water is changed daily by draining and refilling by pumps or as soon as the dissolved oxygen falls below 3 ppm, the water is transferred at a rate sufficient to change 35 l/s of the water daily. Each water entrance is screened for unwanted species.

6.3.4 Feeding

Most farmers depend on natural feeding. The objective of fertilization of rearing pond is to grow sufficient amount of natural food. Fertilization causes a good growth of phytoplankton. Various microorganisms feed on phytoplankton and the shrimp feed on microorganisms. Ponds with dominant growths of diatoms gives high shrimp yeild. Shrimp get entangled or trapped under mats of filamentous algae, Care is thus taken to control excess growth of undesirable filamentous algae.

Most feeding is done to supplement natural feeding. Numerous feeds are in use with varying success, The main point in supplemental feeding is to supply enough meat. The meat source are those that are normally not utilized for human consumption or have any other consumer, such as trash fish, toads, frogs, slaughter house and poultry house left-overs, shrimp heads, mussels, snails, animal skins that are not used for other purposes. The meat is chopped into small pieces (0.5 to 1 cm in diameter) then mixed with rice barn. Chicken feeds are also used. Supplemental feed is given daily or once every two days at a rate of 5 -10% of stimated body weight of the stock, in the late afternoon or early evening. The food is distributed throughout the pond; a catwalk may be necessary to reach the center of the pond.

Intensive Culture

There are only a few reports available on the intensive culture of grass shrimp, *P. monodon*. Aquacap reported their results of a culture effort in Tahiti using a pellet developed for this purpose. They found a growth of 25 g in 140 days, a conversion of 1 :1. Based on this experiment they calculate that 20 ton/ha/year of shrimp can be produced in intensive culture system. There is a report of intensive culture of *P. monodon* from Thailand. An earthen pond with an effective culture area of 4,340 m^2 was used. On one occasion it produced 5,100 Kg/ha for a growing period of seven and a half months with 79% mortality and on a second occasion 2500 Kg/ha/year. Shrimp were fed twice daily with ground trash fish, crab, mussel and rice barn.

Each year many more experiments are done and efforts are being made to come up with processed shrimp feed. The day should not be very far off when intensive culture of shrimp will be very widely practiced.

Harvest

The shrimp grow to maketable size of 15 to 30 heads/Kg or 30 to 60 g each within 5- 7 months. For harvest, the same method is used as is practiced in the case of transfer of juveniles to rearing ponds. Immediately after harvest the shrimp is sorted according to size. They are then beheaded at the harvest site. This keeps the quality of flesh better for a longer period and as well, it takes less ice to preserve them. The head can then be ground and fed to other shrimp.

6.3.5 Management

Even after all careful measures to stop unwanted organisms from entering the shrimp pond, occasionally they do enter. It is then necessary to eliminate them. The, method to be applied depends on the number of the unwanted organisms. Selective poisoning is economical if number of intruders are high, otherwise they are removed by traps, gill nets, hooks and lines. The mesh size of traps and nets used is large enough for the shrimp to escape.

For removing fish through selective poisoning tea seed cake is used as source of an active ingredient called saponin. The effectiveness of saponin is salinity dependent in that for a given concentration it takes longer to kill a fish at lower salinity. The practiced dosage is:

For salinity above 15‰ = 12 g tea seed cake/m^3 of water.

For salinity below 15‰ = 20 g tea seed cake/m^3 water.

Tea seed cake is dried and then ground up. It is then soaked in water for 24 hours to extract the saponin; after which time the water containing tea seed cake is filtered. The filtered fluid is applied to the pond. The soaked tea seed cake may be thrown in the pond as a fertilizer.

For any chemical treatment it is always economical to have as little water as practicable. The water level is lowered late in the afternoon or early evening. The chemical is then applied. The next morning dead fish are removed. The pond is then filled in before the sun heats up the shallow water, thus damage to shrimp avoided Saponin must not be applied in a pond at the period of low dissolved oxygen content.

Rotenone is also used selectively kill fish and not shrimp. Extreme care must be taken to calculate the volume of water in the pond and the concentration of rotenone applied because the difference between the lethal dose for fish and that for the shrimp is very small. A little mistake in calculating the amount of required rotenone might kill the shrimp as well. The recommended dose is 0.2 ppm of rotenone. As the rotenone concentration of source materials varies, it is advisable to check the porcentage of rotenone in the source material.

Sodium pentachlorophenate commonly known as PCP-Na, a weed killer, also selectively kills fish at a concentration of 0.5 ppm PCP-Na is readily decomposed when exposed to direct sunlight. Its application should therefore be done in the evening.

Crabs are problematic for shrimp ponds. The swimming crabs are fierce predators of shrimp. These are removed by using baited traps. Shrimp are also attracted to the bait. Use of large enough mesh permits shrimp to escape.

The burrowing crabs cause damage to the dikes. Burrowing crabs are removed by placing calcium carbide into the hole and then putting water into the hole. Calcium carbide, coming in contact with water produces acetylene gas which kills the crab. Burrowing crabs may also be killed by poisoning with an sevin insecticide. Savin is also toxic to shrimp but relatively safe for human and domestic animals. Savin is mixed with ground fish, fish balls made out of the mixture, is then placed in crab holes Crab holes below the water line are then sealed with mud to prevent the shrimp from entering. Fish or crabs killed by chemical treatment should not be used for human or shrimp consumption.

6.3.6 Disease and Parasites

Little is known about the importance of diseases and parasites found in shrimp ponds. Usually a farmer knows about the death of his shrimps at the time of harvest when the expected number of shrimps is not found. However there are reports of heavy mortalities from disease in intensive shrimp culture. However the following are known.

Black gill disease: A fungus of the genus Fusarium can cause the gills to have a very deep dark color. It causes mass mortalities. Nystain and Azalomycin F are effective in curing the disease.

A bacterial infection in its final stage turns the gill black in color. In the begining it is orange yellow, then turns dark brown and finaly black. This disease also kills shrimps but not as much as Fuserium. The infected shrimp is treated with a bath of 2 to 3 ppm water solution of farazoline for 2 to 6 nights. Accumulation of dirt may also make the gills look black. Putting the shrimp in clean water clears the gill in one or two days.

Under crowed conditions bacteria erode of exoskeleton, which become the site of secondary infections which may cause death. Sometimes under such condition the gill is destroyed, thus killing the shrimp. A mixture of malachite green (0.5 to 1 ppm) and formaline (20-75 ppm) in water helps to control the situation.

Under adverse environmental condition of high temperature and low oxygen content, tissues of the tail area degenerate giving a white patch at the tail or the whole tail may turn white. This is usually accompanied by jumping at the surface or out of water. Mass mortality may occur due to this disease.

The problem is overcome by improving the environmental conditions.

Microscopidian parasites cause a disease called cottom shrimp. The infected part become white in color. It start at the telson and spreads to other arees. This infection is usually not on massive scale.

There are three kinds of vibro diseases, each one causes mass mortalities. Shrimps attacked by these diseases usually become slow moving, or show reduced activity and disorientation.

Handling or harvesting on hot days causes the body of shrimp to curves and become rigid. The mechanism of this condition is not known. Handling or harvesting at night or during the coolest part of the day helps avoid the problem.

There are other problems mainly associated or evolved because of poor environmental conditions such as the ciliate disease, filamentous bacteria, blue-green algae etc. Improving of environmental conditions usually solves the problem.

It may be safely said that healthy environmental conditions are a must. If the water quality is maintained at the acceptable level and rich food of the required amount is given then many disease problems can be easily avoided. Avoidance of frequent use of chemicals is recommended because long term effects of these chemicals are not yet fully understood.

6.4 OYSTER CULTURE

Oyster clams, and mussels are sedentary intertidal orgaisms. They live in a part of the sea that is effected by tide and as such are at least partly exposed to air during low tide, when they can be harvested easily. Oysters and oyster-like organisms have probably been easten give the begining of human civilization.

Even today oyster meat serves as a basic protein dish within the reach of the common man. Human attempts to culture oyster go as far back as the Romans. Because of ease of harvest, and the complexity of the oyster's life cycle, many of the rich natural oyster grounds were soon memories of, the bygone past. It forced many to look to the alternative of culturing them. Attempts were made in Japan as well as in Europe. Japan started farming oyster in the 17th century. King Napolean III supported the effort of oyster culture in France. Early efforts were not very successful. Slowly the biology and the life history of these organisms were known. The methods of culture were developed and improved. The oyster culture industry or for that matter the bivalve culture ows its sucess to the devoted work of many scientists like Havinga amd Korringa of Holland, Coste of France, Young in England, Stafford in Canada, Galtsoff Loosanoff, Hopkins, Nelson, Kincaid in the US and to many pioneer oyster farmers all over the world. The leading countries in oyster production are France, the Netherlands, Spain, Italy, Japan and USA. Many other countries such as the Philippines, and Korea are involved in large scale oyster culture following methods comparable to that of Japan. Many developing countries like India, Venezuela and Chile are also practicing oyster culture. The prospect is good for the developing countries because it is still a labour intensive culture system. The energy for the growth of bivalves come from the natural production system of the sea. Care and handling is done by the human being. Efforts are being made to make it a capital intensive farming. The greatest problem of oyster farming is pollution. The coastal waters where oyster are grown, are also the water being more and more threatened with pollution. The future of the oyster industry will depend on the capability on human beings to control the environment of their coastal waters.

Oyster although almost universally accepted, are not like everywhere. There are places where because of conservative food habitats or religious beliefs, bivalves are not eaten. Even in those countries the fertility of the sea could be utilized for the production of bivalves. The product then could be recycled as feed for the growth of acceptable food animal like poultry or may be exported to countries where there is a good demand for the product.

6.4.1. Biology

Ecologicaly oysters are considered as animals occupying the lowest place in the food chain. They are herbivorous. Oysters feed on primary producers like the algae, tiny small microscopic floating algae of different varieties are filtered by the oyster. Thus oysters are filter feeders. Their system of feeding is such that they filter less water when there is enough food in the environment, contrarily the rate of filtration increases when food is scarce. Flavor of the marketable oyster will depend on the type of food organisms available. Oysters are sedentary organisms too. Meaning that they need not spend energy in search of food. Thus the energy they get through food is all utilized for their growth, fattening and reproduction. Growth is dependent on the interaction of one or more of such factor as amount of food temperature, salinity and other environmental factors. Thus the time to reach marketable size varies from one to five years. The body is covered by two shells thus their common biological name, bivalve. The shells are joined by sets of powerful muscles enabling the organism to shut themselves of during unfavorable conditions. Oysters live in the intertidal zone, i.e., the area of the sea effected by tide. Thus during low tide when the oyster is exposed to air, the organism shuts the shell and live on the trapped water. Of course during these difficult hours of no fresh water and no food, there is no growth. Similarly during exposure to pollution the organism shuts itself. But if the pollutant stays in the environment long enough the oyster will have to open up for water and food thus will be exposed to it. Some predators find their way inside the shell even in closed condition, some others make then open. The shell is made up of calcium carbonate which is picked up from the sea water. Shape and size of shells are different in different oysters.

Oysters are found over a wide geographical range, mainly in the temperate waters. Reproduction and larval growth is favoured at higher temperatures which is found in the southern region of the temperature zone. But more plankton production is found in the northern part of it, where fast growth of the organism takes place. This characteristic has been used in oyster culture. They are bred in one area, where the spat is collected, which are then transferred to areas with rich plankton growth thus areas with more food, causing rapid growth.

Oysters produce large number of eggs. An average female may produce 14 to 114 million eggs at one time. Females may spawn more than once during each breeding season. Spawning is triggered by rising temperature. When the right water temperature is met, females and males eject eggs and sperms freely into the water. Fertilization is external. Fertilized eggs, within a few hours, develop into delicate larvae called veligers. The free-swimming veliger larvae are weak swimmers. They are at the mercy of the water current and live a planktonic life for two to three weeks. During this period they develop a small, but well developed foot with which they attach themselves to a hard and clean surface. Only a few find a suitable substratum for attachment. Those failing do so die; thus the rate of larval mortality is very high. Places with very low current velocities for prolonged periods are likely places for settling of larvae i.e. places with eddies are the best sites for larval settling. After attachment the larvae changes to a stage called spat which finaly grows into adult oyster, provided suitable conditions are presents. After attachment the larvae looses the foot and velum; simultaneously gills appear. Once attached the oyster can not move from the place by its own locomotion. Oysters like many other bivalves change their sex; young males change to females and after a considerable period of time may even convert back to males. Salient biological features very helpful for farming of oyster, are their high fecundity which result in plenty of larvae. If suitable surfaces for the settlement of larvae are supplied at the right place, and the right time, an abundant quantity of seeds will result. Their sedentary nature makes then easy to handle and harvest. Because oysters can survive for long period of time out of water, they are easily transported long distances. Their food habit makes best utilization of natural production of the sea thus there are no added costs of feed for their culture.

6.4.2. Farming

Seed collection. During spawning season, because of high fecundity, large numbers of veligers, that is free swimming oyster larvae are produced. Placing collectors (materials on which spat setts) will provide plenty of seed. An experienced farmer knows the time and place of spat collection. Water temperature is an indication of spawning time. The temperature requirement varies among species but ranges between 15 to 20° C. When the right temperature is reached then using a plankton net, (a fine mesh net) and by sampling bays periodicaly, one can learn the availability and density of oyster larvae. If the collector are placed too early, then unwanted organisms will settle first thus leaving less space for the spat. Not all places produce equal number of larvae; some produce larger quantities than others, because of unsuitable spawning conditions or inadequate number of spawners. Thus selection of the right place is important. Once the right place and right time of spat collection has been selected, then the spat collector or clutch is placed in water. Different types of collectors are in use. Some farmers just clean and strip the bottom to expose the shell and clean rocky bottom on which the spat will settle. Others spread clean oyster shell on the bottom. The best collector materials are ones that can be easily broken or from which the spat can be easily removed. Oysters, if allowed to remain at the place of their first attachment will have poor growth and unacceptable size because of crowding and unavailability of required growing conditions like salinity, temperature, current and food.

In France, special tiles are used for spat collection. These tiles are dipped into a solution of lime, mire, saw-dust and fresh water. The thickness of the mixture is made such that one dip gives a 2 mm coating on the tile. The coated tiles when dry used for spat collection. The settled spat is scraped of the tile. There are machines for quick liming as well as scraping spat off the tiles.

In Hiroshima Bay, Japan, scallop shells are used as collectors. About 80 scallop shells are used to make a string of 1.6 m, plastic spacer is used to separate two adjoining shells of the string. Many such strings are hung in water from bamboo poles for the collection of spat. Dense accumulations of collectors are avoided by fouling organisms.

In many places like southern Washington State coast and also in Portugal, oyster shells are used to prepare collectors. A two meter long string requires 80 to 100 shells. Although automation has been done to make strings, a special hammer may still be used for making holes in the shell to make string.

In Australia, hard wood sticks are used as collectors. Six feet long by 0.75 square inch sticks are placed 6.2 inches apart to make a latice, two such latices nailed together is used as one collector. The latice once made is then dipped in thin coal tar. The excess tar is allowed to drip out. This tar treated wooden collector is then placed in water for spat collection. Bamboos and twigs are also used as collector.

Planting Spats. Spats are planted for growout in different ways. The sea bottom is used by many. When the sea bottom is used for the purpose, the ground is prepared in advance of the time of planting. The process requires a cleaning of the area from all foreign materials and shells because they may harbour eggs of predators or disease causing organisms. If the bottom is soft, it is made hard by spreading sand, gravel, broken shell etc. The sea-ward side is protected by a fence made of plasticized metal screen and protected by twigs or branches placed close to each other. Collected spats after being scraped off the collectors are spread evenly on the prepared sea bottom at a time when the tide is in over the flats. This plants the spat with right side up and helps their even distribution. Spats collected on oyster shells are separated by many farmers by cutting the collector shell into pieces by use of appropriate saw. These pieces are then spread on the planting park or oyster park. After planting the spats, the park must be cared for, to protect them from predators. During each low tide the area is searched for crabs and starfish. Any predator detected is killed and thrown away from the park. Spats gathered by current and waves near the fence are picked up and redistributed. During high tide crab traps are placed to trap them. From time to time the young oysters are cultivated i.e. the clumps are broken and separated and evenly redistributed so that they get plenty of food and oxygen and during the process the fouling organisms are removed.

