COURSE GUIDE

EMT 326
OCEANOGRAPHY

Course Team: Aderonke O. Lawal-Are (Ph.D.)
(Writer**)-** Department of Marine Sciences
University of Lagos, Akoka, Yaba, Nigeria

NATIONAL OPEN UNIVERSITY OF NIGERIA

National Open University of Nigeria,
Headquarters,
University Village
91 Cadastral Zone
Nnamdi Azikiwe Expressway
Jabi – Abuja

e-mail: centralinfo@nou.edu.ng
URL: www.nou.edu.ng

ISBN: 978-978-058-085-8

UNIT 1 INTRODUCTION TO OCEANOGRAPHY

CONTENTS

1.0 INTRODUCTION

Oceanography is a combination of two (2) Greek words "*Okeanos*" (meaning the Titan son of the gods Uranus and Gaea) and "*graphia"* (which refers to the act of recording and describing). The study of oceanography integrates biological, geological and chemical components with the physical properties and hydrodynamic of the ocean and seas in order to understand their formation, evolution and present conditions and to predict their future development. Oceanographers are in fact trained in one of the traditional sciences (physics, chemistry, biology and geology) or a related field (engineering, mathematic, meteorology, statistics or computer science) and choose to apply their research expertise to the study of the oceans.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Explain the origin of the ocean,
- understand the interactions between the oceans and the earth crust, atmosphere and the sea floor, and;
- explain the properties of the sea water and their biological importance

3.0 MAIN CONTENT

3.1 History of Oceanography

Oceanography derives its name from the mapping of ocean boundaries and the delineation of ocean currents. Because of the importance of shipping and ocean travels, mapping of the ocean margin was an important part of early explorations.

Beginning in the early 1840's, an American Scientist, Mattew Fontacine Maury synthesize data from many years of information. Maury aboard sailing vessels and comprise charts showing the winds and currents of each month of the year. Maury also wrote the first textbook on Oceanography in English titled 'The Physical Geography of the Sea'. Hence, he is today credited to be the father of Oceanography.

The study of Oceanography is interdisciplinary, because the ocean's properties and processes are linked and typically cannot be examined independently from one another. For example, the chemical composition of water influences what kinds of organisms inhabit the area (McDaniel *et* al., 2012). Biological Oceanography is the study of life in the ocean and the interactions of the marine organisms with the physical, chemical and geological processes in the ocean in order to determine distribution, composition, biogeochemical activities and trophic interactions.

The earliest publications in biological oceanography were primarily concerned with the taxonomy and distribution of marine planktonic organisms. But with the introduction of the extensive nutrients analysis, biological oceanography enters a more quantitative energy and some effects were soon made to use biological oceanography information for the solution of practical problems.

More recently, a combination of different approaches has also been introduced to the study of oceanography and this include:

1. Learning the principals and methodology of molecular biology and applying this knowledge in the study of complex marine system in area such as molecular phylogeny and population genetics.
2. The application of bio acoustics to the study of spatial and temporal patterns in the distribution and abundance of marine organisms.
3. In the application of mathematics in the development of population models.

3.2 Origin of The Ocean

Many geologists believe that the ocean is formed through the gradual release of water out of the earth surface through volcanic eruption causing removal of water originally bound in rocks in the earth interior. Humans began studying the Oceans tens of thousands of years ago when people started to venture off the coast and navigate the seas. At that time, people were motivated to learn more about the sea for travel, trade and resources (Dive and Discover, 2005).

These scientists believed that the amount of water releases through earth history can account for the present volume. Some of the rocks e.g. Sedimentary rocks have been dated approximately 3 million years and they contain pebbles and other materials which suggest that the original sediment was deposited in water.

Little is known about the ocean history and even less about the sea water composition. From apparent similarities between fossils and living organisms in rocks as old as 600 million years. Then the geologists concluded that the composition of the sea water has changed very little during this period.

Modern oceanography became a field of science approximately 200 years ago when scientists started studying ocean life, currents and the seafloor off the coasts. The first scientific expedition to study the oceans and seafloor was the Challenger Expedition, from 1872 to 1876, aboard the British HMS Challenger when submarines and sonar were being developed. The ship traveled over 100,000km circumnavigating the world, taking sediment samples, cataloging species, measuring water temperature and more (Bishop *et al*., 2012).

Marine scientists are well aware of the fact that all their work rests on the contributions of the innumerable investigators that came before them. But, obviously, this does not mean that all the conclusions of those early investigators have been validated. Rather, as the science of oceanography has matured and as research vessels, sampling devices and electronic instrumentation have become increasingly sophisticated and more widely applied to probe the ocean's secrets, many beliefs of the past have been disapproved.

A number of remarkably sophisticated scientific probing of the ocean's secrets were made in the eighteenth and nineteenth centuries. The British were preeminent during this stage of ocean investigation. Through government sponsorship and often under the auspices of major scientific societies such as the Royal Society of London, they expanded their geographic and scientific knowledge about the world's seas, which was vital if they were to uphold their maritime and economic superiority. During the World War 11, the U.S. Navy wanted to learn more about the deep ocean in order to gain fighting advantages in submarine warfare.

Satellite navigation was another significant innovation, which further developed the field of oceanography. Until the development of this more accurate mode of navigation, celestial navigation was the dominant method among mariners. Celestial navigation is only accurate to about half a kilometer while satellite navigation is accurate plus or minus 100m (McDaniel *et al*., 2012).

Oceanography is still relatively new and developing field of science. Our knowledge of the world's ocean is still incomplete and many consider the deep ocean as the "last frontier".

3.3 Ocean Basins

Considering the earth's surface which measures 510 million sq. kilometer/197 million sq. miles, the ocean covers 361 million sq. kilometer/139 million sq. miles or about 70.8% of the earth surface. The average depth of the ocean is about 3.73km.

Ocean basins are uniformly distributed over the earth surface. Each of the great continental blocks tend to have an oceanic area, opposite to it is the other side of the earth. Hence, the ocean continent tends to be antipodal. Most continents tend to have triangular shapes. Most of the land (about 67%) lies in the northern hemisphere and between latitude 45° and 70°N.

There is more land than water. Looking at the two hemispheres, the Northern hemisphere may be tagged "the land hemisphere" while the Southern hemisphere could be tagged "the water hemisphere". Not only does the ocean cover 71% of the earth surface between latitude 40° – 65°S but there is almost no land to implement the oceanic circulation in the area.

3.4 Composition of the Sea water

Many of the properties of seawater are crucial to the survival and well-being of the ocean inhabitants. Water accounts for 80 – 90% of the bulk of most marine organisms. It provides buoyancy and body support for swimming and floating organisms, thereby reducing the need for heavy skeletal structures.

It is also the medium for most chemical reactions needed to sustain life. The life processes of marine organisms in turn alter many of the fundamental physical and chemical properties of sea water including its transparency and chemical make-up. This is highlighted in Table 1.

Table 1: Some Biologically Important Physical Properties of Water

S/No	Properties	Comparison With Other Substances	Importance In Biological Process
1	Boiling Point	High for molecular weight (100°C)	It causes most water to exist as a liquid at earth surface temperature.
2	Freezing Point	High for molecular weight (100°C)	It causes most water to exist as liquid at the earth surface temperature
3	Surface Tension	Is the highest of all liquids	It is critical to position maintenance of sea surface organisms
4	Density of solid water	It is unique, more common in natural substances	It causes ice to flow and inhibit complete freezing of large bodies of water
5	Latent heat of evaporation	That of water is the highest; about 540cal/g compare to other bodies	It moderates sea surface temperature by transferring large quantities of heat to the atmosphere through evaporation
6	Latent heat of freezing	Is also the highest of all natural substances ; about 80cal/g	It inhibits large scale of freezing of the oceans
7.	Solvent Power	It dissolves more substances in greater amounts than any other liquid.	It maintains a large variety of substances in solution and enhancing a variety of chemical reactions.