Growth and Fattening

When the young oysters have grown sufficiently they are picked, cleaned, graded and then again planted back to sea for further growth and fattening. Many times they are transferred to richer part of the sea where there is a better food supply and more favourable growth conditions.

Many farmers . . grow the oysters on trays. The trays are placed on racks above the bottom of the sea. Thus avoiding predators like star fish. Oysters thus grown are of uniform shape and size.

Throughout the process of fattening and maturation, oysters are cultivated. It takes about a year and a half to as long as five years to get marketable oysters. Throughout the whole period, care and cultivation must be done, thus making the process of oyster culture labour intensive.

Spats collected on stringed collectors in some systems are restringed and respaced to give oysters more space to grow. Then the string is hung on appropriate poles placed on styrofoam floats. The strings are hung in such a way that they should not touch(Fig.11) the bottom of the sea at any place of tide. The spated strings are hung at an area of the sea rich in plankton, of suitable

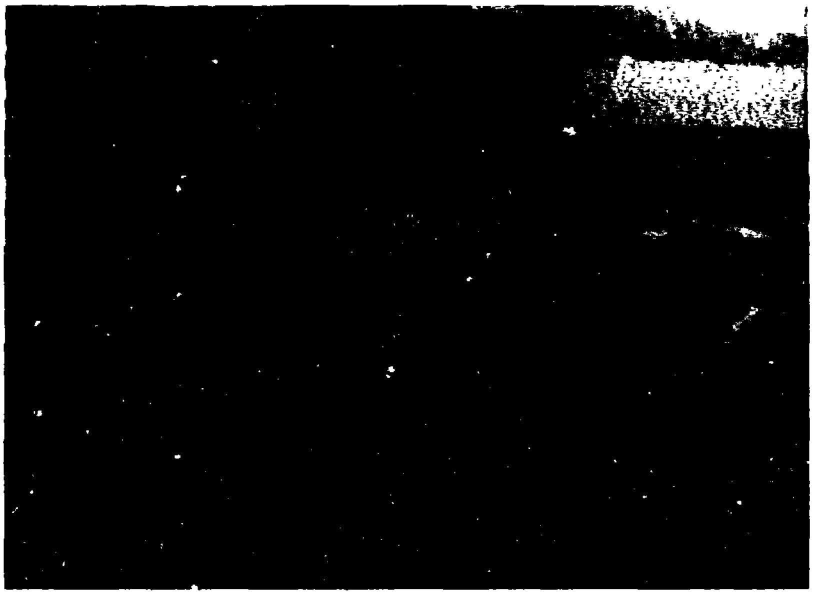


Fig.11. Culture Raft

salinity and favourable environmental conditions. For this reason collected strings with spats are often transported to distant places for hanging during the grow-out phase. Stringed oysters are also cared for and inspected from time to time. The Australian system, wooden lattices on which the spat is collected, are also used for fattening and growth. Lattices with spat are transferred to more productive ground and are hung in water using racks. As the oyster grow, they need more space, which is provided by opening the lattice bundle till finally only one lattice is left, giving plenty of space for the oyster to grow.

There are farmers who specialize in part of the farming process. For example in France there are oyster farmers who sell 18 month old young oysters to oyster farmer in Holland. Many Japanese farmers sell oyster seed to other farmers or countries, thus specializing only in one phase of the oyster culture. Less time spent on the farming, less risk is involved.

6.4.3 Risk

Hydrographic conditions. Sudden and long term changes in salinity are of considerable importance to oyster industry. Oyster survive best in low salinity but best quality is obtained at higher salinities. High salinities also cause high mortalities. Thus care is taken to keep oysters at the correct salinity. Gales, hurricanes, storms also cause serious damage. Some loss due to storms is natural. But at times the whole stock can be whiped out by storm In certain areas of France, approximately every ten years a gale is of such magnitude that it cause catastrophic damage of oyster farms, In 1969, an oyster farm, situated on the Lousiana coast, a hurricane deposited so much sand that oyster farming at the site was impossible for few years. Selection of oyster farms in protected areas of the sea will help prevent or at least minimize these risks.

Pollution. Presence of oil, at least causes tainting of oysters thus making it impossible to market the product, Although oyster farmers in the oil producing areas blame their loss on to mortality due to oil, research results in such places as Lousiana failed to correlate large-scale oyster mortalities with oil pollution.

Seed Availability. Larval development in the sea is dependent on a number of factors. Water temperature, nutrient content and weather conditions will control the quality and quantity of natural food of oyster larvae as well as number of predators. This leads to a variation in the number of available spat from year to year. Under unfavourable conditions, parent stock and the number of larvae produced remaining the same, spat settlement could be extremely poor. In some parts of the world such situations occur once every few years.

Predator. There are large numbers of predators. One or the other at one time or another may inflict heavy losses to the farmer. An alert farmer can avoid the problem and protect his crop. Some fish devour oysters voraciously. Porcupine fish (*Dicotylichthys mysersi*), Bream (*Mylio australis*), Black sea bream (*Mylio macrocephalus*), Toad fish (*Sphaeroides hamiltoni*) and black drum (*Pogonius cromis*) have been reported from different regions of the world as oyster predators. Black drum pose a threat when the water is warm and has a salinity 25% or above. Sting rays are also predators. Different farmers solve the problem differently.

Some put fences made of synthetic or galvanized material around their parks. The economics of raising fences should be figured out; loosing a few oysters to the predators or raising fences to protect them should be judged economicaly and the appropriate decision be taken. In Portugal, small twigs are planted close to each other and all over the oyster park, making it difficult for the predator fish or rays to get to oysters easily. Planting of twigs or sticks costs labour. If the labour cost is less than the oyster thus saved, it is worth trying. In Australia rack farming with wooden lattice has solved this partly.

Wooden lattices are bound in such a way that fish can not enter. All that is preyed upon are a few oyster towards the outer edge of the rack. Birds like the oyster catcher (Haemapotus ostralegus) are also predators.

There are a few invertebrates that inflict heavy loses on oyster farmers. Starfish are one of them. If left unnoticed starfish may kill large numbers of oysters. They are detected and controlled by using a starfish mop. A mop, with cotton fibres attached to an iron frame, is passed over the oyster park infested with starfish, the latter get entangled on cotton fibre. The starfish then is killed by dipping the mop in boiling water. Granulated quick lime @200 lb/acre has also been successfuly used to control starfish. The granulated quicklime is simply spread on the oyster park infested with starfish.

Oyster drills, like the Atlantic drill (Urosalpinx cinera), Gulf oyster borer (Thais haematoma), thick-lipped drill (Eupleura caudata) are serious predators. These organisms produces a toxin which paralyze the oyster, make hole on the shell (enter inside) and eat the meat. Borers usually can not withstand low salinity. The gulf oyster borer can not withstand salinities less than 15%. Thus oyster in less - - -

saline waters are protected from borers or drills. Drills are also controlled chemically. "Polystream", a polychlorinated benzene kills borers but does not harm the oysters. Borers once eliminated chemically remain controlled for as long as five years.

The Japanese system of oyster culture, avoids drills because the drill larvae is not pelagic thus can not reach the hanging oysters.

Flatworms of the genus _Stylochus_ and _Pseudostylochus_ also cause damage. Crabs, like the mud crab (_Neopanope texana_), rock crab (_Cancer irroratus_) Kill spat and young oysters. Crabs are controlled by killing and traping. The technique of selective killing of crabs as is practiced in shrimp cultivation (see shrimp section) although has not been tried for oyster culture, is worth trying. Hermit crabs attack oyster with damaged shells. Occasionally large numbers of octopus may appear on an oyster park and destroy large quantities of oysters. Octopus are easily found in burrows lined with oyster shells. They are controlled by hand picking.

Competitors.

Various benthic organisms may settle on the oysters or on the spat collectors and interface with their feeding activities and growing space, among are bivalves such as slipper shells, Jingle shell, saddle oyster, and different mussels. Epibionts like ascidians, sponges, bryozoans, polychaete worms and barnacles interfere with oyster farming. Shipworms bore on wood. Australian oyster farming uses wood as collector as well as for the growing base. Use of shipworm resistent wood and treatment with coal-tar minimizes the attack but does not prevent the shipworm. Mudshrimp (Upogebia pugettentis) and ghost shrimp (Callianassa californiensis) burrow mud and smother oysters. When present in large quantities they make oyster culture difficult. Polydora sp. a polychaete worm forms mudblisters on oyster shells.

6.4.4 Disease and Parasites

Oyster farmers all over the world have faced mysterious diseases that have taken toll of their stock. Not all the causative factors were identified. For example "opening disease" or "winter mortality" among the Australian oysters; gill disease of the Potugese oysters. Parasite fungus, Dermocytidium marinum was demonstrated to be responsible for devastating loss among Lousiana oysters. The parasite can not survive low salinity and is inactive at a temperature of 18°C or lower. Another fungus, Ostracoblabe implexa, caused outbreak of shell disease in the past in some oyster farms in France. Since it was found that cleaning of oyster beds destroy the shelter of this organism, infection by this fungus has been kept under control.

6.5 DUCK FARMING

There are many breeds of ducks in the world. For commercial purposes only a few are popular. White pekin is liked both for its meat as well as for its egg production. The white paking is hardy, does not fly, sexes are almost equal in size. It reaches a marketable weight of 3 to 3.5 kg within seven to eight weeks. Ruen and Muscovy are also popular for meat production; while Khaki Eambell and Indian Runner àre excellent egg laying breeds.

Important factors to be considered by a beginner are: 1. Breed of duck. Selection of the right breed is the key to success. Although white peking is usually selected other breeds may also be considered. Points to be kept in mind are (a). Hardiness of the breed (b) ease of handling (c) size of carcass when fressed and (d) ease of preparation for market. Feathers are an important byproduct of the commercial duck farm. Each market has its own preferred color of feather. 2. Location of the farm is also important. Ducks need a moderate climate and plenty of non-saline drinking water, preferably flowing water. Transportation will be needed for taking the product to market and bringing in supplies. The farm should therefore be located close to transportation facilities. 3. Adequate market. Prompt marketing of the product is very important. Ducks eat heavily and grow rapidly. If marketing is delayed a loss of profit occurs through increased feeding cost and if held too long, through increased weight loss of the birds. 4. Adequate feeding is the costliest item in duck farming. An inefficient feeding program may inflict excessive loss. Extreme care is taken with the feeding program to meet the best profit.

6.5.1 Facilities required

Water

From the sixth or seventh week to marketing time, a stream or pool of water where the ducks can wash themselves daily is essential. Ducks do not require a large area of water for unrestricted swimming and diving. The size of the water body depends on the number of ducks. One half acre of water surface is sufficient for 5,000 ducks. The pond area needs enough land around it, preferably with shrubs and trees to give shade to the ducks.

The whole area should be provided with at least a 6 foot high fence. Ducks do better if the stream is shallow. Ducklings supplied with water for swimming tend to do better, often being 0.5 lb heavier at 8 weeks of age than "dry land" ducklings. Water for swimming is especialy helpful during finishing time, serving to produce better skin color and helping to clean the bird. The course of the water supply is highly important. Brooks fed by springs are ideal. A dam across the stream and fitted with a flood gate helps to flush the stream occasionally to wash away all manure and filth. The washed manure is taken to a settling basin and the effluent is allowed to return to the main stream. The sludge from the settling tank is removed from time to time by appropriate methods. Narrow tidal streams with appropriate construction may provide enough freshwater. Ducks raised in brackish water may eat less, grow less rapidly and may have rough feathers. In the long Island area of the USA many duck farms are using brackish water without much problem.

Air

Plenty of fresh air must be supplied to the ducklings. This is as important as the feed and water. For growth, full utilization of digested food is necessary and for which sufficient oxygen is needed. Shortage of oxygen results in less assimilation of food which causes appetite thus less growth.

Thus housing must be ventilated. Arrangements are such that there is a constant gradual entrance of fresh air and discharge of used air. The intake and exhaust flues are so balanced as to get maximum replenishment of fresh air. The intake should enter the house at a point not less than 3.5 feet above the floor.

In areas of cold weather the room is kept heated. Care is taken not to make sudden change of temperature within a room. The ducklings of first week of age need 70°F. Reduction of 5°F of temperature a week is done untill heat is discontinued.

The yards of the farm is provided with plants that give some shade where growing breeders can move around. The soil of the farm should preferably be sandy which aids in maintaining good sanitary condition.

Housing

Growing ducks need minimal space to attain economic growth, especially in those areas where during winter and early spring months ducklings must be kept confined indoors. The following space requirements must be met (Table_2). Over crowding and confinement may result in bowed legs. Some farms use wire floors where more ducklings may be kept per square yard. This has the advantage of savings in litter cleaning cost and the disadvantage of difficulty in the removal of manure and proper cleaning of the platform between hatches.

Breeder houses must be well lighted, well ventilated and supplied with plenty of dry litter. Insulation and heating is not necessary because the ducks prefer to be out of doors even during winter. For a small breeder flock, a colony house with doors closed at night and a fenced yard is enough. A dirt floor serves the purpose but needs to be covered with plenty of dry litter made of straw or wood shavings. It is important to add dry litter so that dry bedding material is available.

There are difference of opinion about the floor space

Table. 2. Floor space requirements for growing ducklings.

Age (week)	Floor space (Sq. ft.)
0 - 1	1 / 3
1 - 2	1 / 2
2 - 3	3 / 4
3 - 4	1
4 - 5	1 1/4
5 - 6	1 1/2
6 - 7	2
7 - 8	2 1/2

Table 3. Temperature requirements for ducklings (Data taken from Profitable Duck Management)

Age	Temperature under hover (°F)	Temperature of house five ft. above floor (°F)
first week	90	70
second week	85	65
third week	80	60
fourth week	75	60
fifth week	-	55
sixth week	-	50 - 55

required. It generally varies from 3-6 square feet of floor space per bird depending on the type of house and yard facility.

Breeders may lay eggs anywhere in the floor of the breeding house, however, they prefer a nest. One nest per 3-5 breeders is sufficient. A series of 12 x 16 inch nests may be made on the floor where the top and front are kept open. The bottom of the nest is the floor of the breeding house. Straw or wood shavings are placed on the floor of the nest. Fresh litte not only keeps nests clean but helps to produce clean eggs which otherwise generate a cleaning cost.

6.5.2 BROODING

Before hatching begins the brooder is made completely ready. To make a brooder house ready to receive ducklings, is time consuming, as such the work is started accordingly. If a concrete floor is used, then it is scraped to remove all manure of the previous brood. If an earthen floor is used then about 4 inch of the floor is taken out and is then replaced by clean and dry sand. The floor and walls are thoroughly disinfected. All previously used equipments, such as hoover tops, feed hopper, water troughs arethoroughly cleaned and disinfected.

During the season after each hatch is taken out and before the next one begins the above process is repeated. A brooder house must be rat proof.

After the ducklings come out of the incubators they are placed in a well ventilated box and kept for 2- 3 hours in a room of about 75° F. Brooding may be started on the littered floor or on a wire floor. Many prefer to start on wire floors for a few days before putting them on a littered floor. Brooding of ducklings on wired floors require less floor space per duckling and reduces cleaning costs. However, for a small flock a litterred floor arrangement is more often used. Keeping the room warm is very important. Temperature requirements for the growing ducklings are presented in Table-3 . Faulty temperature regulation may cause problems including mortality. Too much heat also is not desirable. The behaviour of bird is an indicator of the heat requirement. If they are noisy and crowded together, it indicates they need more heat where as if they breath quickly through mouth and raise wings frequently the indication is of excess heat. A circular guard is placed approximately 2 feet from the hoover for a day then gradually moved back each such that finally within a week the guard is removed completely. Good ventilation without chilling the bird is very important.

Sufficient food and enough fresh drinking water is a key to success. The ducklings are started on shallow pans and small feeders. An automatic feeder helps reduce labour cost and ensures adequate food supply. Hanging tube type feeders with pan of 50" circumference may be used. Two such pans are enough for a hundred birds up to two weeks old and three pans will suffice from three weeks untill market size.

Feeding Program

For the first two weeks ducklings are fed 22 to 24% duck starter ration. In the absense of duck starter ration chick starter is used. Where prepared feed are not available, the information of Table 4 may be used to prepare necessary feed. However better growth is obtained by feeding pellets.

Table 4. Duck feeding formula (taken from Snyder S. Duck and goose raising; weight of ingredients are in lb.).

Ingredients	Starter	Grower	Breeder
Ground wheat	500	600	300
Wheat shorts	200	200	200
Wheat middlings	200	200	200
Ground yellow corn	300	300	300
Pulverized oats	-	-	220
Ground barley	340	340	-
Dehydrated geen feed	60	60	220
Meat meal(50% protein)	40	50	40
Fish meal(65% protein)	50	30	80
Dried whey	40	40	60
Soybean oil meal(44% protein)	210	130	300
Ground limestone	20	20	50
Dicalcium phosphate	20	20	30
Iodized salt	10	10	20
Vitamin A supplement (10,000 I.U./gm)	0.5	0.5	0.5
Vitamin D supplement (1,500 I.C.U./gm	1	1	1
Manganese sulphate(feed grade)	0.25	0.25	0.25
Vitamin B 12 supplement(6mg/lb)	1	1	2

At two weeks of age the ducklings are changed to 18 -20% duck grower feed. The feed may be continued till marketable age. Young ducklings at 3 -4 weeks may have access to pasture. Ducks are not good foragers like geese, nevertheless green feed will reduce cost of feed. Birds reared in confinement grow somewhat more rapidly than pastured ones however the former require more feed per unit gain in weight. Growth and feed consump tion of white Pekin ducklings may be seen in Table 5.

6.5.3 Processing and Marketing

Ducks selected for killing should have empty crops. Ducks to be killed in the morning should get their last feed the night before; those to be killed in the afternoon get a light feed in the morning. Under all circumstances ducks receive plenty of drinking water. Exciting the duck before killing is avoided, because . excited duck does not bleed well when killed. Over-crowded retaintion pens many result in injuries especially scratched skins.

There exist modern mechanised processing facilities in many parts of the world. If such a facility exists in the place of intended farming then processing is done easily. If not then the owner of a small flock may proceed by the following process.

Ducks are killed by placing them in proper sized funnels. They are then killed by cutting the throat at the base of the beak and severing the jugular vein and carotid artery. Rack and wheel methods are also practiced for killing. After cutting the throat, care is taken so that the duck bleeds properly If a clot is formed at the throat it is removed and the head is

Table 5. Feed cosumption and feed conversion ratios of white peakin ducks from 1st week to marke table size.

Age (week)	live weight (lb)	feed consumption weekly	cumulative	feed/lb of weight gain (lb)
1	0.6	0.5	0.5	0.8
2	1.7	1.6	2.1	1.3
3	3.0	2.6	4.7	1.6
4	4.0	2.6	7.2	1.8
5	5.1	3.3	10.5	2.1
6	6.2	3.6	14.1	2.2
7	7.0	3.9	18.0	3.0
8	7.5	3.4	21.3	2.8

rinsed in water. If blood spots get on the skin or feather they are hard to get rid off.

Ducks can be picked dry or scalded. The former results in an attractive carcass but is slow and laborious; in addition there exist the danger of tearing the skin. Scalding is preferred, which may be done mechanically or by hand. For scalding the bird is dipped in hot water at 140 ± 2° F. The duration of the dip varies from 1.5 to 3 minutes depending on the age of the bird, density of feather and temperature of water. The lower the temperature the longer is the time of scalding.

Hand scalding is done by grasping the bird by the bill in one hand and by the legs on the other and submerging the remainder of the body in the scalding water, breast first. The bird is then pulled back and forth in the water against the lay of the feather so that the water penetrates up to the skin which help loosen the feather. Sparser feathered areas needs less scalding while heavier feathered areas like the breast needs more.

After scalding the birds may be picked by hand or on a conventional rubber-fingered picking machine or on a snipper type picker. Pins and downs are removed by using a blunt knife. It is a common practice to remove the pins and downs by wax treatment. There is special wax for this purpose. Two tanks of wax are used side by side one at 170° F and the other at 150°F. Both waxes are melted on a wax batch and the temperature is controlled thermostaticaly. Wax is flameable. Care is taken not to use an open flame for melting it. The bird is dipped in the hotter one first and then in the colder one. This way a thick coating of wax will be obtained. The bird is then dipped in cold water for hardening. The harnened wax is then removed by hand. The process removes the remaining feather. After cleaning the carcass is hung, eviscerated and washed. At this point health inspection may take place. After which operation the heat of the animal body is removed by chilling the carcass in ice plus water or in cold running water. Next the carcass is drained and then vacoum packed and frozen. Ducks may be sold fresh unfrozen. In a big farm the whole operation from after killing to packing can be done by automated systems.

The floor of the killing, plucking and dressing house is made of concrete and the walls are smooth and made of materials that can be washed easily. After the day's job, equipment is disinfected with hot water at 180°F or with steam. The room is thoroughly washed and disinfected. The scalding tanks and the wax tanks cleaned and all organic materials removed. All doors and windows are well screened. Each day these screens are sprayed with fly killing spray. It is also important that clean rest rooms be provided for the pickers and dressers. Cleanliness of the operation system is very important.

Feathers are a good by product. Under good conditions every five birds will produce 1 lb of feathers. Feathers may pay for the cost of picking. In many places there are feather processing plants, advantage of these may be taken when present, if not the farmer himself may be able to process and market feathers.

6.5.4 EGG PRODUCTION

Careful selection of breeders will improve the flock and the productivity of the farm. Breeders ducks should be vigorous and well built. A good breeder has a healthy look, strong head, strong well separated legs, and is wide between the pubic bones. The body is well proportioned and with a uniform width between the ribs. The abdomen of a good and persistant breeder is full and deep. Vigourous persistant breeders can be used in the second year as well.

Breeders are selected from a flock when the birds are 6 -7 weeks of age. At the primary selection, development of body frame, fleshing and body deformities are checked. It is good practice to select 20 - 30% more than required at the primary selection. From the time the birds are selected for breeding, untill the final selection is made all care must be taken for the proper development of the birds as they are conditioned for egg production. A second selection is done at 9 weeks of age at which time fleshing and body type is checked. In the breeder flock one drake to every 5- 6 ducks is enough because ducks are polygamous and drakes mate with practically any female. Excess numbers of drakes in the flock may cause injuries to ducks through excessive treading. Injured ducks are removed at once kept separate from the flock till fully recovered and then brought back to the flock. Final selection is made approximatelly two months before the begining of production. At this stage the bird should have a strong rugged head, must be active, must not be over fat and must be able to move well. Some farms practice the separation of drakes from ducks at an age 4.5 months and keep them separated untill the ducks are ready for breeding. Ducks start laying at an age of 6- 7 months.

After selecting, breeders are fed a holding or breeder development diet. During this period only 80% of the normal consumption is provided on an unrestricted basis to avoid accumulation of fat in breeders. Feed is given in a large enough feeder so that all birds in a flock get a chance to eat at a time. The amount of feed given depends on the type of feed; 0.5 lb of all mash and 0.25 lb of whole grain per bird per day is given to the selected breeds. The all-mash food may be replaced by 0.25 lb of mash-grain diet. The feed is sprinkled with insoluble hen size grit. The amount of feed of course depend on weather, temperature and availability of pasture.

Approximately four weeks before hatching time the holding diet is replaced by breeder or hatching diet. A hatching diet can be 50: 50 mixture of all-mash : grain feed. Coarsely ground limestone or oyster shell is given on a free-choice basis during the breeding season.

Like the holding period, the feed of the breeders is also restricted, however, enough feed space is provided so that all birds can eat a time.

A continuous supply of clean fresh water, preferably flowing water, must be available at all time. The place where feed is supplied must also have drinking water facility. But water is kept at a distance from the feed to give birds opportunity to exercise.

Layers are allowed to go out doors during the day time. Swimming is not absolutely necessary, however, it provides exercise and keeps the body and plumage clean.

Ducks like chickens turkey and geese, are easily stimulated by light, to egg production. Young birds of laying age are brought to production, by exposure to bright light for fourteen hours during short day light hour seasons. Once they come to production, the period of bright light exposure is reduced slowly to dim light. This practice helps to maintain the egg production for a longer period. For a flock of 175 breeders with 4 x 2ft of floor space each, a 10- 15 watt lamp gives enough of dim light, a 25- 40 watt lamp is sufficient for medium light and 60 watt lamp provides enough bright light. The bulb is so housed as to give uniform lighting all over the floor with a minimun of shadows. If the flock start laying eggs at a time or age not desired by the farmer then the egg production can be stopped by moving the birds to different quarters. Or if light was used for egg production then by using dim light egg production can be stopped. Under no circumstances should birds be starved nor light cut off completely.

Ducks, like Indian Runner or Khaki Campbells are steady layers; yearly average of 250-300 eggs per flock is common. Pekins give an average of 120 or better. Muscovys are not good layers.

Ducks lay most of their eggs early in the morning although some may lay late in the afternoon and early evening. Thus gathering eggs twice, once before dusk or early in the evening and then between 9- 10 AM is adequate. Persons attending the birds for feeding and egg gathering should, at all times, avoid exciting the breeders. During severe weather conditions the birds are kept confined within the house until the morning eggs are collected.

Dirty eggs are cleaned by first soaking them in water over a sink with open drain. This soften the dirt. Then using or steelwool soaked in detergent the eggs are cleaned and then briefly rinsed in water at 110- 120°F. Eggs soaked for prolonged time in hot or cold water result in excessive spoilage. Eggs are then allowed to drip dry. Thoroughly dry eggs are placed in egg cases. Empty egg cases to be used for storage of eggs are kept in the egg storage room sufficiently ahead of time to have them cooled to the room temperature.

Clean and dry eggs are stored in a cool and humid place. Temperature is maintained between 50- 60°F and at relative humidity of 65-75. Eggs are stored with their small face down. Daily turning of egg increases the chance of hatching. Best hatching is obtained by using eggs of 6 day or less of age. The hatchability decreases rapidly after sixth day of storage; however eggs properly stored for as long as fifteen days gives fair results.

Sexing

In adults differentiating the sexes is not difficult. The males are usualy larger than females. The voice is also different, in male it is soft, throaty, where as in females it is loud and distinct. The middle and main tail feathers are curled forward in drakes but not in ducks. In colored breeds males are more brillently colored than females.

To distinguish the sexes through the above characters in young stage is rather difficult. For breeding purpose sexing at an early stage is desirable. The vent sexing of a day old bird is easily done by identifying male or female organs. Sexing is done in a warm room with abundant light so that the small penis of the male can be seen easily.

Handling and Holding

Many a times it is necessary to hold and examine a bird. If holding is not done properly painful blows to the handler and or injuries to the bird may result. The individual bird is grasped firmly around the neck close to the body by one hand without chocking the bird. Then the other hand is slid under the breast and abdomen in such a way that the weight of the bird is totaly supported on the forearm. Catching water fowl by the leg is to be avoided because it easily results in lamenes or disjointed legs.

6.5.5 INCUBATION

The process of incubation is rather complicated because various makes and types of incubators exist as well as variation in individual room conditions and the experience of the hatchery personal. Although commercial incubators are preferred and efficient, natural incubators can be used in small flocks.

An average size chicken hen may cover nine to eleven eggs. The muscovy duck is an excellent setter while other breeds are difficult to use as setters. Ducks can cover 10 to 13 eggs. The nest may be made on the ground with some protection using clean dry nesting materials. Best results are obtained by turning the eggs at least twice daily, four turnings are even better. Eggs are sprinkled or sprayed with warm water daily. Brooding birds should have access to adequate good feed(mash or pellets, oyster shells) and plenty of fresh, clean drinking water.

The incubation period of most domesticated ducks including pekin is 28 days; that of muscovy is 35 days.

For artificial incubation a good incubator, a well ventilated room and enough caring time are prerequisite to satisfactory results. If large mechanically turning incubators are used, satisfactory results are obtained between 99.25 and 99.5°F. The wet bulb setting should be between 86- 88°F during incubation and 92°F during hatching.

In small still incubators the temperature setting is 100.5, 101.5, 102.5 and 103°F respectively during the first, second, third and fourth weeks of incubation. All temperature measurements are taken immediately above the egg surface.

In incubators, eggs are placed at an horizontal position. Eggs are turned two to four times a day. Duck eggs during incubation require a more humid atmosphere than chicken eggs. To increase humidity, duck eggs are sprinkled or sprayed with warm water twice a week till the 25th day, then sprinkling is stopped till pipping time. During pipping time the eggs are sprinkled two or three times daily. A water pan covering the entire floor of the incubator during the hatching period definitely helps. After hatching and after they are dry the ducklings are removed immediately. Too much water during incubation is harmful and increases the number of rotten eggs.

Rotten, infertile or cracked eggs are removed as soon as they are detected. If allowed to stay in the incubator, rotten eggs may explode. After removal each egg may be tested in front of a lighted candle. On candling infertile eggs will appear clear; dead germ cells will appear as a spot stuck to shell membrane and often a dark blood ring is also observed. On the other hand a fertile egg with living embryo will show a dark spot with blood vessels radiating from the area.

Hatchery Sanitation

Incubators are ideal place for multiplication of microorganisms. Good sanitary practices therefore are a must for the successful operation. Before starting a new hatching season the incubator room should be throughly cleaned and disinfected, including, floor, wall and ceiling. An ammonia compound does a good job. After hatch, the incubator is throughly cleaned and made free of all foreign materials. Before using the incubator for a hatch, it is fumigated with potassium permanganate and commercial formalin at the rate of 1 g and 1.5 cc respectively for each cubic foot of incubator space. During the fumigation process humidity within the incubator is kept high, ventilators closed and dry bulb readings maintained at 100°F potassium per manganate placed on an earthenware or enamel ware container located centrally on the incubator. The chosen container should have at least 5 times as much space as the quantity of permanganate used. Then formalin is poured on the permanganate and quickly the door is shut. After 20 a 30 minutes the door is opened and the incubator is cleaned with a clean cloth.

6.5.6 DISEASE

Of the poultry organisms, ducks are subject to fewer disease problem. Most problems originate from unsanitary conditions and a bad food supply. Because prevention is better than cure, extreme care is taken towards sanitation, adequate ventilation, enough nutritious feed and plenty of clean drinking water. Other wise, birds raised at a high concentration, in a confined place may end up infected and heavy mortality may result. Infection may be prevented by taking the following sanitary measures.

Between seasons. All manure from all quarters should be removed and taken away from the duck yard. Floors, walls, and ceilings scrubbed, cleaned, disinfected. If a dirt floor is used, about four inches should be scraped out and then filled in with fresh sand. Windows, screens and doors be throughly cleaned and then left open for fresh air to enter. All containers used for feeding, watering and partitioning, in other words all those that can be brought out to the sun should be taken out, cleaned thoroughly and left to sun for a few days. All yards must be scraped and cleaned and the manure be taken off the farm premises. The cleaned yard must then be spread with fresh dry sand. Fresh and dry bedding materials can be used for the floor.

During the Season. The screens, windows and doors of brooder rooms had to be painted with insecticide. All dead birds must be burned or deeply burried.

After taking all these precautions and disease nevertheless breaks out, a vetenararian should be contacted. There are some common diseases of ducks. A common disease is cholera, the same as is seen in chicken and caused by the same bacteria, *Pasteurella multocida*. Ducks of all ages are susceptible to it. The disease is spread by infected and recently recovered ducks, by wild birds, by persons, by animals and by utensils which have been used in premises of infected birds. Infected birds move only when disturbed, have watery eyes, slimy nostrils and the droppings are watery or greenish or yellow in color. The treatment is Sodium sulfamethazine mixed in drinking water at a concentration of 0.80% for 1 to 5 days. Also mixing sulfaquinoxaline in feed at the rate of 1 lb/ton of feed for a day and a half and then again after four days for a day.

EXERCISES:

1. Post larvae and juveniles of shrimp and fish larvae are found near the shore during certain time of the year. These can be cultured in a lagoon or in a shallow pond built near the shore of brackish or estuary waters. There is a regular exchange of water during the high tides through entrance channels. This regular exchange of water will provide sufficient food and thereby no artificial food will be needed. By opening the gates of ponds, fish and shrimp larvae are allowed to enter the pond; or additional larvae can easily be collected nearby with beach seine. Shrimp can reach to commercial size in 80-90 days. Find out an appropriate site to built 3 ponds and practice such a culture. Initiate a monoculture of shrimp and mullet in separate pond and a polyculture of shrimp and mullet in another pond. Calculate the productivity of each pond per acre area and find out the difference between the mono- and polycultures.