3.5 The salinity of seawater

Salinity is a measure of the total mass in grams of solids dissolved in a kilogram of seawater, a mass ratio. It is composed almost entirely of elements that do not measurably change concentration geographically owing to chemical reactivity. It is thus used as a property against which individual chemical species can be compared to determine their stability in the sea; conservative (unreactive) elements have constant or nearly constant ratios to salinity everywhere in the ocean. Relatively small changes in salinity are important in determining the density of seawater and thermohaline circulation. It can also be useful as a tracer for the mixing of different water masses since salinity values that are determined at the ocean’s surface can be traced for great distances within the ocean interior. For all these reasons it is essential to have a relatively rapid and accurate measurement of seawater salinity.

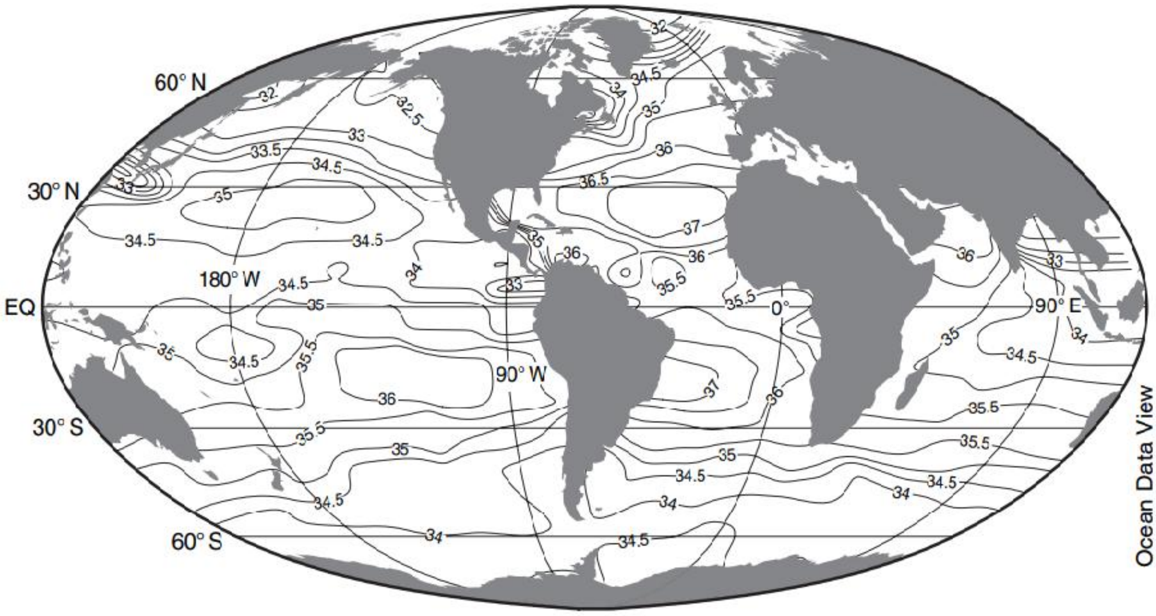
The obvious method would be to dry seawater and weigh the leftover residue. This approach does not work very well because high temperatures (c. 500 8C) are required to drive off the tightly bound water in salts such as magnesium chloride and sodium sulfate. At these temperatures some of the salts of the halides, bromides and iodides, are volatile and are lost, while magnesium and calcium carbonates react to form oxides, releasing CO2. Some of the hydrated calcium and magnesium chlorides decompose, giving off HCl gas. The end result of weighing the dried salts is that you come up ‘‘light’’ because some of the volatile elements are gone. Although there were schemes created to obviate these problems, for many years the preferred method for determining salinity was titration of the chloride ion by using silver nitrate

$$Ag^{+} + Cl^{-} \rightleftarrows AgCl_{(s)}, \quad (1.1)$$

which is quantitative. The chloride concentration, $[Cl^{-}]$, could then be related to salinity, S, via a constant number,

$$S(ppt) = 1.80655 \times [Cl^{-}](ppt), \quad (1.2)$$

where ppt indicates parts per thousand (gsolute kg1 seawater). The exact relationship between chlorinity and salinity, however, has evolved over the years, and it is not as accurate and universal as the present method. Salinity is presently determined by measuring the conductance of seawater by using a salinometer. The modern definition of salinity uses the practical salinity scale, which replaces the chlorinity–salinity relationship with a definition based on a conductivity ratio (Millero, 1996). A seawater sample of salinity S ¼ 35 has a conductivity equal to that of a KCl solution containing a mass of 32.435 6 g KCl in 1 kg of solution at 15 8C and 1 atm pressure. No units are necessary on the practical salinity scale; however, in practice, one often sees parts per thousand, ppt, or the abbreviation ‘‘psu.’’ New salinometers using this method are capable of extremely high precision so that the salinity ratio can be determined to 1 part in 40 000. At a typical salinity near 35 this procedure enables salinities to be determined to an accuracy of 35.000 0.001. This is much better than most chemical titrations, which, at best, achieve routine accuracy of 0.5 parts per thousand. The distribution of salinity in surface waters of the ocean is presented. Because the concentrations for many major seawater constituents are unaffected by chemical reaction on the time scale of ocean circulation, local salinity distributions are controlled by a balance between two physical processes, evaporation and precipitation. This balance is reflected by low salinities in equatorial regions that result from extensive rain due to rising atmospheric circulation (atmospheric lows) and high salinities in hot dry subtropical gyres that flank the equator to the north and south (20–35 degrees of latitude) where the atmospheric circulation cells descend (atmospheric highs).



Annual mean surface salinity of the world’s ocean.

Salinity and temperature are the primary factors that determine the density of seawater. The densities of most surface seawaters range from 1024 to 1028 kg m^3, and it is possible to evaluate density to about 0.01 of these units. In order to avoid writing numbers with many significant figures, density is usually presented as the Greek letter sigma. The density of the sample (kg m^3) and 0 is the maximum density of water at 3.98 8C (999.974 kg m^3), (Note that the numerical value of this expression is only slightly different from, ¼ – 1000, which appears in many texts.) Density is calculated from temperature, salinity and pressure (because of the compressibility of water) by using the international equation of state of seawater (Millero, 1996).

The expression above represents the density in situ of a seawater sample determined from the measured temperature, salinity and depth. Because all water acquired its temperature and salinity while it was at the ocean surface, it is convenient to know the density corrected to one atmosphere pressure, which is indicated by sigma with a subscript t (sigma-tee). By the same reasoning, it is often advantageous when tracing the source of a water parcel to calculate density by using temperature corrected for increases caused by water compression under the influence of pressure. The potential temperature is the temperature the water sample would have if it were raised to the surface with no exchange of temperature with the surroundings, i.e., if it changed pressure adiabatically. At the depths of the ocean this is a large effect. A water parcel gains c. 0.5 8C when it sinks from the ocean surface to 4000 m depth (c. 400 atm). Potential temperature is the temperature it had before sinking. Density calculated at one atmosphere and the potential temperature is called sigma–theta, y.

Table 1.3. *Temperature, salinity, and flow rate of major deep-ocean water masses*

Water mass	Temperature[e] (°C)	Salinity[e]	Flow estimate[f] (Sverdrups)
AABW[a]	– 2.0 – 0.0	34.6–34.7	5–10
NADW[b]	2.0–3.0	34.9–35.0	15–20
MW[c]	12.0	36.6	—
AAIW[d]	2.0–3.0	34.2	5–10

[a] AABW, Antarctic Bottom Water
[b] NADW, North Atlantic Deep Water
[c] MW, Mediterranean Water
[d] AAIW, Antarctic Intermediate Water
[e] T and S characteristics from Picard and Emery (1982)
[f] Flow rates are in Sverdrups (10^6 m^3 s^{-1}).

Note that the North Atlantic surface water is nearly 2 salinity units saltier than North Pacific surface water. At first this seems counterintuitive because larger rivers drain into the Atlantic. The reason for this difference has to do with the relative rates of evaporation in the high latitudes of the two oceans. North Atlantic surface water is on average warmer (10.0 8C) than North Pacific surface water (6.7 8C). Warmer water leads to warmer air, which has a higher specific humidity (the mass of water per mass of dry air) and increases evaporation and consequently salinity as well. The temperature difference is due to the warm Gulf Stream waters that flow north along the east coast of North America having a greater impact at high latitudes than their Pacific counterpart, the Kuroshio current. The resulting salinity difference has very important consequences for the nature of global thermohaline circulation. Because salt content (along with temperature) influences the density of seawater, the higher salt content of North Atlantic surface waters gives them greater densities at any given temperature than North Pacific waters. This is the main reason for massive downwelling, all the way to the ocean bottom, in the North Atlantic where the water is cold and salty, but no deep water formation in the North Pacific. There is no North Pacific Deep Water.

This explanation for the surface salinity differences between the Atlantic and Pacific does not provide the whole story because it overlooks the need to budget atmospheric water transport on a global basis. In fact, the only way to cause a net salinity change in an ocean due to evaporation is via net transport of water vapor to another region on a time scale that is short with respect to the residence time (decades to centuries) of the surface water in question. Simply removing water from an ocean to the atmosphere or to an adjacent landmass is insufficient if that same water rapidly returns to the source ocean. To create a salinity difference between oceans, water must be removed across a continental divide so that it precipitates either directly on another ocean or into the drainage basin of a river discharging into another ocean. This budgetary constraint makes global salinity patterns the net result of local evaporation, wind patterns, and continental placement and topography. An ideal ‘‘vapor export window’’ from an ocean would be through a region where initially dry prevailing winds blow continuously over warm ocean surface waters and then across a low continental divide. Inspection of the North Atlantic Ocean shows such a window at about 208 N, where the North East Trade Winds blow westward across the Sahara Desert, subtropical Atlantic, and then over the relatively low continental divide of Central America.

The surface Atlantic Ocean expresses its highest salinity at this latitude, and high rainfall over western Panama and Costa Rica indicates substantial vapor export to the subtropical Pacific. In contrast, the expansive subtropical Pacific Ocean has few upwind deserts, and a Trade Wind window that is effectively blocked by Southeast Asia. Thus the percentage of net water loss is much less in the bigger ocean. In the large perspective, the North Atlantic Ocean is now saltier than the North Pacific as a result of the present distribution of ocean and atmosphere currents and continents over the surface of the Earth. Other distributions, as occurred in the past owing to different distributions of ice, deserts or continental topography, would produce very different water balances and global current systems. Temperature differences in the sea are large, ranging between 30 8C in equatorial surface waters and –2 8C in waters that are in contact with ice. By comparison, salinity is remarkably constant, S ¼ 33.0–37.0, necessitating very accurate determinations in order to distinguish differences. The average temperature and salinity of the sea are 3.50 8C and 34.72, and 75% of all seawater is within 48C and 0.3 salinity units of these values. Cross sections of the potential temperature and salinity of the Atlantic and Pacific Oceans demonstrate how water masses can be identified with distinct origins at different densities and hence different depths. The water masses are characterized by the temperature and salinity that is determined at the surface ocean in the area of their formation. The deepest waters, Antarctic Bottom Water (AABW) and North Atlantic Deep Water (NADW), are formed at the surface in polar regions. AABW is dense because it is formed under the ice in the Weddell and Ross Seas and is thus extremely cold. NADW is not particularly cold, but is highly saline because of the source waters from the Gulf Stream and high evaporation rates in the North Atlantic. Antarctic Intermediate Water (AAIW) is both warmer and less saline than either of the deeper-water masses and thus spreads out in the ocean at a depth of about 1000 m.

4.0 CONCLUSION

The understanding of the interactions between the oceans and the surrounding environment (earth crust, atmosphere and the sea floor) and the biological importance of the ocean water will enable scientists to understand the formation, evolution and the present conditions of the ocean. This will also afford them the opportunity to predict the future development of the ocean bodies.

5.0 SUMMARY

In this unit, we have learnt that:

i. Oceanography is derived from two Greek words – *Oceanus* and *graphia*;
ii. American Scientist, Mattew Fontacine Maury is known as the Father of Oceanography;

iii. The Northern hemisphere may be tagged "the land hemisphere" while the Southern hemisphere could be tagged "the water hemisphere";
iv. The life processes of marine organisms alter many of the fundamental physical and chemical properties of sea water.
v. Salinity is a measure of the total mass in grams of solids dissolved in a kilogram of seawater

6.0 TUTOR MARKED ASSIGNMENTS

1. Define the word "oceanography" and explain how it differs from other fields of science.
2. List and explain some of the properties of sea water;
3. Who is regarded as the father of Oceanography?
4. Discuss salinity of seawater
5. Explain factors that determines the density of seawater

7.0 REFERENCES AND OTHER RESOURCES

Aleem, A. A. (1990). German contributions to marine biology in the Red Sea during the 19th century In Ocean Sciences: Their History and Relations to Man, eds. W. Lenz and M. Deacon, Proceedings of the Fourth International Congress on the History of Oceanography, Hamburg, Germany, 1987, *Deutsche Hydrographische Zeitschrift*, *Erg*, **22**, 109-113.

Cohen, H. J. (2003). Matthew Fontaine Maury: pathfinder of the seas.

(Bethesda, Md): U.S. National Imagery and Mapping Agency, 14 pages.
Dive, M. A. and Discover, P. R. (2005). *History of Oceanography.*

Retrieved from http://www.divediscover.whoi.edu on the 14th of November, 2018.

UNIT 2 OCEAN STRATIFICATION

CONTENTS

1.0 INTRODUCTION

Stratified ocean occurs when water with different properties such as salinity, density and temperature form layers, which act as barrier for water mixing which could lead to anoxia or euxini (Miller, 2004). This barrier prevent water from passively mixing across the thermocline boundary (boundary between warm water and cold water)

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Explain the layers of the open ocean;
- understand the ocean surface conditions
- discuss the interaction of the ocean's atmosphere.

3.0 MAIN CONTENT

3.1 Ocean Layers

Changes in temperature (°C) and salinity (‰) greatly affect the water density. Ocean water is usually layered by density with the densest water on or near the bottom. Light, temperature and salinity control the behavior of the oceans. The absorption of insulation at the ocean's surface cause the 3 layered structure of the open oceans into the following:

3.1.1 The Surface Zone or Mixed Layer

The stratification of water due to density is mainly a function of the temperature and salinity. Seawater density increases with increasing salinity, increasing pressure and decreasing temperature. The surface zone or mixed layer contains less dense water usually as a result of higher temperature causes by warming of the surface water. Temperature and salinity are relatively constant with depth in surface zone consist of water in contact with the atmosphere and is exposed to sunlight only and contains 20% of the entire ocean volume and contains the lease dense water.

The surface zone or mixed zone typically extent to say about a depth of 50m or 500ft nut depending on the local condition, it may reach about 1000m or about 3300ft or may be absent entirely. The thickness of the surface zone is controlled by the depth of mixing caused primarily by winds.

In certain areas, convective verticals water movement are caused by density changes resulting from changes in temperature and salinity. The mixing of the water in this zone results in its nearly neutral stability so that water particles can easily move vertically. Surface waters have the ample condition to adjust to atmospheric conditions and dissolved oxygen.

3.1.2 The Pynocline

Below the surface zone is the Pynocline where the water density changes significantly with depth. Due to the large change in density with depth, water in this zone have very great stability. The Pynocline contains about 18% of all ocean waters. The Pynocline acts as an effective barrier, though slightly leaky to vertical water movements serving as a flora to the surface ocean circulation with its seasonal salinity and temperature changes. This layer coincides with the thermocline and the halocline.

The thermocline here corresponds to the zone where temperature changes rapidly with depth while halocline is the zone of rapid salinity increase with depth. The halocline coincides with the thermocline and their combination produces the Pynocline.

3.1.2 The Deep Zone

Below the Pynocline lies the deep zones at a depth below 1000m. In this zone, there is little additional changes in density with increasing depth throughout the zone. The deep zone contains about 80% of all oceans waters. Over most of the oceans, this deep water is isolated from the surface. There is no opportunity for heating or cooling of water at the surface or charging dissolved gases except high latitudes that is why the deep ocean waters are cool with an average temperature of 3.5°C.