2. Define: Intensive culture, extensive culture and polycultures. What are the different factors one should take into consideration before beginning an intensive culture?

3. What are the chemical fertilizer generally used for pond fertilization? What are the proportion used and how one decide the proportion? When fertilizer is required to use in a pond? What is food conversion ratio?

4. How you measure O_2 consumption in a pond by visibility? Why it is done? (The visibility can be studied by

Secchi disc. It consists of a white disc made of a piece of wood or plastic(painted white) of about 20cm in diameter. The visibility can be estimated very simply by lowering the weighted disc into the water on the end of a graduated string. The disc is lowered until it can no longer be seen; the depth of disappearance is recorded as secchi disc reading. It is repeated several times to take a mean value).

5.Both the new born brine shrimp nauplii and the adults are excellent fish food.The nauplii are especially valuable for raising juveniles fish and shrimp.Nauplii are raised in the laboratory from brine shrimp eggs,which are available in the commercial shops or can be collected from a salt marsh or lake.Brine shrimp live in salt water and they die within 2 to 3 hours in freshwater. Brine shrimp eggs are palce in a salt solution or in natural seawater in a container(glass jar). The water must be agitated. At 24°C most eggs will hatch within 48 hours.The pink larvae will stay on the bottom and the empty egg shells will float. The brine shrimp are collected in a fine-meshed net.This is good food for shrimp or fish larvae. Try to set up a series of hatching jars initially to practice and refine your methods.

7: ECONOMIC EXPLOITATION

The greatest importance of the seas lies in the possibility that its inhabitants can supply part, if not all, important proteins to the ever incréasing population of the globe. There is hardly a sea animal that cannot be eaten after proper preparation; yet we utilize only a small number of all species of animals that live in the sea. Of the 25,000, or more, existing species of fishes, we capture for food only about 200 (0.8%); of the molluscs, such as clams and oysters, and of the crustaceans, including shrimps and crabs, and of the algae and seaweeds, we use proportionally even less. All these resources can be exploited for economic porposes, but if over exploited may harm the population of any species leading to their extinction. The Antartic blue whale is a prime example.

The oceans hold great promise to pròvide future generations with minerals, food, energy and enough water. We must use it appropriàtely, neither damaging the flora and fauna that live in it, nor polluting their habitat.

7.1: Food from the Sea

One of the most important resources that has remained relatively untapped is the supply of food contained in the seas. About 80 percent of the animals are to be found in the sea. About 40,000 species of molluscs, about as many crustacea, and possibly 20,000 species of marine fishes, as well as the largest animals and plants, are found in the sea. Most of marine fish are predators and hence 80% of the marine yield is in the form of carnivores. In terms of human food, the sea provides roughly 1% of our intake, the remaining is provided by land and freshwaters.

Some 30-40% of world fish catch (trash) is not consumed directly by man but used for making a variety of products. This group of fish has been made to oil, fish meal for use as agricultural fertilizer or as an animal food; and also used for preparing Fish Protein Concentrate(FPC). Swimbladder of some fish have been made to itching glass. Glue has been manufactured from fish skins and waste material. Leather has been obtained from seal fur and walrus hide and also from some kind of sharks. Crustaceans (lobsters, crabs, and shrimps) are widely valued as food products. The United States of America, Japan, and some European countries provide markets for frozen shrimps. Seaweed or kelp are utilized as food mostly in oriental countries, but now available in natural food stores in American cities. The utilities of seaweed are described in section 7.2.

Fishing in salt waters ranges from traditional operation involving one man and a row boat to a huge private or guvernamental enterprises with large fleets for deep-sea and distant fisheries. Inshore and coastal fisheries are separated from sea fisheries or trawl fisheries by the frontier limits, three miles in most countries. This area is reserved for fishing vessels with small gear; trawling is forbidden in this limit.

The most important sea fish are the herring like fishes such as anchovies, herring, and pilchard. In second place are the representatives of the cod family. The third group include fishes such as the horse mackerel and the mackerel. According to the statistics of the Food and Agricultural Organization (FAO), roughly 90 % of fish are caught in the sea.

In the decades between 1950 and 1980 the world population increased an average of 2 percent annually of the previous year– from 2.5 billion in 1950 to 4.5 billion in 1980. During the first two decades the fish catch was expanding at an annual rate of 6%, but during 1970 and 1980, world catch some what stablized at 70 million tons with a slight fluctuation on either way (Fig12). It has been found that natural fluctuations in fish stocks or catch caused by climatic changes are not allways predictable. Generally, short live fish and pelagic fish are specially affected. It has also been observed that over-fishing can damage stocks, if it takes large catches when the fish stocks are low. Over-fishing may occur by making too great an effort to catch too many of the organisms, causing future catches to decline. One can avoid over-fishing by correlating fishing effort with the catch, to obtain maximum sustainable yield of the organisms concerned (Fig13). It is required certain regulations (mesh size, minimum fish size, etc) to maintain a sustainable yield. It is necessary to provide basic information on population size, recruitment rates of youngs, migrating patterns and other essential biological factors to implement an efective regulation.

What is the potential of the world harvest of marine

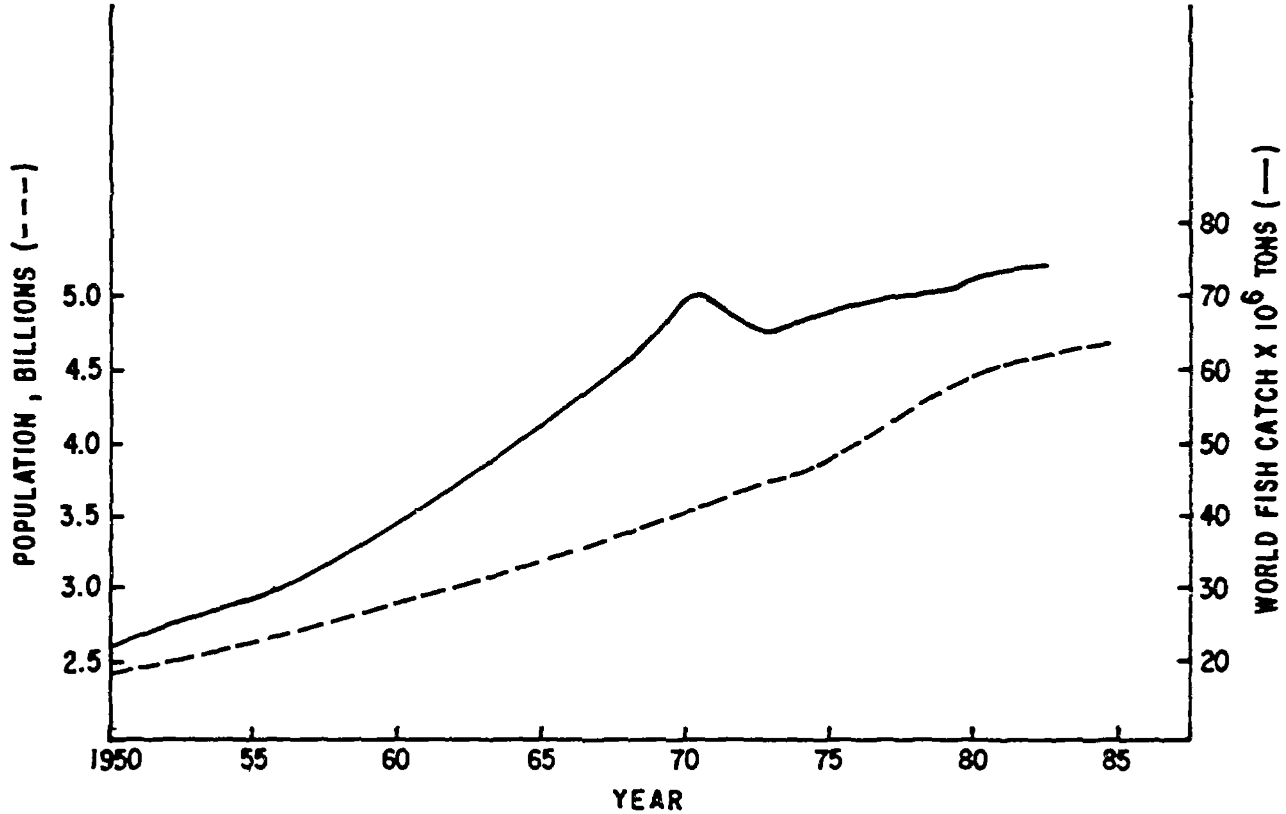


Fig 12 Growth of human population and of world total fish catch. (Data from FAO).

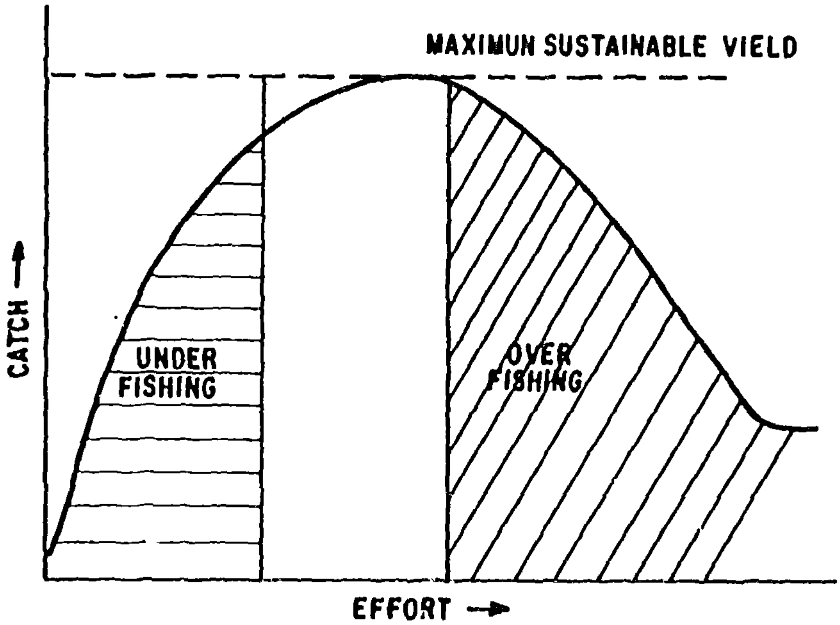


Fig 13 The relationship between the fishing effort and the sustainable catch of fish.

organisms? Many scientists have attemted to estimate the oceans maximum sustainable yield of fish and other edible organisms, based on extrapolation of past and present catch results, and/or on marine productions at trophic level. The magnitudes of estimates vary between 61 million to 4 billion tons per year. A some what liberal estimate of the maximum future sustainable harvest from sea is between 150 and 200 million tons annually.

7.2: Seaweeds and their Importance

Seaweeds belong to the group of plants known as Algae, containing some of the most primitive members of the plant kindom. The algae differ from the higher plants in that they do not possess true roots, stems or leaves. However, some of the larger species, possess attachment organs or holdfasts, that have the appereance of roots, and there may also be a stem-like portion called stripe, which flattens out into a broad leaf-like portion or lamina. The smaller species are mainly filamentous.

The algae are divided into four principal groups: the green algae or Chlorophyceae, the brown algae or Phaeophyceae, the red algae or Rhodophyceae, and the blue-green algae or Cyanophyceae. The green algae and the blue-green algae occur in the sea, freshwater, or land (tree trunks), and in the soil; on the other hand , brown and red algae are nearly confined to the sea. On the economic point of view, red and blue algae are most important, partly because of the nature of the material they contain and partly because they occur in sufficient quantity to possess an economic value.

Brown Algae:

Belongs to the Phaeophyta division,and are common in cold waters along continental coasts. Freshwater species are rare. The colour varies from dark brown to olive green, depending upon the proportion of brown pigments(fucoxanthin) to green pigments(chlorophyll). They also vary in form and size, from small filamentous epiphytes to complex giant kelps that range in size from 1 to more than 100 meters(Laminaria, Macrocystis,Nerocystis). Rockweed, another group of brown algae, is found attached to rocky coasts in temperate zones(Fucus, Ascophyllum) or free floating (Sargassum) Brown algae was once a major source of Iodine and Potash and is still an important source of algin, a colloidal gel used in the baking and icecream industries. It is used also as a fertilizer and eaten as vegetable(Kombu) in the orient .

Green Algae:

Belongs to the Chlorophyceae division. Most green algae occur in freshwater, usually attached to submerged rocks and wood pieces or as scum on stagnent waters; there are also terrestrial and narine species. It is a important component of plankton- free floating microscopic species that serves as food and oxygen sources for many aquatic organisms.

Red Algae:

Belongs to the division of Rhodophyta, predominantly marine. Usually attached to other plants near tropical and sub-tropical shores. The red and blue colour is the result of a masking of chlorophyll by the phycobilin pigments (r-phycocyanin and r-phycoerthrin).

Red algae retain both their colour and gelatinous nature when cooked. Industrially, Irish moss (chondrus) is used as a gelatin substitute in puddings, toothpastes, and ice creams. Agar is prepared primarly from Gracilaria and Geliclium species.

Blue-Green Algae:

Belongs to the division of Myxophyta or Cyanophyta. Blue-green algae resemble bacteria in that both lack a distinct nucleus, chromotophores, and mitochondria. Blue-green algae are widely distributed. They occur in rocks, trees, hot springs, ice, etc. Several species of Chroococcus, Oscillatoria, and other genera are important in tropical marine reef formations. Free floating (planktonic), in all types of aquatic environments, blue-green algae can occur in great quantities to colour a body of water (e.g. Red Sea). The dense concentrations of organisms, called blooms, are caused by species like Nostoc, Oscillatoria, etc.

Economic Importance

The most important water plants commercially obtained in seawater and freshwater are the algae. Seaweed is harvested in the water or collected on the sea shore. Seaweed plays an important role in many countries, not only as human food but also as a raw material for certain industries.

Great Britain, at one time used seaweeds to produce soda and Iodine industrially. The manufacture of agar, alginates and carrageenan has replaced these industries.

The planktonic algae of sea are primary, and they are the bottom level of food pyramid; without them no higher life could exist in the sea. Certain dinoflagellates and cyanophytes produce algal blooms and liberate toxins that kills animals. In addition, seaweeds are used as raw materials for the following industries:

A. Kelp industry:

The word kelp in Europe refers primarily to the burnt ashes of seaweeds, but in America, the large brown seaweeds are regularly known as kelps as well as the ash that is prepared from them. The kelps which occur in sufficient quantity are Macrocystis, Nereocystis, Alaria and Laminaria, all belonging to the Order Laminariales of brown algae. Until early in the 19th century it was an important source of potassium(derived from the stripe) and iodine(extracted from the fronds).

Macrocystis, giant kelp, are rich in minerals and produce algin, useful in various industrial processes including tyre manufacture. Algin is added to icecream before freezing to prevent crystallization and is used as a suspending and emulsifying agent.

Laminaria , a large brown seaweed(1 to 3 meter long), abundant along the Pacific coasts and the British Isles, is a source of commercial iodine and produces acetic acid when allowed to ferment.

Macrocystis, the largest known kelp, upto 65 meters long, is limited in distribution because it reproduces only at temperature below 18-20°C. It is regarded as very valuable plant as two crops are expected to harvest a year, because it has a steady regrowth. This is used for production of potash and acetone.

Nereocystis or sea otter cabbage, grow in deep water and rapid tideways, can attain length upto 40 meters. Alaria also grow in rapid tideways. Both these plants have to be harvested after sporing has taken place, otherwise there won't be any young plants to provide an abundant supply for the following seasons. They are available from California to Alaska.

B. Production of Iodine:

Iodine occurs in animals and plants, in very small amount, but very abundantly in seaweeds. France and Great Britain for long time and more recently Japan has been recovering iodine from seaweeds(brown algae). Kelp industry started in Great Britain as early as 1720 and by the middle of 19th century; the manufacture of iodine from seaweeds has died out almost completely, due to problems of collecting(high manpower cost), drying, wasting, escape in the air during burning,etc. So far as the iodine industry is concerned, Russia must today be the sole producer of iodine from seaweeds. The iodine from seaweed industry seem to have reached to an end, probably for finding the alternative source of iodine and high cost of collecting and wastage during drying.

C. Potash industry:

Brown algae, *Macrocystis*, *Nereocystis* and *Alaria* were used to produce potash. *Nereocystis* contains an average of 19.6% dry wt. of potash as compared to 0.19% dry wt. of iodine. Potash is found in higher quantity in stripe and iodine in the frond of the weeds. The seaweeds once collected, could have been used in four different forms:

i) It could be used directly in the dry state as fertilizer, ii) after burning the ash could be used for the preparation of potash and iodine, iii) the dried weeds could undergo destructive distillation in order to obtain carbon and inorganic salts, and iv) a fermentation process could be employed for the purpose of preparing acetone. Whilst the potash and iodine industries are not likely to be reinitiated, these kelps have subsequently proved valuable as a source of aliginates.Kelp tablets are used as food and cure for different diseases.

D. Agar industry:

Agar is dried amorphous, gelatin-like, non-nitrogenous extract from red algae and its composition varies with the species of algae. The principal raw sources of agar production are species of *Gelidium*, *Gracilaria*, *Pterocladia* *Acanthopeltis* and *Ahnfeltia*.

Agar manufacture originated in China, then spread to Japan and later to U S S R, U.S.A., Australia, New Zealand, Great Britain and South Africa. The uses of agar are manifold, but probably its most important use is in bactereological and fungal culture works, in which it functions as solidifying factor in growth media. Agar is also used in canning fish, transporting cooked fish, sizing fabrics, making films, finishing leather, producing high grade adhesives, cooking, manufacturing ice creams and icing, manufacturing shoe stains, etc.

E. Carrageen:

Carrageen or Irish moss is another edible algae that are found on both sides of the North Atlantic. This is prepared from *Chondrus crispus* and *Gigartina stellate*. This is mainly available in Ireland, France, U.S and Canada.

Carrageen is used commercially as the Sodium, potassium or calcium salts. Carrageen extracts are important in the stabilization of emulsions, suspensions and foams, and their uses parallel to agar. The dried plants are used for making jellies, clarifying agents for beers, wines, coffee, honey and shoe polishes. The refined extracts of Carrageen are used in preparation of tooth paste, hand lotions, ice cream stabilizers, etc. In the textile industry, it is used extensively at a concentration of about 5% as a stiffening and binding material. It is also used to stiffen snd provide a gloss printing to leather goods.

F. Algins and alginates:

Alginic acid is a major algal colloid which is first discovered in 1883, in brown seaweed. It occurs in commercially obtainable quantities in large brown weeds(e.g. *Fucus*, *Ascophyllum*, *Laminaria* and *Macrocystis*). They are collected and processed for alginates in U.S.A, Canada, France, Great Britain, Norway, Japan and Tasmania.

Seaweed is dried and milled to a fine powder to produce alginate fibers. The alginic acid in the seaweed is converted to sodium alginate, which spun wet into a coagulating bath containing dilute sulphuric acid and sodium sulfate to produce alginic acid fiber. It is non-inflamable. Calcium alginate yarn is useful in hosiery manufacture. Alginates are utilized in industries concerned with cosmetics(e.g. creams, jellies, hair spray,dyes), car polishes, paints and phamaceuticals. Alginates are used in clarification of sugar solutions and mineral waters. It is also used in dental surgery to plug cavities. The insoluble alginates are used in the preparation of films,gels, plastic and imitation leathers.

G. Algae as food:

i) Animal consumption: Fresh seaweeds like *Fucus*,*Ascophyllum*, *Laminaria* were used as food for horse, cattle, sheep and pig in the past but recent methods involved drying and grinding the seaweeds into a meal. Seaweed does not provide a balanced diet and therefore provide only 10-15% of total animal diet.

ii) Human consumption: Laver or nori as it is termed in Japan, is a product from red algae and a traditional part of japanese diet. The seaweed usually is obtained from cultivated areas. Japanese first cultivated it in 17th century in the brackish water of Tokyo bay. Now it is grown commercially in factories that use artificial water. Laver is useful in a variety of foods, including sandwiches soups and biscuits. The nutritional value of laver lies in its highprotein contents(25-30% of dry wt.), vitamins

(B and C) and mineral salts, especially iodine. It is used to bring down the incidence of goitre.
It is stable food in Hawaii, where the various edible seaweeds are known as different kinds of limu. Dulse is collected and packaged in Nova Scotia. Different species of Laminariales are used to prepare kombu in Japan. Many other smaller brown and red seaweeds are collected, dried and eaten in various ways in different countries. There is little food value in algae because human can break down complex nitrogenous and carbohydrate compounds into useful metabolites during digestion. Algae do have value as roughage and their minerals, vitamins contents provide valuable nutrients.

H. Seaweed as Fertilizer:

Wherever seaweeds occur in great quantities they are used as fertilizer nad usually are applied fresh. The rich agricultural crops typical of northwestern France are attributed directly to regular use of seaweed fertilizer. In recent years liquid extracts of brown rockweeds and oarweeds have used for growing vegetables and glasshouse crops. These extracts are valuable for their nutrients, trace elements and other growth promoting substances.

I. Minor products:

i) Mannite or Mannitol: It is a sugar alcohol which was first recorded in brown algae in 1844. It is used in pharmaceuticals, paints, leather, in the preparation of lacquers. Mannitol can also be nitrated to form nitromannite, a powerful explosive similar to nitro-glycerine.
ii) Laminarin: This is a polysaccharide sugar, the main food reserve of the Laminariales. At present there is no major use, but may some day be useful as an anticoagulant.
iii) Algae in medicine: From historical times seaweeds have been employed for medicinal purposes but there is no proof of its effect. Chinese uses certain algae as cure

for goitre. The great consumption of of seaweed by Japanese is reflected by the low incidence of low goitre in the country. Kelp pills are suggested to use as detoxicant of blood. Brown liquid extracted from Ascophyllum is useful in the treatments of sprains and rheumatism. Short pieces of stems of Laminaria are employed in surgery for widening fistulae and wound entrances. This use is based upon their large swelling capacity when moistened. A number of seaweeds have been named as useful in cases of lung diseases. Sargassum is said to be used in cases of bladder disorder and kidney diseases. Algae may come to play an important role in the development of long term life support systems that will be necessary for space exploration.

7.3: Use of marine organisms for decorative purposes

Shell:

Collection: Beach is the most popular place for collecting shells. During low tide the beach is searched for shells. Spring tide being the greatest, is the time to get the biggest reward. Dead shell and live specimens are also found after storms. All different equipments are in use for the collection of shells. There is a special aluminium stick with finger at the end, which is used frequently for collection of shells. It is handy to poke into the pile and sometimes to pick the shell. Bare finger may not be used for the possibility of getting hurt from shells or other organisms. A container is necessary to carry shells. Shells are also collected by wading along the shallow water during low tide. Use of a pair of heavy -soled sneakers is highly desirable, because shallow water contains broken glasses, metal containers, spiny sea urchins, broken mollusc shells and animals with stings. Any one of these may inflict injury if wading is done barefooted. A stick to poke and to keep balance during wading and a pair of gloves to protect teh hand is adviceable. A diver's goggle is needed to see under water. Besides digging tools, a small shovel and trowel are needed to collect specimens. On rocky shores a chisel and a hammer will be required to bring out specimens that live in the tunnels of stones. A knife is absolutely necesssary.

Molluscs, specially bivalves, generally hide themselves. One has to be extremely careful to locate them by patiently watching for the siphon; and recognise them by knowing their track and look. Bivalves often live in beds- if at least one is found, there are many around.

Molluscs are also collected by moping and skin diving. The equipment used for moping is like a mop- a metal frame with cotton fibres attached (Fig 4). When the mop is dragged over an area, molluscs get clung or entangled in the cotton fibres. Shelled molluscs on coming in contact with a foreign body quickly close their shells, in doing so, cling to the strings of the mop. Trapping is another method. Baited traps attract carnivorous molluscs. The construction of the trap should be such that it prevents the entrance of other organisms, the latter might otherwise finish the bait before the mollusc has a chance to enter in the trap. Keeping contact with comercial trapers also helps getting shells. Trawlers can also supply shells because during their normal operations molluscs are captured along with their preferred organisms. Draging is also a means of collecting shells.

Cleaning: The animal body should be removed from the shell soon after collection. If left for a longer period, the animal may die and harden inside the shell difficulting the removal of the muscle. When facilities are not available

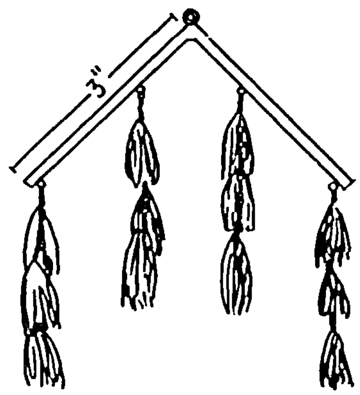


Fig 14 Starfish Mop.

for quick cleaning, animals may be kept in water, but care should be taken to change the water frequently. Dead and decomposing bodies degrade the water, which ruins the colour brightness of the shell.

Organisms are killed by boiling. They are first placed in lukewarm water and then slowly brought to boiling point. Five minutes of boiling is enough for most organisms. Larger organisms may take longer; very large specimens may take upto half an hour.

Bivalves are easy to handle. Boiling usually leaves the shell open. All that is needed is to carefully scrap the muscle without damaging the shell. After cleaning if it is desired to keep the shells closed, then an elastic band will keep them in position.

Cleaning of univalves or gastropods is the most challenging job. Boiling kills the animal allright, but, the muscle does not come out of the shell. Sometimes the operculum gets so tightly closed that it becomes difficult to open it. The cleaning must begin when the muscle is still warm; in fact, it desirable to start when the water is still hot but cool enough to work comfortably. If the body is allowed to cool after boiling, the body will "set" and then it will be even harder to take it out.

A tightly closed operculum is separated by using a thin-blade knive; a curved blade is better, Once the operculum is removed, the removal instrument is then inserted from the siphon canal as far into the flesh as possible. The instrument is twisted a little to drive the hook inside the muscle. Then, very carefully and gently the shell is unscrewed from inside. Once an end is broken it is hard to bring it out, so if the muscle does not come out easily it is reboiled and tried again.

Another way is to keep the animal wrapped in polyethene bags, in freeze. After a day or two when the animal is dead, it is thawed, then the muscle is picked little by little until all of the muscle is taken out. It is a painstaking process but works, the only disadvantage is that the left out muscle rots and smells terribly. Many workers prefer to use formaldehyde to kill the smell. A four percent formalin solution does the job very well.

Many enthusiasts use alcohol for cleaning, but the muscle shrinks. Sometimes due to shrinkage the opercolum gets inside the shell so deep that the shell cannot be cleaned. With small gastropods another method is tried very successfully, where the shells are left near anthills. Ants and flies clean the shell, but the process is very unhealthy and smelly and also time consuming.

Once the inside is cleaned, the next problem is to clean the outside. The periostracum when present is removed by carefully scrapping with knife. The remaining dirt is removed with the help of an used toothbrush and soap-water. Clorox solution is used when soap and water does not work. Many prefer soaking in weak solution of clorox for varying period of time and then washing it in water. Others prefer to dip it in strong clorox solution while carefully observing the process. It should be borne in mind that prolonged soaking in clorox may destroy the brightness of the colour of the shell.

There are reports of use of hydrochloric acid for the removal of periostracum. Shell is made up of calcium carbonate and so is the periostracum. Hydrochloric acid will act on both the shell and on the material desired to be removed. Extreme care should be taken if hydrocloric acid is used for cleaning to avoid damaging the shell. Shell must be rinsed thoroughly in water immidiately after acid treatment.

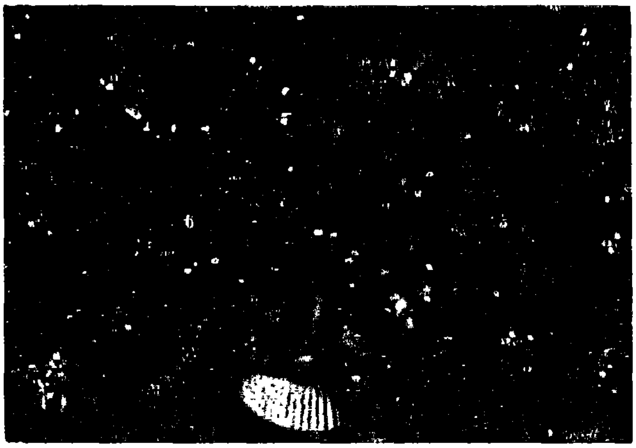
There are various practices in use to give brightness to the shell. Beach worn specimen are treated in a weak solution of hydrochloric acid which removes the deteriorated layer of shell and brings out the brightness. Cleaning the shells with a clean oily rag makes them look brighter than dry shells. Oil treatment replaces the dried up oils and brings back life to the colour of the shells. Oiled shells accumulate dust very easily and a dust cover helps. Lacquer or varnish also gives brightness.

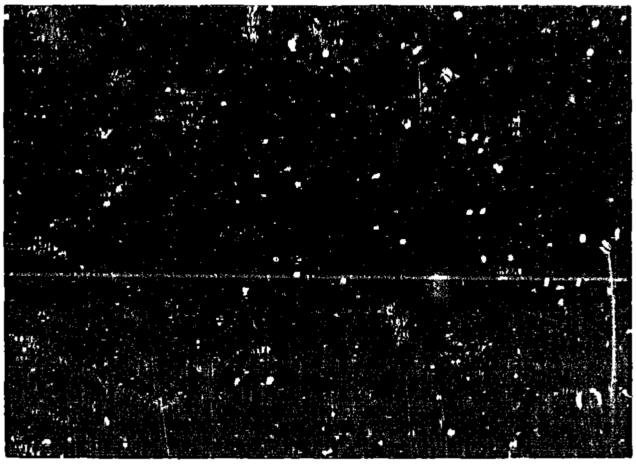
When the shell is cleaned and ready, the opening is stuffed with cotton wool. the operculum is glued to the cotton and the entire shell is wrapped in tissue paper and stored.

Shellcraft: The art of putting the shells together in an artistic manner is an old practice. Not all who practice shellcraft are celebrated professionals. There are examples of huge works of shell decorations like that of shell pavilion at Goodwood Park, Sussex, England. Some sea side cottages have outside walls encrusted with shells and some parks use shells to decorate gardens.

There are no limit of making things with shells, one can create hundreds of decorative pieces like shell animals, shell flowers, decoration of picture frames, ornaments, etc (Plate II-IV). With practice, perseverance, and effort one can establish one self in the field and make good contribution to shellcraft.

Equipments used for shellcraft are very simple and inexpensive, such as a pair of jewellery pliers, some tweezers, water colour paint brush, match stick and strong adhesive.