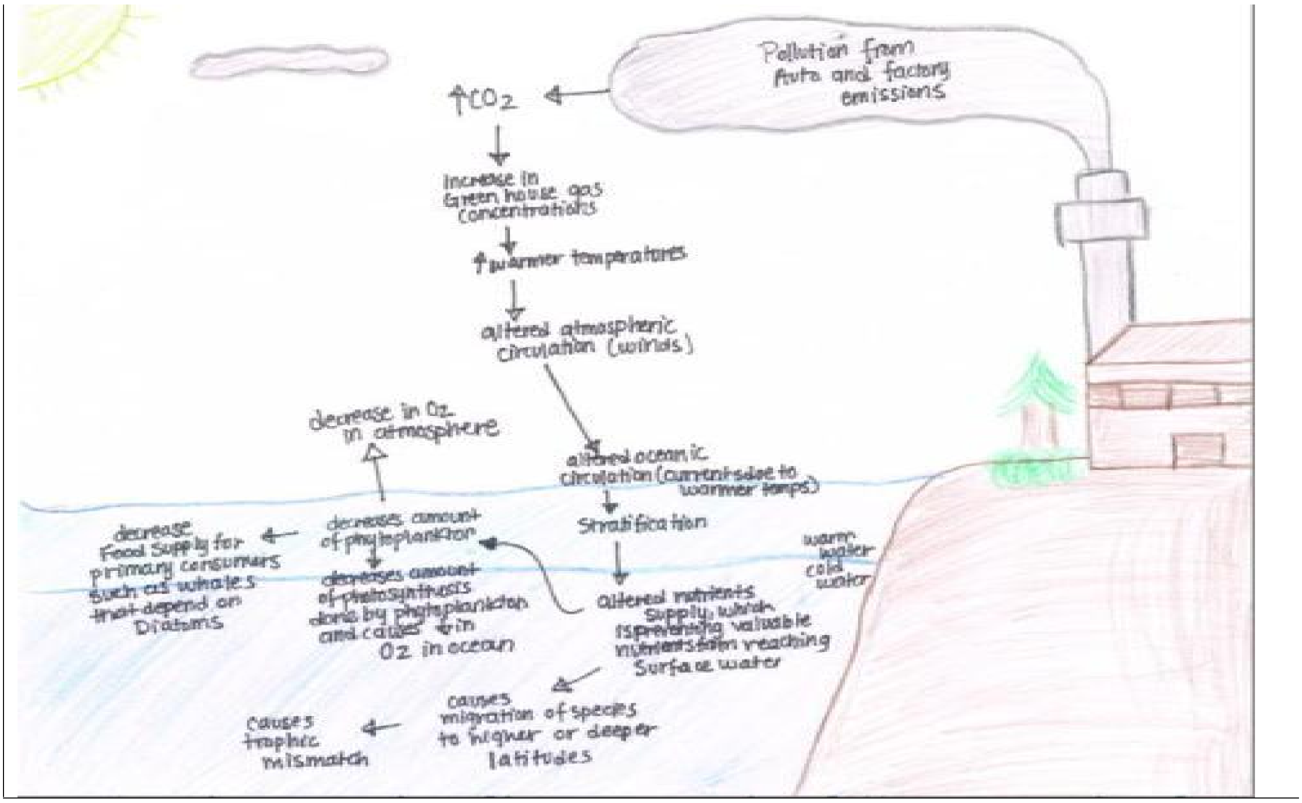


Figure 1: The Ocean Stratification
Source: Marshall *et al*., (2002)

3.2 The Ocean Surface Conditions

The ocean surface temperature is more variable throughout the year in the temperate zone than in either in the tropical or polar zones, its salinity also stays relatively constant. In the tropical zones, evaporation exceeds precipitation while precipitation exceeds evaporation in the temperate and polar zones. Surface salinity is high in the warm North and South Atlantic where evaporation rates are high and the surface water is isolated by the current flowing around the oceans periphery. This is highlighted in Table 1.

Table 1: Characteristics of World Ocean Surface

S/No	Characteristics	Tropical Oceanic waters	Temperate Oceanic waters	Polar Oceanic Water
1	Temperature	20 – 25°C	5 -20°C	-2°C
2	Annual Variations of temperature	Less than 5°C	10°C	Greater than 5°C
3	Average Salinity	35 – 37‰	35‰	28 – 32‰
4	Precipitation (Evaporation balance)	Evaporation exceeds Precipitation	Precipitation exceeds Evaporation	Precipitation exceeds Evaporation

3.3 Ocean Atmosphere Interaction

The thermostatic properties of water are those properties that act as moderate changes in temperature. Water temperature rises as the sun energy is absorbed and is changed to heat but since water has a very high specific heat, its temperature will not rise very much even if a large quality of heat is added. The tendency of a substance to resist change in temperature with a gain or loss of heat energy is referred to as THERMAL INERTIA. Heating of the ocean's surface waters occur only during day light hours and surface waters are warmest in late afternoon. The amount of energy absorbed by the ocean depend on the local cloud cover and the sun's altitude.

This sun's altitude also depends on the latitude and time of the year. So, more energy is absorbed when the sun is high in the sky and less when the sun is near the horizon. In the tropics and sub-tropics, the sun is well above the horizon at all seasons. Near the polar, the sun is never far above the horizon, so the polar and sub polar regions receive much less insulation. Consequently, the earth is heated in the tropics and sub-tropics and cooled by radiating energy primarily from the polar and sub-polar regions. Only about one part of the sun's 2.2 billion radiant energy is intercepted by the earth. This amount to 7 million calories/sqmeter/day at the top of the atmosphere.

Out of this figure on a daily basis, 76% is reflected back into spaces from clouds or scattered by ice, water droplet or particles in the atmosphere, another 18% is absorbed by the vapor, cloud dust and carbon dioxide in the atmosphere. About 4% bounces up the shining sea surface, ice or snow, rock and soil. Only 2% is absorbed by the earth’s land and water surfaces.

The quality of light that penetrates the ocean greatly depends on several factors:

1. The angle at which it approaches
2. the sea state (state of the surface of the sea)
3. presence of an ice covering or light colored foam

If the ocean retains all the heat it absorbed, ocean water would reach a boiling point in slightly less than 300 years. It is therefore necessary that the oceans lose as much energy as it absorbs from insulation. The heat loss at the ocean surface continues day and night in all seasons.
Three (3) processes involved in the Ocean’s heat loss are:

- Radiation of the heat back to space
- heating of the atmosphere by conduction
- evaporation of water.

Therefore, 51% of the solar radiation striking land and sea is converted to heat and is transferred back into space in the form of Infra-red radiations. The heat input and outflow account for the earth’s can be thought of as ‘the Heat Budget”. Over a long period of time, the total incoming heat equal the total outgoing heat. Therefore, the earth is said to be in “Thermal equilibrium”. While the heat budget for the earth as a whole is balance, the heat budget for different latitude is not. Looking at the area figure, the sun light strike the polar latitude spread over a greater area and therefore filter through much atmosphere and approaches the surface at the low output thereby favoring a strong reflection.

On the other hand, the ice solar angle in the tropics distribute the same amount of sunlight over a much smaller area. The more nearly vertical angle by which the light approaches means that it passes through less atmosphere and the reflection is minimized. Tropical latitude receives significantly more solar energy than the polar region while the mid tropical area (temperate) receives more heat in summer than in winter.

4.0 CONCLUSION

From the above, it becomes obvious that the ocean is divided into three (3) layers as determined by light, temperature and salinity. Considering the fact that the ocean also losses heat in three conventional process, it is said that the earth is in a thermal equilibrium where the heat output equals the heat input.

5.0 SUMMARY

In this unit we have leant that:

- the characteristics of the world's ocean are largely determined by the physical properties of the sea;
- the ocean layer is divided into three based on the absorption of insulation (heat) at the ocean's surface, and;
- The knowledge of knowing that the Sun's altitude depends on its latitude and time of the year.

6.0 TUTOR-MARKED ASSIGNMENTS

- Discuss in details, the three layers of the Ocean
- in a tabular form, list the characteristics of the world ocean surface
- Explain the theory of the Ocean's interaction with the atmosphere

7.0 REFERENCES

Hoehler, S. (2002). Depth records and ocean volumes: ocean profiling by sounding technology, 1850-1930. *History and Technology*, **18** (2): 119-154.

Marshall, J., Jones, K. and Wardle P. (2002). "Can eddies set ocean stratification?" *Journal of Physical Oceanography*, **32** (1): 26 – 32.

Miller, C. B. (2004). *Biological Oceanography*. Blackwell Publishing. 67pp.