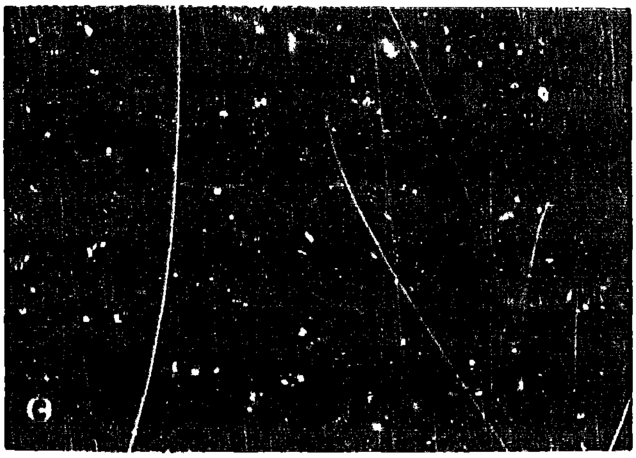
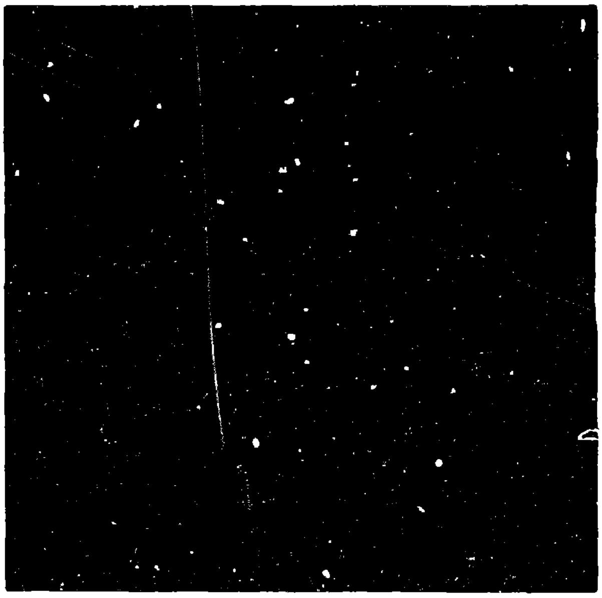


Plate II - Shell decoration
a) photostand
b) table mat made of cowries
c) necklace and earrings made out of bivalve shells



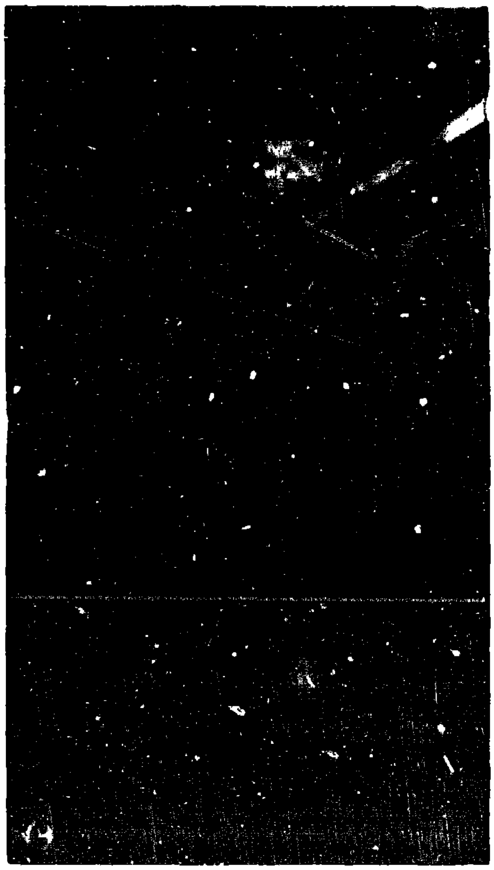


Plate III - Shell decorations
a) an owl
b) an owl
c) lamp shade

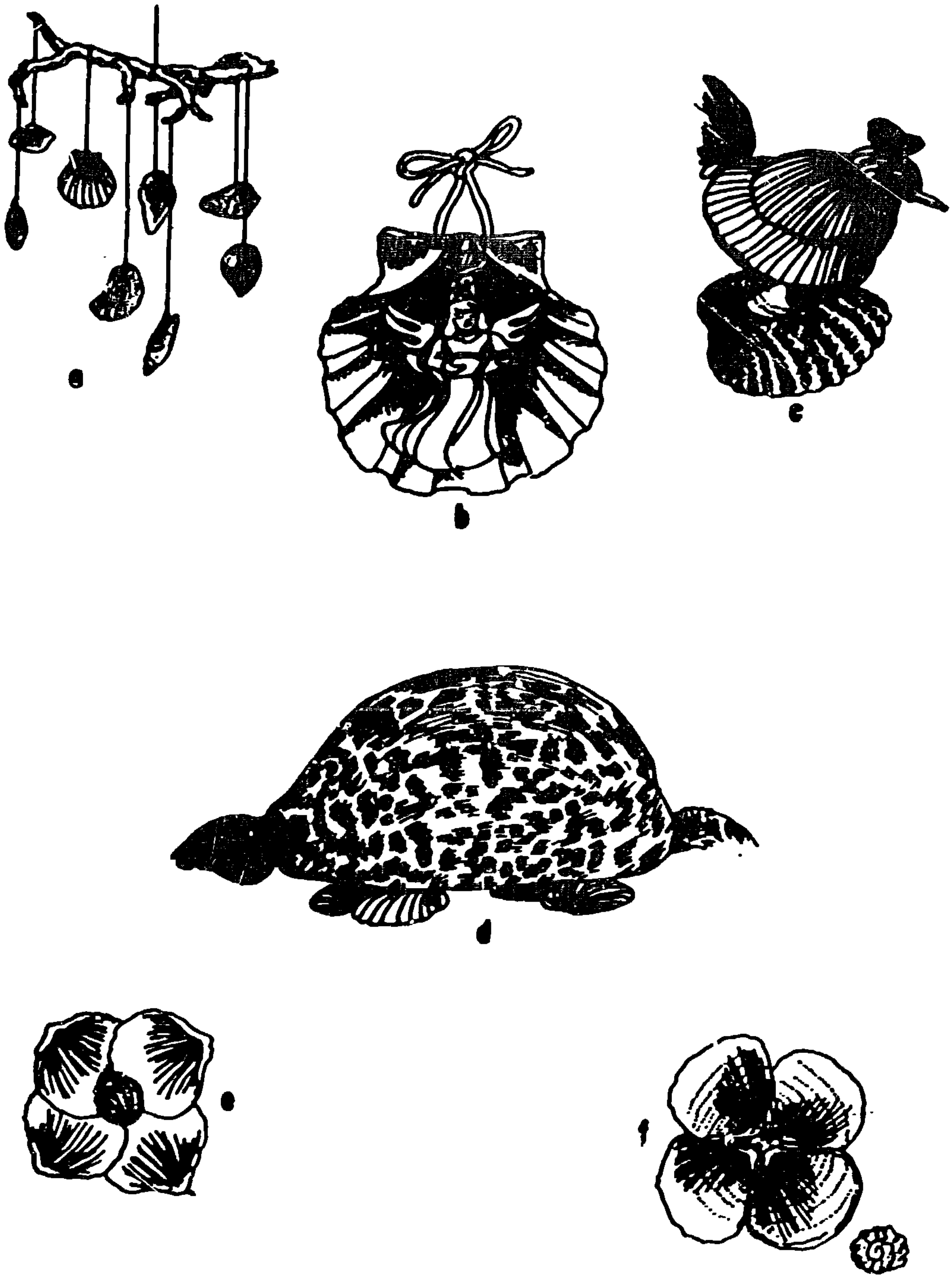


Plate IV - Shell decorations

a) Shell mobile
b) Shell angel
c) Shell bird
d) Shell turtle
e) Shell flower
f) Shell flower

The most important item is the choice of appropiate glue, commonly used adhesive are epoxy resins(half resin and half glue), sobo, elmer's formica, and Bordens. Water soluble glue is preferred because if spilled it can be cleaned with a wet cloth. A match stick is used to avoid spilling.

To glue individual small shells, a puddle of glue is made on a piece of paper, and then with the help of a tweezer the shell is drawn through it and put on place. When a large area is decorated with shells the entire area is painted with glue; the shell is then stuck directly on the glue. If the area is very large, care should be taken to paint small enough areas at a time otherwise the glue may get dried. Also, one should have a good idea of the pattern to be done so that no mistake is made in placing shells. Adhesive must be used very careflly, applying just the right amount, too much glue or too little glue will cause problems. Glueing smooth side of two shells require patience. For making jewellery, a Sharpened matchstick is used as a applicator of glue, anithing broader than that will be inaccurate.

Shells can be fixed not only to each other but also to wood, hardboard, cardboard, mounting board, plaster, metal, and glass or on any rigid surface. Corals, pebbles, driftwood, dried seaweed, seahorse and bits of glass smoothed by wave actions are used in association to shells to complete decorations.

There is no set of rules to achieve interesting arrangements of shapes and colour. Each artist has his or her own choice, on the basis of his/her imagination. Look at the shells from different angles, let the shell dictate the arrangement and let the artist's imagination take over from there. The colour combination can be kept as natural as possible. The use of man-made things to complete the design can be avoided whenever possible.

Corals:

Corals make good decorative materials. There are many different types of corals, such as, horny corals, sea pens,sea whips, sea fans, sea pansis, sea feathers and they grow in shallow to moderately deep water attached to reef or on isolated stony substrates. They are also found just below the low tide level, frequently in channels, bays and estuaries. Stony corals are dominant forms of warm seas, occupying the inter-tidal zone and extending down to considerable depths. Corals are collected by skin diving. A geology pick is helpful in dislodging corals and a chisel and a hammer are used to chip off coral pieces.

After collection the coral is placed in a container with water for 3-4 days, after which it is washed thoroughly to remove rotted tissues and debris. It is placed in a 10-20% solution of household bleach for one day or until the specimen is whitened, and rinsed thoroughly in several changes of freshwater. It is allowed to dry in a well ventilated place, avoiding constant direct sunlight.

Starfish, Sea Urchins, and the likes:

Starfish, brittle stars, serpent stars, sea urchins, and the sand dollars occupy intertidal and deep-water habitats with both rocky and sandy substrates. Specimens can be collected by wading in water during low tides or by skin diving. Starfish, brittle stars, and sea urchins remain exposed to sea bottom, and therefore are easy to collect. Sand dollars bury themselves but leave tentacle rings in the sand where they are buried. Sand dollars are usually found on sandy beaches near the freshwater sources entering the sea. In deeper waters, dredges and drags are used. Drags fitted with starfish mop are very effitient in collecting starfishes. These mops (Fig 14) are simple equipment made of a 6' heavy metal pipe with a 90 degree bend at the center where a ring is welded to receive tow rope. On the inside wall of the pipe four rings are welded at equidistance. Galvanized chain of 4' long is attached to each one of the four rings. Then with the help of split rings several mops of cotton fibre are installed on each chain. The starfish mop is operated with sufficient line so that the mop is dragged flat on the sea floor. Starfish and sea urchins are entangled on the cotton fibre, and the entangled echinoderms are removed from the mop by dipping in fresh sea-water.

Live starfish are placed on flat bottomed trays with sufficient water to cover the body. Commercial epsom salt (magnesium sulphate) is added gradually to the water every hour during the day and then allowed to stand overnight for proper narcotization , which can be tested with a drop of formalin. Fully narcotized organisms are then given the desired shape and then 10% formalin is added to preserve, as well as fix the animal. After fixation the animal is allowed to dry, which takes between two to three weeks, depending on the size of the specimen.The specimen is then mounted on desired base and painted with varnish to give lusture.

Sea urchins, sand dollars, etc,are killed by 5% formalin or 70% alcohol. Drying specimens will cause dropping of spines and the rest are removed carefully. The natural colour is usually preserved in good condition. Retouch with water colours makes a beautiful fished product(plate_V).

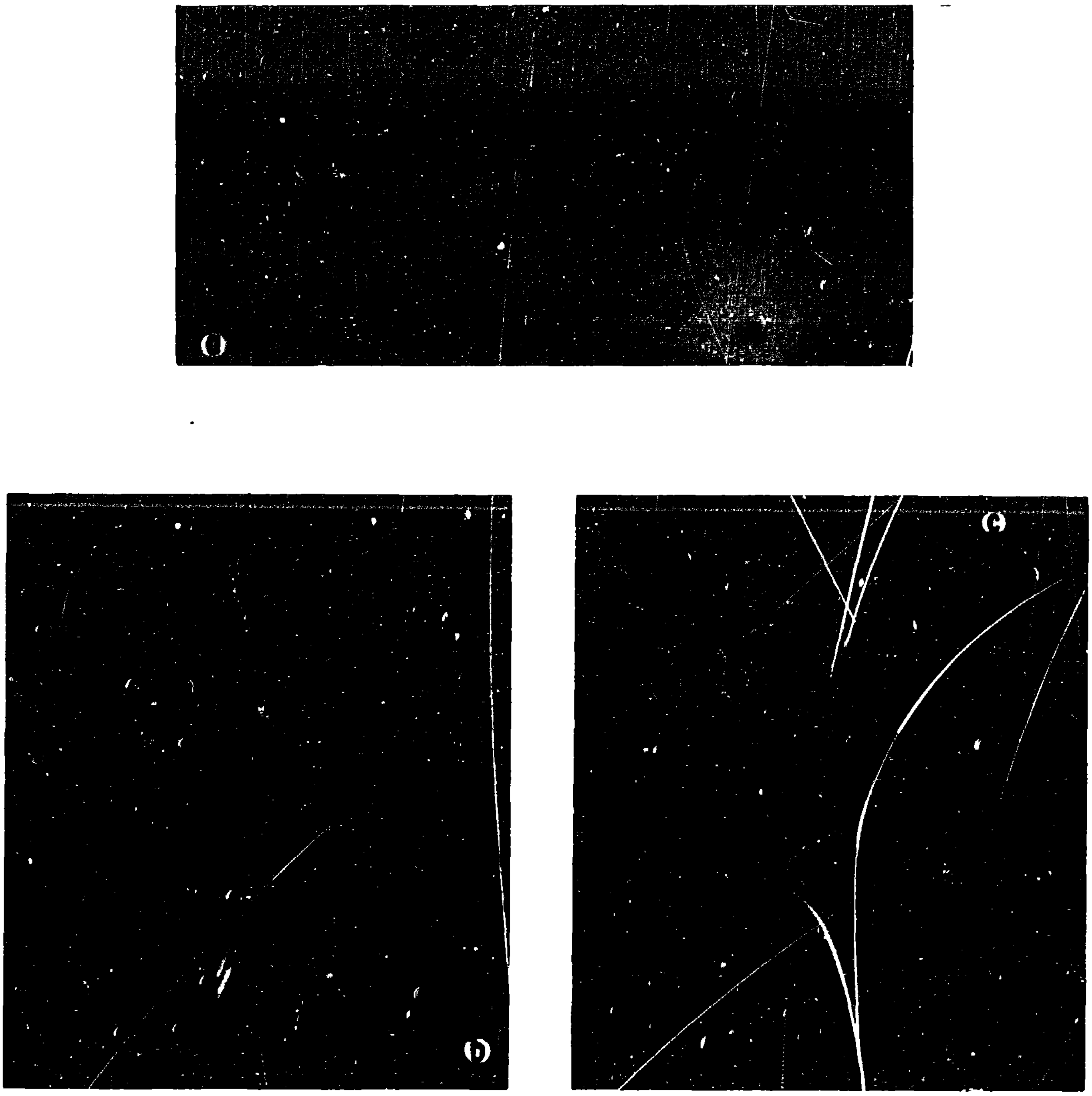


Plate V - <u>Starfish, sea urchins and sand dollar</u>

a) Sand dollar
b) A frog in a buggy made of sea urchin and other shells
c) Dried starfish

Fish:

Mounting of fish is a delicate job. There are several ways of doing it. The method described here is easy to perform and even at the first gives encouraging results. Fish with thick skin and hard scale are easy to handle. Thin fish must be handled carefully. Specimens desired to be mounted should, if possible, be colour photographed right after it comes out of the water. This will help in the exact restoration of colour in the final product.

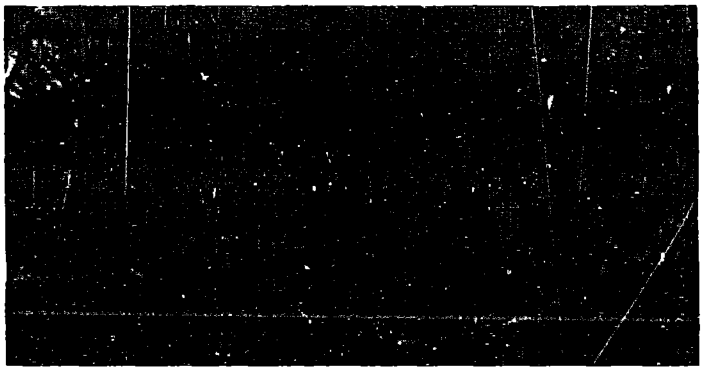
Fish body is covered with slimy mucus, which should be removed before the process for mounting begins. Mucus can be removed by washing in water and wiping out in paper towel or cheese cloth. Care should be taken to remove mucus from inside the mouth as well as from the gills. Alum water removes the mucus quickly and then the specimen is washed thoroughly in water to remove the chemical as well as the mucus.