UNIT 3 CLIMATIC REGIONS OF THE OCEAN

CONTENTS

1.0 INTRODUCTION

The open ocean can be divided into climatic regions with relatively stable boundary that run generally East / West. The temperature (°C) and salinity (‰) of surface water are determined by the amount of:

- Solar radiation
- Evaporation
- Precipitation

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- understand the division of the ocean based on temperature, salinity, evaporation and precipitation, and;
- understand the phenomenon of ice formation

3.0 MAIN CONTENT

3.1 CLIMATIC OCEAN REGION

The man known as Elliot in 1960 divided the ocean into a number of classes based on difference in temperature, rate of evaporation, salinity as well as rate of precipitation (Duxbury *et al.*, 2000). Using this climatic ocean parameters, the ocean body is divided into the following:

3.1.1 Low Latitude Tropical Oceanic Water

- This area lies between 30°N & S
- Usually warm with an annual temperature variation of less than 5°C.
- Evaporation usually exceeds precipitation,
- Salinity is often high (35 – 37 ‰).
- Major currents are West-bound since the Trade wind blows in this region.

3.1.2 Mid Latitude Oceanic Water

- This area lies between the tropics and the Polar region (30 – 60°N & S).
- This area is cooler as the annual temperature variation is as high as 10°C.
- Precipitation is slightly greater than evaporation
- Salinity is equal to ocean's average of 35 ‰
- Surface temperature and salinity are variable i.e seasonal from place to place.
- The major current moves Eastward
- Moving deflection with rain and snow are common.

3.1.3 High Latitude Oceanic Water

- This consists of the Artic and the Antarctic oceans
- This area is covered with ice most part of the year.
- Have temperature of 0°C almost all through the year
- Precipitation is low but exceeds evaporation
- Salinity is low, between 28 – 32 ‰
- winds and currents circulates clock wisely around the pole particularly in Antarctic

3.2 Phenomenon of Ice Formation in the Sea

Water exists in 3 states; Vapor (gases), Liquids and Solid (ice). As a result of lower temperature, ice formation occurs at the sea under certain temperature. At temperature of -18°C, sea water becomes frozen. Ice formation in the ocean are of four (4) types namely:

3.2.1 Polar Cap Ice Formation:

This is the most extensive ice consisting of about 70% of the polar sea. It is virtually in penetrable, leaving an average thickness of about 3 – 4 m. it is fairly permanent, only melting slightly during high solar months.

3.2.2 Pack Ice Formation:

This forms about 20% of the Polar Sea but not as thick as cap ice and most of it melt during the solar months as a result of high temperature and can be penetrated by ice-breakers.

3.2.3 Fast Ice Formation:

This ice is formed starting from the land and extends into the sea. It is constant and melt completely during the solar months.

3.2.4 Ice bergs Formation:

These are not derived from frozen sea water but originates from land just as fast ice. They originate as glaciers or flowing ices and as a result of the mode of formation, contains varying amount of air and consequently varied density. They are notorious because they cause obstacle especially in the North Atlantic regions. In this region, there is an international arrangement that warns ships to beware of Icebergs.

4.0 CONCLUSION

In this study, it is noted that the climatic regions are divided into three (3) based on several factors and that low temperature causes water to form ice at the sea.

5.0 SUMMARY

In this unit we have leant that:

i. a man known as Elliot in 1960 divided the Ocean into three based on temperature, salinity, evaporation and precipitation.

ii. the main factor that forms Ice in sea is as a result of low temperature in certain regions of the world, and;
iii. Iceberg is a notorious ice because it causes obstruction on the surface of the water, preventing smooth sailing of objects especially Ships, thereby causing sea accidents.

6.0 TUTOR-MARKED QUESTIONS

1. What were the parameters used by Elliot (1960) to divide the ocean?
2. List 4 ways by which ice can be formed in the ocean.
3. Explain 3 attributes of each of the following oceanic region

- Low Latitude Tropical water,
- mid Latitude Oceanic water

7.0 REFERENCES AND OTHER RESOURCES

Duxbury, A.C., Duxbury, A. b and Kieth A. S. (2000). *An introduction to the World's Oceans*. 6th ed. New York: McGraw-Hill.

Seto, K. C and Shepherd, J. M. (2009). Global Urban Land-Use trends and Climate Impacts, *Current opinion in Environmental sustainability*, 1: 89 -95.

Tom, L. M and Darrel, H. (2000). Climate Zones and types: the Kòppen System. Physical Geography: A Landscape Appreciation. Prentice Hall. 226 – 235pp.

UNIT 4: THE OCEAN IN MOTION

CONTENTS

1.0 INTRODUCTION

At the entrance of most beaches, there is a bulletin board with notices about water conditions, maybe a faced sign warning about rip currents and a list of tide tables. Most people pass them by without a second thought but if you want to enter the ocean, it is important to know its movement, whether to avoid being caught in a riptide or to figure out when the waves will be at their best.

2.0 OBJECTIVES

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

- Differentiate between the waves, tides and currents of the ocean
- Explain the formation of the waves, tides and currents
- List the different types of current under the Gyral system

3.0 MAIN CONTENT

3.1 Sea Waves

Waves play an important role in the coastal ecosystems function, also provide tourism dollars because of their draw for surfers. Sea waves are an irregular variation in the level of ocean water. Waves are not caused by gravitational pull but as a result of wind action, transferring its energy to the water and big waves or swells can travel over long distances. It sets up orbital motion both vertically and horizontally.

A wave's size depends on the wind speed, wind duration and the area over which the wind is blowing (the fetch). They are also influenced by the width of the surrounding areas and the depth of the water body itself. Powerful waves such as tidal waves or tsunamis can also be formed as a result of earthquakes, landslides or volcanic eruption.

While no two waves are identical, they share common traits like having a measurable height which is defined as the distance from its crest to its trough. When waves crash onshore, they can make a significant impact to the landscape by shifting entire islands of sands and craving out rocky coastlines.

The overall result of this motion is a general undulating movement creating peaks and troughs on the surface of the ocean. The distance between two (2) peaks constituents a wavelength (λ) and the difference between that of the peak and that of the trough constituent a wave height.

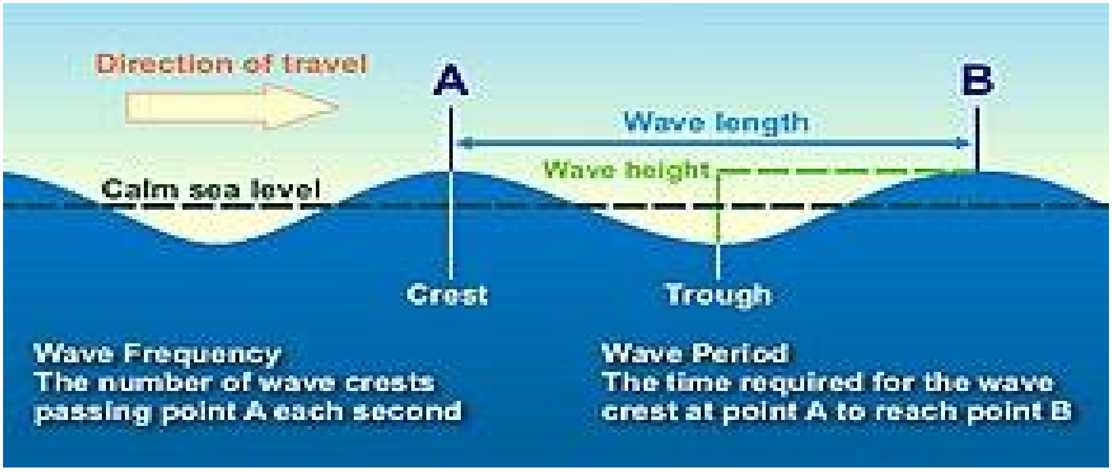


Figure 1: the wave movement

Three important factors are responsible for the variation of the wavelength and the wave height. These are:

- Velocity of the wind
- Duration and activity of the wind
- Area of activity or “fetch” of the wind

As the wave travels away from its form of origin, its shape becomes modified and hence, we describe its shape by its height and length but as a general rule, as the height reduces, the length increases.