The fish is examined and the display side is selected. The fish is placed on a thick brown paper and an outline is drawn. Measurements are noted too. The drawing and the measurements are needed to restore the body form during mounting. The fish is then laid on a cheese cloth (never on paper) with display side down. A cut is made along the side, from under the pectoral fin to the base of caudal fin(PlateVI,Fig A). Next , the skin is separated from the body with the help of a niper or scissor. Working from inside,the dorsal, pectoral, anal, ventral, and caudal are cut. The work of separating the skin from the body is continued till only the head remained attached to the skin. The vertebral column is cut where it joins the head. At this point the head renains attached to one side of the skin and the excess muscle is scrapped off from the skin.

The tongue, the eyes, the brain, and flesh from the head are taken out, for whibh some cuts are made on the head bone. Care is taken not to remove too much body material off the head.

The head and skin is soaked in saturated borax water after cleaning the excess flesh. A little salt or alum is added to the borax water if the scales show tendency to loosen or if the skin is in bad condition.

Using the outline of the fish, drawn on brown paper the form is traced on a piece of styrofoam. If the styroform is not available laminated wood 3/4" thick may be used instead. The skin is then removed from the borax water and the inside is wiped dry. Dry borax powder is liberally rubbed over the inside of the entire skin and all around the head. A little of modeling clay is applied on the inside of the skin at the base of the fins. Then the holes are filled with little straw or papier-mache. The skin is filled on the form and checked if the two sides of the incision can be brought together, then the two sides are nailed on the form starting on the center. The bottom of the mouth is packed with modeling clay, papier-mache or plaster of paris. The mouth is tied up now if it is to be closed in its final form and a wooden piece is placed inside the mouth if it is to be kept open. At this point, the skin (exposed side) is sponged lightly with clear water to remove all foreign bodies. Then each fin is erected and held in place with two pieces of waxed card-board fastened with straight pins. A series of steps are shown in the plate no. VI. The fish is allowed to dry un-distributed in a warm, dry, and airy place for upto 25 days. During the drying process the fish is checked daily and if necessary corrections are made.



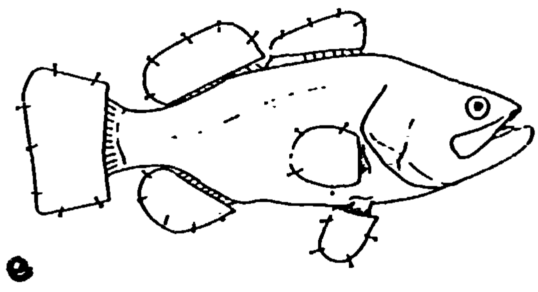


Plate VI - <u>Different steps of mounting a fish</u>

a) Making incision
b) Cutting the fins and skinning
c) Removing the skin
d) Making a shape of a fish
e) Carding fins

Fish is mounted on a mounting board when it is completely dry. Modeling clay is put on the orbit and the eye is placed into position. The colour photograph of the specimen is used to restore the colour of the final product, using fine painting brushes. When the paints are dry, the fish is varnished with a glossy varnish. At least four coats are applied at six hour intervals.

Driftwood:

Use of driftwood as a decorative material has become popular during the recent years. Driftwood implies to wood that has been worn smooth by wind, wave, and sea; and the same terminology is also used to denote any natural formation of plant that can be used for decoration. However, the former terminology will be used for the discussion.

The best place to collect driftwood is along the coast, particularly at the mouth of rivers and creeks specially after storms. After collecting, the wood is cleaned with water and soap with a hard or soft metal material, depending on the amount of dirt present on the wood. Hard brush gives roughness to the wood which is desirable at times. Following cleaning, sanding is done with fine sand paper to give a smooth finish. Unwanted parts of the wood are chopped off before brushing and sanding. Sometimes naturally clean and smooth wood are found which does not need any hard cleaning.

Sometimes bleaching is done to get the right colour. If bleaching is desired, then all softwood from every crack and crevice must be removed prior to the application of bleach; otherwise softwood will absorb the bleach, preventing it from getting down to hard surface. Old toothbrush and small stiff brush similar to bottle brush is excellent for the job. Full strenght laundry bleach gives the wood a yellow beige cast, while a saturated solution of oxalic acid crystals in water gives a pink beige tone. The wood is washed with hot water after ten minutes of the application. Rubbing with leanseed oil gives a soft lasting sheen , or may also be painted with clear plastic or varnish.

7.4: Tourism and Sea

Tourism is defined as travelling for recreation or as the industry involved in guiding and accomodating tourists. The uprush of tourism as an industry, involving enormous economic importance, came into prominance only after the second world war. In the two decades between 1950 and 1970, there was an enormous economic growth in the Western industrialized countries, and that economic growth popularized travelling, mainly in two directions— one towards Europe to know the history and culture and the other , towards the Mediterranean and the Caribbean islands in search of the warm climates. This travelling involved mainly the professional working class. The mass movements of tourist towards the coasts and the islands iniciated huge development proyects in the construction of hotels and residential buildings all along the coastline of the countries concerned. The Mediterranean, the Caribbean, Hawaii, Miami Beach, Jamaica, Barbados, Puerto Riço, the Virgin Islands, the Bahamas, Trinidad and Tobago, Curacao, Aruba,etc. all count tourism as one of their most important industries. The Riviera and Black sea, among the most famous resort areas. Monaco provides the most luxurious tourist facilities in the world. Spanish coast and islands have attracted thousands of tourists and Portugal is also becoming very popular among the european tourists. Resort areas in the Pacific are increasing in popularity. The islands of the Caribbean, the Mediterranean, and the Pacific possess outstanding assets in its climate, its scenery, its magnificent coastline and its crystal clear water provides enjoyment to millions of tourists temporarily when they cluster on the sea coast during their vacation.

Tourism dominated the economy of the many countries concerned. It is responsible directly or indirectly for the economic growth, employment,etc of those countries. Tourism also push up the construction of resort areas, development of residential area on the coastline as well as mass promotion of air travel. People often purchased condominiums as an investment. The owner spent his vacation there and offer condominium for rent by transient at the other times, under the supervision of condominium management. This concept is growing in popularity.

Many industries have flourished around the aquatic sports, that people enjoy while they are on the coast, and at the same time created jobs in the industry and in the management of the sports.The following activities in water are practiced commonly by the tourists in the seas and at the same time beneficial to mankind:

Swimming, surf bathing and skin diving;

Boating and navigation; water skiing and other amrine sports; sport fishing and commercial fishing. The relative importance of the beneficial uses vary with season, with locality, and with the viewpoint of the user.

Tourism, on the one hand benefitted the people and the country,but on the other hand, has brought social disequilibrium in many countries. This activity has negative impact on the nearshore environment, which is sometimes modified by human activities. In view of public uses of the beaches, a special service has been organized in many countries that must watch all the changes in the beaches and maintain them clean and free of pollution.

EXERCISES:

1. The ocean covers almost 71% of Earth's surface and produce only ±1% of the total human food supply and the rest is produced in land and freshwater. Explain.

2. The lagoons and estuaries are rich in productivity. Describe some of the ways in which man can try to increase food production through lagoons and estuaries.

3. The beaches that you visit regularly are full of different invertebrate organisms, specially varieties of shells. Could you suggest different ways that people can use those organisms for economic benefit?

4. Shorelines are inundated at the time of high tides and are exposed at the low tides. Different molluscs and polychaetes live on rocks and in the crevices. Select a study site of rocky shore, design a quadrant of one square meter and find out the following:
   a) differences in population of exposed and unexposed rocks,
   b) number of population per square meter, and
   c) estimate the total population of each species in the study area.

5. Tourism brings foreign currencies to the country and also create jobs. Can you imagine a creative project for developing a resort center on the coast? You should provide all the facilities that a tourist expect and at the same time, you should take adequate measures not to deteriorate the environment.

8: EFFECT OF OIL POLLUTION

Oil in the marine environment has become a very common phenomena. The contamination generally results from accident during transportation and production. The busiest routes of oil transportation are usually the sites of oil spills. From the begining of the century the Baltic has experienced regular spills from transportational hazards. Actions of war destroy oil tankers, storage facilities, and oil terminals and thus spill thousands of barrels of oil on marine environment. Currently the Persian Gulf is experiencing such frequent spills.

Coastal areas are the usual sites of oil spills. It is the coastal zones that are more productive than oceanic areas. In many parts of the world the productive areas of the sea are also the sites of offshore exploration where oil spills are common. Then again there are areas of estuaries where regular oil exploration activities accompanied with spills from production sites contaminate the marine environment. The estuarine environment, specially the intertidal zone is inhabited by many forms and number of organisms and where juveniles of many oceanic species live. Oil spills in these areas cause the most damage. The effect of oil on sea will therefore depend on the area of the spill.

When the oil is spilled on the sea, many times a clean-up effort is done. A type of detergent is used to disperse the oil from the sea surface. These chemical agents are commonly called dispersants. There are many different dispersants. Toxicity of the dispersants are also different. Dispersant are more toxic than oil to a species. Even more toxic is the emulsion of oil and dispersant. More organisms are usually killed by the clean-up operation than by the oil alone. In deeper water the dispersant helps the oil to sink and thus remain in the bottom for longer period as a source of contamination.

The oil, that is the crude oil, is of different types, the aromatic compounds and the specific gravity are particularly variable. The light crude mixes more readily with sea-water than the heavier ones. Refined oil mixes even more rapidly in water. There are many different types of refined oils and their aromatic components varies. The more rapidly soluble a component, the more damage it does to the biological system. Thus the impact of oil on marine environment depends on the type and amount of oil spilled.

Tolerence to oil polution differs among organisms —. a given concentration may kill one species but will have no effect on another. Even the action varies on different life stages of the same species. In some, the juveniles are more sensitive than the adults, in others the egg and fry are more tolerant. In many cases the adults show marked seasonal variation in abundance and sensitivity to oil. The effect of oil will therefore depend on the species, its life stage and the season.

The biological effect of an oil spill depends on a large number of factors, such as the type and quantity of spilled oil, the season,prevailing hydrographic conditions (salinity, temperature, dissolved oxygen, waves, current, wind, turbulance, sun light, etc) at the spill site, clean up efforts including the type and amount of dispersant used, life cycle of the organism affected and the structure of the ecosystem (considering the ecosystem as one unit that includes the organisms and the environment). As each oil spill is rather unique, generalization is difficult. Predicting the effect of oil is even more difficult because of the complexities of the problem. It is no wonder that the world has experienced devastating damage from Tory Canyon Spill in one hand and relatively minor effect of the Santa Barbara incidence on the other.

The following generalized account of the effect of oil on marine organisms is described below:

a.- Microbes:

The effect of oil on this ecologically important bacterial group are (1) inhibition of activities of some group and/or (2) acceleration of number and activities of petroleum degrading groups.

b.- Plankton:

Phytoplankton (drifting microalgae) of the aquatic environment may be compared with the grass of a pasture land. The mayority of the energy circulated in the marine environment is fixed by the phytoplankton. They are minute microscopic organisms of different species with short life spans controlled by temperature, light and nutrients. They show rapid natural and seasonal variation in species composition, abundance and succession.

Although oil kills the dominant group at the time of a spill, within a short period of time overall population density is regained or at times increased. The increase in bloom is explained by the process of species succession i.e. when the dominant species is wiped out, some other species takes over the space.

The lethal concentration of oil varies between species and for a given species it varies between types of oil. At sublethal concentration, in some species, retardation of cell division, reduced growth rate and reduced photosynthesis have been observed. On the other hand there are observations of the stimulation of growth in natural populations of some other species caused by certain type of oil. The picture is made complicated by short life span and natural species succession of phytoplankters and the variability of tolerance to oil such that in nature a final adverse affect of oil on phytoplankton is not clearly observed. This does not necessarily mean that oil does not effect the natural phytoplankton community.

Zooplankton (drifting or weakly swimming minute animals) are the primary consumers and are the food of a variety of fish and comercially important organisms. There are many different forms and species of zooplankton . The effect of oil on all of them is not known. A few works are reported on copepods in laboratory condition where the lethal effect of oil was observed. But the lethal dose varies between species. For a given species (Acartia clausii) the young are more sensitive than the adults. The sensitivity depends on the type of oil and the duration of exposure. Oil spills may have some indirect effect on natural zooplankton population. A good size oil spill covers a wide area of sea; sometimes for several miles. A thick slick will prevent light penetration. without light there will be no photosyntesis and not enough phytoplankton to eat. Also zooplankton has a habit of making vertical migration which is light dependent. The oil slick by blocking light penetration interferes with the regular life process of zooplankton.

c.- Macroscopic Plants:

Green algae, like Enteromorpha, Chaetomorpha and Ulva seem to be slightly effected by crude oil spills. Where as the blue-green algae appears to be oil resistant and may even obtain nutrients from it. The brown algae, also seem to be slightly effected by crude oil spills. This is because, usually, their body is covered with a mucilaginous slimy substance which prevents the adhesion or penetration of crude oil. This is aided by normal growth pattern of the plants. They normally grow from their bases. The distal parts are usually lost during unfavourable environmental conditions. Thus when oil spills effects the distal ends these are discarded by the plant and normal growth from the base bring the plant back to its original condition. But refined oil (diesel) cause serious problem in Macrocystis. Bunker C oil completely eliminated Fucus spiralis from an area and at sublethal concentration the oil inhibits photosyntesis. Red algae are the most sensitive and suffer most loses.

A single spill is usually not very damaging to sea grass; the plant recovers and comes back to its original coverage. Repeated exposure to oil cause long term damage and makes recovery impossible. Among the sea grasses there are varieties that are sensitive (Saulda and Salicornia) and resistant forms (Oenanthe lachenalic). The sensitive forms are effected more easily and

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resistant forms can withstand longer. Plants usually die for being coated with oil. Low boiling fractions of oil enter the intercellular space, even in the vascular system thus interfering with normal life process of plants. Some observations show that oil actually stimulated growth of macrophytes. Among the reasons postulated for growth stimulation was the presence of growth stimulating substance in oil.

The seasonal effect of oil of salt marshes is very spectacular. Flower buds exposed to oil do not open and exposed flowers usually do not produce seeds. But oil coated seeds germinate. Cleaning operations— either detergent, burning or cutting does more damage than the oil alone. It is suggested to leave the oil polluted vegetation alone. Thus giving it more chance of survival.

d.- Intertidal Organisms:

The area of the sea effected by tide is the intertidal zone which is inhabited by a large variety and number of organisms. Some of the organisms like molluscs are economically important. However in intertidal areas the consequence of oil pollution is readily seen and thus was investigated very intensively. In general, during spill effecting intertidal areas mulluscs frequently suffer heavy mortalities. Some species like abalone are more sensitive than others.

Quahogs (*Mercenaries mercenaria*) seems to be more resistant than most molluscs. The toxicity varies not only according to species but also according to the kinds of oil and oil products.

The sessile crustaceans like barnacles of the intertidal zone frequently suffers extensive mortalities during an oil spill. Among the barnacles too, there are oil resistant species like the oceanic barnacle, Lepas fascicularis.

Echinoderms i.e. the starfishes and sea urchins are very sensitive and were virtually eliminated from the area effected by TAMPICO MARU and Gen.M.C. Meigs.

The organisms of the sublittoral zone like the lobsters, shrimps and the crabs because of their mobility can avoid the polluted zone. Yet during TAMPICO MARU incident they suffered heavy mortality. A crab, Pachygrapsus margoratus, from the Black Sea, lives in rather oil polluted waters without showing sensitivity. The juviniles of lobter and brown shrimp are more sensitive to oil pollution than the adults. A wide variety of benthic invertebrates are killed in each spill in the intertidal zone.

.e.- Fish:

Most of the pelagic fish species are good swimmers, have their body coated with a protective slimy mucous substance and have chemoreceptors on their skin. Thus during a spill they can very quickly leave the scene and avoid contaminated water. Possibly this is why there seems to be no report of large scale fish mortalities due to crude oil spills. Between 1960 and 1975 some 216 spills were produced all over the world, where only a few cases of mass fish mortality occured and that too in enclosed parts of the sea and with refined oil products and dispersants. The slimy substance that cover the body of the fish prevents the contact of crude oil with its body but dispersants destroy the protective cover, whereupon the fish become susceptible to oil.

Pelagic fish are very sensitive to refined oil. Massive fish kill have been reported from the R.C. STONER accident which spiled high octane aviation gasoline, diesel oil, Bunker-C oil, a Florida spill of no. 2 fuel and many others.