3.1.1 Factors that influences the waves

They are usually created by winds which transfer energy to the water as they blow over. This results in the production of small water movements know as RIPPLES. These ripples can subsequently grow in size, length and speed to form what we know as waves. These waves are commonly also known as ocean surface waves due to them being generated from the wind passing over the surface of the water.

3.1.2 Types of Sea Waves

The Sea waves have 4 main types of waves. These are tabulated in Table 1.

Table 1: Types of Sea waves

Wave type	**Typical wavelength**	**Disturbing force**
Capillary wave	< 2cm	Wind
Wind wave	60 – 150 m (200 – 490ft)	Wind over ocean
Seiche	Large, variable; a function of the basin size	Change in atmospheric pressure, storm surge
Seismic Sea wave (Tsunami)	200km (120 m)	Faulting of sea floor, volcanic eruption, landslide

3.1.3 Classification of Sea Waves

Sea Waves can be classified based on the following:

- Disturbing forces that create them,
- The extent to which the disturbing force(s) continue(s) to influence them after formation;
- The extent to which the restoring force(s) weaken(s) or flatten them, and
- Their wavelength or period e.g. Seismic sea waves have a period of approximately 20 minutes and speeds of 760km/h (470 mph). wind waves (deep-water waves) have a period of about 20 seconds

3.2 Ocean Tides

This can be defined as the periodic but regular rise and fall of the level of water surface in the oceans. All the water movement associated with this phenomenon are described as TRIDAL MOVEMENT. They are formed primarily as a result of centrifugal force and the gravitational pull of the sun and the moon on the earth. The rise and fall of water or rather the differences between the crests and troughs are defined as tides.

3.2.1 Factors that influences the Tides

The rotation of the Earth together with the gravitational force of the moon results in water being pulled towards the moon. This causes a rise in the water. As the moon rotates around the earth, the areas experiencing this pull will form what is known as high tides (when the crest of the waves reaches the coast) while other areas not feeling this pull will experience a low tide (when the trough of the waves reaches the coast).

A similar effect is caused as a result of the sun, however, this pull is not as strong because the sun is further away from the Earth. Tides mostly occur in deep oceanic regions and are affected by a range of factors such as the alignment of the sun and moon, the pattern of tidal movements and the shape of the coastline.

3.2.2 Types of Tides

3.2.2.1 Tides based on the Sun, the moon and the earth's position

1. **SPRING TIDES**: when the sun, the moon and the earth are in a straight line, the height of the tide will be higher than normal. These are called Spring tides. They occur twice in a month, one on the full moon (Poornima) and the other on the new moon (Amavasya).

Figure 2: Spring tides during the full and New moon

2. **NEAP TIDES**: normally after seven days of a spring tide, the sun and the moon become at a right angle to each other with respect to the earth. Thus, the gravitational forces of the sun and the moon tend to counteract one another. The tides during this period will be lower than the normal which are called as the neap tides. They also occur twice in a month, during the first quarter moon and the last quarter moon.

Figure 3: Neap tides during the 1st quarter and the Last quarter moon

3.2.2.2 Tides based on the frequency

1. **Semi-diurnal tide**: they are the most common tidal pattern, featuring two high tides and two low tides of equal size every 24 hours and 50 minutes.
2. **Diurnal Tides**: experiences one high and one low each day.
3. **Mixed semi-diurnal**: tides having variations in heights re known as Mixed- semi diurnal, they experience two high tides and two lows tides every 24 hours and 50 minutes and generally occur along the west coast of North America.

3.2.3 Magnitude of Tides

1. **Perigee**: when the moon's orbit is closest to the earth, it is called Perigee. During this period, unusual high and low tides occur.
2. **Apogee**: when the moon's orbit is farthest from the earth, it is called Apogee. Tidal ranges will be much less than the average during this period.
3. **Perihelion**: it is the position where the earth is closest to the sun (around January 3rd). Usually, high tides and low tides occur during this period.
4. **Aphelion**: it is the position where the earth is farthest from the sun (around July 4th). Tidal ranges are much less than the average during this period.

3.3 CURRENTS

Any movement of an identifiable mass of water in a definite direction within the ocean constituents an ocean current. Currents can be temporary or long-lasting, they can be at the surface or in the deep ocean.

These currents play an important role in the distribution of heat and nutrients and other gases. Currents also have an important effect on the distribution of marine organisms in particular, the floating communities known as planktons. Many large currents are driven by differences in temperature and salinity and are usually measured in knots or meters per second.

3.3.1 Factors that influences Current

Oceanic currents are directly influenced by five (5) main factors:

1. The rise and fall of the tides: this is also known to influence oceanic currents by creating currents either near the shore or in bays or estuaries. These are known as tidal currents and are the only type of current that changes in a regular pattern and whose changes can be predicted.
2. Winds: are known to drive currents at or near the oceanic surface and can influence water movements on a localized or global scale.
3. Thermohaline Circulations: temperature also plays a major factor when it comes to currents. Water bodies near the poles are cold while water near the equator are warm / cold water currents occur as the cold water near the poles sink and moves towards the equator while warm water current move outward from the equator along the surface towards the poles in an attempt to replace the sinking water.
4. Ocean bottom topography: this is influenced by slopes, ridges and valleys on the bottom which in turn can affect the direction of the currents.
5. Difference in density: density of sea water varies from place to place according to its temperature and proportion of salinity. Increase and decrease in density due to the differences in temperature and salinity causes the water to move from one place to another.

3.3.2 Causes of Currents

Currents are caused in the following ways:

i. Wind action: as a result of wind action, this leads to wind driven circulation. This type of circulation is superficial and restricted to only a few 100m below the surface.
ii. Differences in parameters: as a result of differences in temperature and differences which occur in salinity as well as differences in densities of water.
iii. Rotation of the earth: the rotation of the earth which creates a CORIOLIS FORCE that causes a movement towards the right in the Northern Hemisphere and to the left in the South Hemisphere. This Coriolis force also affects the wind system of the world.
iv. The shape of the continent also determines the direction of the current.

v. The shape of the ocean floor also affects the direction of the currents.

vi. Gyral system or Gyres: ocean currents flow in circles, one after the other which are involved with large wind movements are known as Gyres. They are caused by the Coriolis force. There are two types of gyral systems – the Northern gyral system (ocean currents move in clockwise manner) and the Southern gyral system (ocean currents move in an anti-clockwise manner).

3.3.3 Types of Ocean Currents

A. Warm Ocean Currents

- Those currents which flow from equatorial regions towards poles which have a higher surface temperature and are called warm current
- They bring warm waters to the cold regions.
- They are usually observed on the east coast of the continents in the lower and middle latitudes of both hemispheres.
- In the northern hemisphere, they are also found on the west coast of the continents in the higher latitudes (E.g. Alaska and Norwegian Currents).

B. Cold Ocean Currents:

- Those currents which flow from Polar Regions towards equator have a lower surface temperature and are called cold currents.
- They bring cold water to the warm areas.
- These currents are usually found on the west coast of the continents in low and middle latitudes of both hemispheres.
- In the northern hemisphere, they are also found on the east coast in the higher latitudes (E.g. Labrador, East Greenland and Oyashio currents).

3.3.4 Classification of Ocean Currents

1. **Surface Current**: they constitute about 10% of all the waters in an ocean. These waters are occupied at the upper 400m of an ocean or the EKMAN LAYER.
2. **Deep Water Current**: they constituent about 90% of the ocean water. They move around the ocean basin due to variations in the density and gravity.

Table 1: Differences between Waves, Tides and Currents

S/N	Waves	Tides	Current
1.	Formed due to the forces exerted by winds on the water surface	Formed due to the interaction of the gravitational forces between the Earth, sun and Moon	Formed as a result of temperature differences on oceanic surfaces
2.	Waves are defined as the energy that moves across the surface of the water	Tides are defined as the rise and fall of the sea level	Currents are defined as the direction of flow of a body of water
3.	The intensity of waves are influenced by wind factors	The intensity of tides are influenced by the location and position of the Earth	The intensity of currents are influenced by winds, temperature differences in water and the oceanic surface topography
4.	Waves occur regularly across bodies of water	Tides occur twice a day	Equatorial currents like El Nino occur every few years
5.	Waves move from side to side	Tides moves up and down	Currents flow clockwise in the Northern hemisphere and counter clockwise in the Southern Hemisphere. This is known as Coriolis Effect

4.0 CONCLUSION

Tides, waves and currents are completely different. They form under different conditions and are influenced by different factors. Waves are somewhat more noticeable than tides and currents while tides can often be seen on the shore.

5.0 SUMMARY

Waves, tides and currents are three types of natural phenomena that occur on water and whilst they are similar in nature, they are not the same thing. While all three are related to bodies of water, they differ based on their causes, intensity and frequency among other factors.

6.0 TUTOR MARKED ASSIGNMENTS

i. List the factors that Wave sizes are dependent on?
ii. What is the standard unit to measure the current?
iii. What are the differences between spring tide and Neap Tide:

7.0 REFERENCES AND OTHER RESOURCES

Charlier, R. (2003). A "sleeper" awakes: tidal current power. *Sustainable and Renewable Energy Reviews*, **7**: 515-529.

Dean, R. J. and Dairymple, R. A (2002). *Coastal Processes with engineering applications.* Cambridge University Press. 2pp.

Loren, R. D and Hayes, A. G. (2012). "The Growth of wind-waves in Titan's Hydrocarbon Seas". *Icarus*, **219**: 468 – 475.

Rahmstorf, S. (2003). The concept of the thermohaline circulation. *Nature*, **421** (6924): 699 – 708.

UNIT 5 ORGANIC PRODUCTION IN THE SEA

CONTENTS

1.0 INTRODUCTION

Production is the synthesis of organic compounds from inorganic constituents of sea water by the activities of organism. This is affected almost entirely by the photosynthetic activities of marine plants with traces or organic matter also formed by chemosynthesis.

2.0 OBJECTIVES

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

- understand the process of photosynthesis
- understand the different trophic levels in the Ocean.
- Explain the methods of measurement of primary production in the sea.

3.0 MAIN CONTENT

3.1 ORGANIC PRODUCTION

Ocean productivity largely refers to the production of organic matter by "phytoplankton," plants suspended in the ocean, most of which are single-celled. Phytoplankton are "photoautotrophs," harvesting light to convert inorganic to organic carbon, and they supply this organic carbon to diverse "heterotrophs," organisms that obtain their energy solely from the respiration of organic matter. Open ocean heterotrophs include bacteria as well as more complex single- and multi-celled "zooplankton" (floating animals), "nekton" (swimming organisms, including fish and marine mammals), and the "benthos" (the seafloor community of organisms).

3.1.1 The raw materials of organic production in the sea are:

- Water (H_2O)
- Carbon dioxide (CO_2)
- various substances including inorganic ions.

Chlorophyllous plants make use of light energy and combines these simple substances to synthesize complex organic molecules. Such synthesis is known as GROSS PRIMARY (1°) PRODUCTION.

The chief products are the major categories of the food materials such as carbohydrate (CHO), proteins and fats. The formation of such organic carbon compounds from inorganic compounds involves a reduction reaction and the reducing power comes from either the absorption of light (Photosynthesis) or the oxidation of other compounds (Chemosynthesis).

Phytoplankton are the principle agents responsible for photosynthetic primary production in the ocean. In coastal regions, benthic micro and micro algae and submerged vascular plants all contributes to the organic production in the sea. It is significant that primary production provides a base for most of the marine food chains.

Primary production is also a rate which involves dimension of time and that is why the rate of primary production is given as:
$mgCm^{-3}s^{-1}$ (milligram of carbon incorporated per unit area per unit time).
Typical rates for the oceans are between 10 – 100 $mgCm^{-3}d^{-1}$.

The rate of primary production is set by the concentration of phytoplankton (which is called also the photosynthetic biomass), particular the concentration of Carbon or chlorophyll A.

Photosynthetic Biomass = mass of carbon contained within living phytoplankton cells per unit volume per unit area. Mathematically represented thus: $mgCdm^{-3}$.
For typical oceanic water, the range of biomass (carbon) per unit area is $1.2gCm^{-2}$. This can be determined in the laboratories using Float Cytometer.

The mass of chlorophyll A contains within living phytoplankton cell per unit volume or per unit area is known as Photosynthetic Biomass (Chlorophyll A). The typical oceanic range is between 10 – 100 $mgChla/m^2$ i.e. milligram of Chlorophyll A per meter square surface area.

3.2 MAJOR PLAYERS IN ORGANIC PRODUCTION IN THE SEA

3.2.1 Photoautotrophs: in contrast to the terrestrial biosphere, most marine photosynthesis is conducted by single-celled organisms, and the more abundant of the multicellular forms are structurally much simpler than the vascular plants on land. During much of the twentieth century, it was thought that cells in the range of ~5 to ~100 microns diameter account for most phytoplankton biomass and productivity. This size range is composed mostly of eukaryotes, organisms whose cells contain complex membrane-bound structures (“organelles”), including the cell’s nucleus and chloroplasts.

Well studied forms of eukaryotic phytoplankton include the opal-secreting diatoms, prymnesiophytes (including the CaCO3-secreting coccolithophorids), and the organic wall-forming dinoflagellates. The centrality of these organisms in early oceanographic thought was due to their accessibility by standard light microscopy. Only with recent technological advances have smaller organisms become readily observable, revolutionizing our view of the plankton. In particular, the cyanobacteria, which are prokaryotes (lacking a nucleus and most other organelles found in eukaryotes), are now known to be important among the phytoplankton. Initially, the cyanobacteria were identified largely with colonial forms such as Trichodesmium that play the critical role of “fixing” nitrogen (see below).

However, major discoveries over the last thirty years have revealed the prevalence across the global ocean of unicellular cyanobacteria of ~0.5

to ~1.5 microns' diameter. It is now recognized that two cyanobacterial genera — *Synechoccocus* and *Prochlorococcus* — dominate phytoplankton numbers and biomass in the nutrient-poor tropical and subtropical ocean (Waterbury et al. 1979, Chisholm *et al.* 1988). In addition, new methods, both microscopic and genetic, are revealing a previously unappreciated diversity of smaller eukaryotes in the open ocean.

Mapping ecological and biogeochemical functions onto the genetic diversity of the phytoplankton is an active area in biological and chemical oceanography. Based on observations as well as theory, the smaller phytoplankton such as the unicellular cyanobacteria are thought to dominate regenerated production in many systems, whereas the larger eukaryotes appear to play a more important role in new production.

3.2.2. **Heterotrophs**: just as large eukaryotes were once thought to dominate the phytoplankton; it was long believed that multicellular zooplankton of ≥200 microns dominate heterotrophy — the small crustaceans known as copepods are the prototypical example. We now know that heterotrophy is often dominated by single-celled eukaryotes ("microzooplankton," of ~1 to ~200 microns) and by bacteria (of ~0.3 to ~1 microns), the latter carrying out most of the organic carbon decomposition in the ocean.

The food source of a given form of zooplankton is typically driven by its own size, with micro zooplankton grazing on the prokaryotes and smaller eukaryotes and multicellular zooplankton grazing on larger eukaryotes, both phytoplankton and microzooplankton. Because of their relative physiological simplicity, microzooplankton are thought to be highly efficient grazers that strongly limit the biomass accumulation of their prey.

In contrast, the multicellular zooplankton, because they typically have more complex life histories, can lag behind the proliferation of their prey, allowing them to bloom and sometimes avoid predation altogether and sink directly. The multicellular zooplankton also often facilitates the production of sinking organic matter, for example, through the production of fecal pellets by copepods.

3.3 Photosynthesis

Photosynthesis is the process by which absorbed light energy is used to split or oxidized water and reduces inorganic carbon dioxide to organic carbon compounds. This is represented with this equation:
$CO_2 + 2H_2O \rightarrow (Ch_2O) + H_2O + O_2$ (in the presence of Sunlight and Chlorophyll A)

For this to take place, the following requirements are needed:

1. Available solar energy in a wave band of 400 – 700nm.
2. Presence of pigments to absorb protons
3. Electron transport chains and biochemistry to produce Adenosine triphosphate (ATP), reducing power NADH and ultimately, a variety of organic compounds must be present.

Some of the organic compounds produced by plants is broken down again to inorganic state by plants themselves in the cause of respiration. The reminder of the manufactured food becomes plant tissues and is referred to as NET PRIMARY (1°) PRODUCTION.
Net Primary Production = Gross Primary Production – Respiration.