The sublethal effects of oil on fish is long-lasting and effects their feeding, migration, equilibrum and reproduction.

Vasts amounts of spilled crude oil tend to float on the surface of the water. The eggs and larvae of a wide variety of commercially important fish either float or live in the surface of the water column as well.

Wave action and/or dispersant cause the oil to come in contact with subsurface organisms. Thus an oil spill claims heavy mortality on fish larvae and developing eggs. Laboratory experiments showed that those fertilized eggs which survived exposure to oil contaminat produce abnormal or weak larvae. The intensity of the effect depends on the kind of crude as well on the species concerned. The older fry are thought to be more susceptible to oil than the younger ones and that the older one can detect and avoid oil. It is important to note that like adults, the juviniles too show different sensitivity to different types of oil or oil products. And that juviniles of some species are more resistant than others. Those that regularly come in contact with oil pollution are relatively more resistant than those that are not.

f.- Birds:

Birds are the most effected organisms during oil spills. The birds live on the surface of the water where during spilt oil also floats. Some of the birds spend most of their life in sea. There are birds that dive in water in search of food. Thus the birds are severely effected by the floating and sinking oil. Birds may even injest the oil during the food search process, which enhances the action of oil. The effected birds are easily seen on the surface of water or on the beach, the observation of the number of organisms effected in most cases are accurate. There are innumberable accounts of bird kills associated with oil spills. Yearly mortality of birds caused by oil spills in the North Sea and north Atlantic has been estimated to be 150,000 to 450,000.

However there are birds, for example the auks, the diving sea duck, murres, and Guillemots which are usually effected more severely than other birds. Because of their ecology these birds suffer most. Birds in this group live most of their live in water, dive to get food and are poor reproducers. They are attracted by the slic on the water. Once they are in the water, oil covers part of the body, when they dive to catch food, the oil is then all over its body. The oil enters the stomach as they feed. Thus they are killed either by the oil in their gut or because of inmobility caused by the oil. The remaining population, because of their poor reproductive power, cannot bring the population back to its normal level. The damage is so severe that certain species and subspecies are threteneded with extinction.

Birds, on coming in contact with oil, loose the water -

proofing system of their feather resulting in loss of buoyancy. It cannot fly because of wet and sticky feathers; neither can it float because of the loss of buoyancy, nor can it keep its body warm because of the loss of water proofing of its feather. The result is death due to cold and drowing. Laboraory experiments have shown that birds fed oil developed disorder of the liver, pancreas, spleen, and kidney. Ingestion of oil disrupts intestinal absorptive mechanisms for example the function of the two nasal glands. Thus oil interferes with the internal and external life processes of birds.

g.- Mammals:

Unlike the birds marine mammals live in water and when dead seldom drift ashore, such reported incidents are few. Like the birds the mammals are effected by loss of water proofing and insulation proporties when exposed to oil. The effected animal suffer from restricted mobility and are thus unable to feed themselves or protect themselves from predators. On occasion the number of deaths caused by oil was of such order that the severity of the oil spill on mammal life was questioned. Yet there are reports of mammals killed by oil spills like the Santa Barbara incident, when large numbers of sea-lion pups, 5 grey whales and several porpoises were killed. During the ARROW spill several harbour seals and some grey seals were killed and many oiled ones were observed. Usually following a spill,the number of mammals operating in the area decreases. All these are indications that sea mammals are effected by oil spills, but more studies and observations are needed.

h.- Fisheries:

The term fisheries includes all aquatic organisms, from algae to whales of commercial importance. The instanteneous effect of oil on various organisms has already been discussed. The fishery may be effected indirectly by interference with the food organisms, with the eggs and larvae and through interaction of several factors each or some effected by oil.

Turtles are exploited in tropical and subtropical regions of the world. They spawn in the beach which, when oiled will interfere with the future maintainance of the population.

The bivalves like oysters, clams are benthic sessile organisms, which when coated with oil, usually die. The bivalve are filter feeders; they filter their food. Innocently filter certain size particles. When the right size oil particle come in, it is filtered too and taken inside the body, and when of sufficient concentration will kill the organism. When they are not killed the muscle become tainted with oil and thus becomes unfit for human consuption. When the spill occurs in a bivalve infested area many usually die and the remaining are declared unfit for human consumtion.

The shrimps and lobstors are good swimmers. They may avoid the polluted area but are also effected by an oil spill. Long term effects on these types of fisheries is not known.

A variety of edible aquatic birds are commercially exploited on a moderate scale in various parts of the world. These birds have suffered from oil pollution.

The effect of the petroleum industry on fisheries may be looked at from the following two viewpoints: (1) the effect of the instalations and structures related to petroleum industry and (2) the effect of crude oil and its dispersants.

It is known that the instalations of the petroleum industry have increased the sport fishing activities in the Gulf of Mexico. Work done in California demonstrated that more fish aggregate under the platform of offshore petroleum rigs than near by open areas. In Galveston Bay, Texas, 87% of the boat-fishing activities are done at or around the petroleum platforms. From this observation the Sport Fishing Association has requested that inactive offshore oil rigs be made available to fishing activities. Petroleum related instalations therefore may serve as artificial habitat for the fish and thus help increase production.

In the coastal waters of the petroleum producing countries good fisheries exist in Venezuela, Gulf of Mexico, North Sea, Caspian Sea, Persian Gulf, and Indonesia. Good fisheries also exist in the Baltic, which although is not a petroleum producer, yet from the begining of the century was the scene of frequent oil spill from oil transportational hazards. Long term effect of petroleum on fish production may be infered from the fisheries characteristics of the above mentioned areas where reliable data exist. In spite of the presence of 11,500 oil wells, the fish production of the Gulf of Mexico has increased since 1939, although species diversity has changed. On the coast of Louisiana, USA, there are approximately 2,500 producing oil wells, and where the petroleum related activities are in effect for over 45 years. In spite of receiving 1.1 million barrels of petroleum over a period of 30 years, the fish production in Louisiana coast is still high. The total catch in the Baltic and in the North Sea, has increased, between 1920-1972. The Caspian Sea has received large quantities of oil from oil wells and refineries. During the same period, the Caspian Sea has experienced a lowering of sea level, and has received less fresh water because of change in the flow of the River Volga. During the last 35 years fish production in the Caspian Sea has decreased which could very well be due to less inflow of freshwater. Lake Maracaibo, Venezuela, although called a lake is part of the sea. Lake Maracaibo is one of the most oil polluted water of the world; the fish production is about the same as before. From the above it may be concluded that the petroleum production activities alone, does little effect on the fish production.

EXERCISES:

1. What are the different categories of contamination in the sea? How an oil spillage can affect the different marine organisms? Discuss the ecological consequences of an oil tanker explosion in the sea.

2. LD_{50} is described as the lethal dose which produce 50% mortality of the organism in concern. Set up an experiment to find out LD_{50} of kerosene, gasoline and any crude oil on the larvae, juveniles and adult mullets.

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GLOSSARY

Acclimatization: habituation of an organism to an environment under human management.

Advective circulation: commonly known as wind-driven circulation in the upper few hundred meters of the ocean; it is primarly a horizontal circulation.

Agar: a medium for bacterial and other cultures, prepared from a gelatinous substance, yielded by red algae.

Algae: a major division of the plant kindom, embracing seaweeds and allied forms.

Algin: a complex organic substance found in brown algae.

Anadromous: an animal (such as a salmon) which spends much of its time at sea, then returns to a freshwater stream or lake to spawn.

Anions: a negatively charged ion.

Aphotic zone: the portion of the ocean where the absence of sun light prohibits plant growth.

Aquaculture: the art of breeding and cultivating aquatic organisms.

Aquafarm: a piece of water used for breeding and cultivating aquatic organisms.

Atoll: a ring-shaped chain of coral reefs from which a few low islands project above the sea surface.

Autotrophic: an organism (such as a photosynthetic plant) capable of manufacturing its own food from inorganic raw materials and energy.

Barnacles: any of numerous shellfish that, in the adult stage, adhere to rocks and sea bottoms.

Bathymetric: vertical distribution of organisms in space.

Baumé°: a scale designating an oil's specific gravity.

Benthic: pertaining to the sea bottom and the organisms that inhabitat the bottom.

Bivalve: an animals having a shell in two valves or parts. (like an oyster)

Brackish: a water that has a salinity between 0.5 and 30 parts per thousand.

Brine: water with a particularly high concentration of salt.

Brine shrimp: common name for the members of the genus Artemia. They live in very salty water.

Buoyancy: capacity for floating lightly on water or air.

Carnivore: an animal which preys on other animals.

Carrageen: an edible seaweed also known as Irish Moss.

Cations: positively charged ions.

Chlorinity: a value that expresses the concentration of chlorine in water.

Chlorophyll: the green pigments of plants and bacteria which is necessary for photosynthesis.

Ciguatera: a toxin found in some tropical fish that is thought to be produced by blue-green algae which the fish eats.

Ciliates: the common name for the Ciliata or Ciliophora.

Clams: a bivalve shellfish.

Condensation: the process of converting vapour into liquid.

Consumers: an heterotroph organism.

Continental shelf: the relatively smooth underwater extension of the edge of the continent which slopes gently seaward to a depth of about 200 m.

Continental slope: the relatively steep portion of the sea bottom between the outer edge of the continental shelf and the deep ocean basin.

Convective circulation: is a thermohaline circulation. It is referred to the movement of water that takes place when its density is changed by a change in temperature or salinity in a suitable part of its bulk.

Coral: a hard substance of various colours deposited on the bottom of the sea.

Dam: an embankment to restrain water.

Decomposers: organisms that feed on dead plants and animals, thus breaking them physically and chemically.

Dehydration: excessive loss of water from the tissues of the body.

Desalination: the process of separating salt from water.

Detritus: excrement and other waste products of all types of organisms including their remains after death.

Dike: a mound raised to prevent inundation.

Distillation: the process of evaporating and then condensing a liquid (generally water) so to purify it.

Driftwood: it refers to wood that has been worn smooth by wind, wave and sea.

Duckling: a young duck.

Ecosystem: an ecological system formed by the interaction of coacting organisms and their environment.

Egestion: the process of ridding the body of any waste material as by defaecation and excretion.

Enzymes: a protein which acts as a catalyst for chemical reactions.

Epiphyte: a plant which attaches itself to other plants or animals without parasitizing them.

Epizootic: disease affecting a large number of animals simultaneously, corresponding to epidemic in man.

Estuary: the wide lower tidal part of a river.

Eutrophic: providing rich plant nutrients in aquatic ecosystem.

Evaporation: the process turning a liquid into gas.

Eviscerate: to tear out the viscera or bowels.

Exogenous: originating outside the organism.

Exoskeleton: an external skeleton, particularly characteristic of arthropods.

Extensive culture: cultures made in a large area. Generally having low per square meter productivity.

Fauna: the animals of a region or period.

Fingerling: A young stage of salmon of finger size.

Flora: the plants of a region or period.

Food chain: sequence of organisms in which each is food of a later member of the sequence.

Frond: thallus of certain seaweeds; a leaf-like structure.

Fry: young fishes fresh from the spawn.

Fungus: a plant of one of the lowest group, without chlorophyll, and therefore living as a parasite.

Gastropods: one class of moluscs, having a muscular disk under the belly, which serves them as feet.

Goitre: morbid enlargement of the thyroid gland in the throat.

Gradient: rate of change of any quantity with distance or elevation.

Guano: the droppings from nesting colonies of sea birds.

Gular: throat; pouch of skin below beak in Pelicaniformes

Haemoglobin: the red oxygen-carrying pigment in red blood corpuscles.

Harvest: the time of gathering the product of any labour.

Hatchery: a place for artificial hatching of fish eggs.

Herbivore: an animal adapted to feed on plants.

Haterotrophs: an organism that is unable to synthesize its own food from inorganic substances and must utilize other organisms for nourishment.

Hurricane: wind of extreme violence.
Hydrography: the investigation of seas and other bodies of water, including charting, sounding, etc.
Hyperhaline: hypersaline(very high concentration of salt).
Hypertonic: a water medium with a higher concentration of ions than that of another solution separated from the first by a selectively-neremable membrane.
Inlet: a small bay.
Intensive culture: cultures made in a small area. Generally having a high per square meter productivity.
Intertidal: is the zone binded by the high and low water extremes of the tides.
Ion: an electrically charged particle.
Kelp: a group of larger brown seaweeds.
Lagoon: a shallow pond into which the sea flows.
Latitude: angular distance from the equator.
Lattice: a network of crossed wooden bars.
Leeward: the direction towards which the wind blows.
Lethal: designed to cause death.
Littoral: the strip of land along the seashore.
Locomotion: capability of making movements.
Longitude: angular distance from the Greenwich meridian.
Mangrove: genus of trees that grow in swamps covered at high tide, or on tropical coasts and estuary shores.
Mariculture: the art of breeding and cultivating marine organisms.
Marshes: a tract of low wet land.
Maximum sustainable yield: the maximum level of fishing effort which a fish stock can withstand without causing mayor upsets in the stock abundance.
Microbe: an organism that can be seen only through a microscope.
Migration: act of passing from one habitat to another.

Mineralization: production of inorganic ions in the soil by the oxidation of organic compounds.

Monoculture: culture of one species of plant or animal.

Nauplius: the earliest larval stage of certain crustaceans.

Neritic: pertaining to the portio of the marine environment which overlies the continental shelves.

Net primary production: the excess plant production after the plants themselves have utilized whatever photosynthetic products they need for their respiration.

Nutrients: elements needed for feeding.

Oceanic: pertaining to the portion of the marine environment which overlies the deep ocean basins.

Osmoregulation: regulation of osmotic pressure in the body by controlling the amount of body water and salt.

Osmosis: diffusion of material across a selectively-permeable membrane.

Omnivorous: eating both plants and animals.

pelagic: living in the sea and ocean and the organisms which inhabit the water column.

pH: is referred to the hydrogen ion concentration in grams molecule per liter.

Photic zone: a portion of the ocean where light intensity is sufficient to accomodate plant growth.

Photosynthesis: the biological synthesis of organic material from inorganic substance using as an energy source.

Phytoplankton: microscopic plant members of the plankton.

Pigments: colouring matters in plants and animals.

Polyculture: culture of more than one plants or animals in the same pond or area.

Predator: an animal that kills other animals for food.

primary production: synthesis of organic materials by plants.

Producer: an autotrophic organism, usually a photosynthetic green plant in an ecosystem.

protein: a lon chain nolymer of amino aoi s whtch funt ons as en,ymes a.net st,-r11cturfl.lcomnonents of' cells,

puln: soft, snoncYy ti ss118 of nlRntR.

Reefs: ridae of rock or sanrl ahove or elow the WRter surface,

Resn rat{on: the nrocess bv Wh{ch energy ls acnu1rect in a l\Vin organ{sm or ce11, hy the hreakdoWn of organic molecules.

Sal i nity: a measure of the total amount of dissolved salts in sea-Water.

sea ranching: is another asnect of mariculture where the 1uveniles are reared {n the hatchery and wnen they become stron enouah to ta e cflre or t,hem_selves are released in the sea. qalMon is an evamnl

Rea urchin: common name for the Echinojdea,

qeaweects: martne al"ae,

nat: the snaWn or young of hi val.ve molluscs.

trine: the flev:h1e, steM-li e str11ct11re founn in the large seaweerls.

qwamn: 1ece of wet, snongy, marshy ground•

Tonogranhv: detatled aescrintion an anning of surfane of a body Wtth reference to the narts beneath.

Tovto: of the nature of a noison,

ovtn: any nofson aer:Ved from nlant or animal.

Trade Winds: subtronical W{nds Which hJ.oWs from northeast to southwest in the ,orthern Hemtsnhere an from souti• A.Rt, to northwest in the qouthern Hemiennere,

TrPob 1ah: non commercial ORtoh oP fiRh that is dieca ed.

Trench: deen a ea ;n the ocean floor, enerally cteener thnn 6,000 meters,

Tronhio 1evel: the nosition or an oraAnis or sneci eR in a f"OOxl ohR in.

tTniva1ve: a ahe11 conAiAt{na or one ni8n or Valve.

oonlan tan1 rnicrosconic enimal memhera oP the pl n ton.