So, this is a major importance as a source of food to herbivorous animals. The animal production of the sea depends directly or indirectly upon the net primary production. The greater part of the primary production in the sea are formed by phytoplankton under favorable conditions, the phytoplankton is capable of remarkably rapid growth, sometimes producing its own weight of new organic materials in 24 hours. A rate greater than this is achievable by land plants.

The large marine algae growing on the sea bottom in shallow water makes only relatively small contributions to the total production in the sea because they are of restricted distribution. The consumption of plants by herbivorous animals leads to the formation of animal tissues, this is secondary (2^{o}) production which in turns becomes food for the 1st rank carnivorous animals ie 3rd production and this may fall prey to other carnivores.

It is this successive stages of living tissues that forms a series of trophic levels or links in the food chain. The connections are complicated because many creatures take food from several trophic levels and the links of the food chains becomes interconnected to forms intricate food webs.

Between each trophic levels, there are large losses of organic materials caused in several ways. For instance, a proportion of each organism at each trophic levels are not eaten by animals but simply die and decompose by autolysis and bacterial actions.

Some of the food that animals consume is injected and unassimilated and most of the assimilated food is broken down by respiration, leaving only a small proportion to form new tissues. The efficiency of transfer from organic matter from one trophic level to the next varies with the type of organisms; herbivores generally doing better than carnivores.

As a result of respiration and excretion, death and decomposition, organic matters become broken down and returns to water as simple substances which plants can utilize in primary production. Therefore, matter is continuously cycled from inorganic to organic forms and back to inorganic states.

3.4 Methods of measurement of primary production in the sea

There are several attempts to estimate the rate of primary production in the sea. It is pertinent to point that the accuracy of any of this method is in doubt. Production rates are usually expressed as "the weight of Carbon fixed in organic compounds beneath unit area of sea surface in unit time".
Mathematically, this can be represented thus:

$$gC/m^3/day$$

Estimate of Net primary production often falls within the range of 0.05 – 0.5g/m^2/day or within values as high as 5.0gC/m^2/day in most production sea area. Compared to land however, the production rate in most fertile agricultural land may exceed 10gC/m^2.

3.4.1 Methods of Estimation:

1. **Standing Crop Measurement**: This is an indirect method that estimate the total amount of plant materials in the water which is referred to as the standing crop. Taking into account, the rate of change in population.
2. **Direct Count Measurement**: this is a direct count of the plant cells in a measured volume of water. These must be taken note of; plankton net may not collect all the water; possible influence of other inorganic compounds of the cells that are not useful.
3. **Chlorophyll Estimate**: this is usually written as U.P.P. (Unit of Plant Pigment). Chlorophyll A present in the chloroplast of plants is extracted using alcohol.
4. **Carbohydrate Estimate**: when the food matter is synthesized, the primary production is made. All the carbohydrate present in the measured volume of water.
5. **Zooplankton Cell Plants**: this involves estimating the properties of the zooplankton, having in mind the type of food that the zooplankton feeds on. It is an indirect method and has its own disadvantages.
6. **Measurement of Nutrients Uptake**: this is important in the ocean before without it production of food will not take place. Example of nutrient uptake include phosphates, nitrates, e.t.c.

7. **Measurement of Photosynthesis**: oxygen bottle experiment and the carbon dioxide uptake experiment can be used in this measurement. In photosynthesis, carbon dioxide and water are used to produce carbohydrate and oxygen. So, either the increasing amount of oxygen is calculated or the decreasing amount of carbon dioxide is measured.

4.0 CONCLUSION

The diversity of the plankton interacts with open ocean environmental conditions to affect the productivity of the larger ecosystem (Buesseler 1998). In the nutrient-poor tropical and subtropical ocean, the (small) cyanobacteria tend to be numerically dominant, perhaps because they specialize in taking up nutrients at low concentrations. Small phytoplankton have a greater surface area-to-volume ratio than do large phytoplankton. A greater proportional surface area promotes the uptake of nutrients across the cell boundary, a critical process when nutrients are scarce, likely explaining why small phytoplankton dominate the biomass in the nutrient-poor ocean.

5.0 SUMMARY

Ocean productivity refers to the production of organic matters by green plants (phytoplankton) in the ocean in the presence of raw materials like water, carbon dioxide, inorganic ions, etc. photosynthesis is the process by which absorbed light energy is used to split water and produce food. Various methods of estimations are standing crop, direct count, Chlorophyll estimate, etc.

6.0 TUTOR MARKED QUESTIONS

i. Explain the term “Organic productivity”.
ii. List the raw materials needed for productivity to occur in the sea.
iii. Define the term “photosynthesis” and include its equation.
iv. List the methods of estimation and explain any three (3).

7.0 REFERENCES AND OTHER RESOURCES

Buesseler, K. O. (1998). The decoupling of production and particulate export in the surface ocean. *Global Biogeochemical Cycles*, **12**: 297-310.

Morel, F. M. M. (2008). The co-evolution of phytoplankton and trace element cycles in the oceans. *Geobiology*, **6:** 318-324.

Sarmiento, J. L. and Bender, M. (1994). Carbon biogeochemistry and climate change. *Photosynthesis Research*, **39**: 209-234

Sigman, D. M., Hain, M. P. and Haug, G. H. (2010). The polar ocean and glacial cycles in atmospheric CO_2 concentration. *Nature,* **466:** 47-55.

Weber, T. S. and Deutsch, C. (2010). Ocean nutrient ratios governed by plankton biogeography. *Nature*, **467:** 550-554.

UNIT 6 ENERGY TRANSFERS AND PYRAMIDS IN THE SEA

CONTENTS

1.0 INTRODUCTION

Production is the synthesis of organic compounds from inorganic constituents of sea water by the activities of organism either by photosynthetic activities or by chemosynthesis. The energy captured by this process is the source of the carbon in all the organic compounds within organisms' bodies. In an ecosystem, the energy transfer pathway can be a linear food chains or the cross-linked food web. All plants and animals in an ecosystem are part of this feeding relationship. The number of steps an organism is from the start of the chain is a measure of its trophic level. An ecological pyramid (also known as trophic pyramid or energy pyramid) is a graphical representation designed to show the biomass or biomass productivity at each trophic level in a given ecosystem.

2.0 OBJECTIVES

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

- understand the process of energy production and accumulation
- Explain the various mode of energy transfer pathways in the sea.

- understand the different ecological pyramids

3.0 MAIN CONTENT

3.1 ENERGY TRANSFERS AND PYRAMIDS

A small amount of the energy stored in plants, between 5 and 25 percent, passes into herbivores (plant eaters) as they feed, and a similarly small percentage of the energy in herbivores then passes into carnivores (animal eaters). The result is a pyramid of energy, with most energy concentrated in the photosynthetic organisms at the bottom of food chains and less energy at each higher trophic level (a division based on the main nutritional source of the organism).

Photosynthesis from the Greek word *[photo-]*, "light," and *[synthesis]*, "putting together", "composition") is a chemical process that converts carbon dioxide into organic compounds, especially sugars, using the energy from sunlight. Photosynthesis occurs in plants, algae, and many species of bacteria, but not in archaea. Photosynthetic organisms are called *photoautotrophs*, since they can create their own food.

In plants, algae, and cyanobacteria, photosynthesis uses carbon dioxide and water, releasing oxygen as a waste product. Photosynthesis is vital for all aerobic life on Earth. In addition to maintaining normal levels of oxygen in the atmosphere, photosynthesis is the source of energy for nearly all life on earth, either directly, through primary production, or indirectly, as the ultimate source of the energy in their food, the exceptions being chemoautotrophs that live in rocks or around deep sea hydrothermal vents.

The rate of energy capture by photosynthesis is immense, approximately 100 terawatts, which is about six times larger than the power consumption of human civilization. As well as energy, photosynthesis is also the source of the carbon in all the organic compounds within organisms' bodies. In all, photosynthetic organisms convert around 100–115 pentagrams of carbon into biomass per year.

3.2. FOOD CHAINS AND FOOD WEBS AND/OR FOOD NETWORKS

The feeding of one organism upon another in a sequence of food transfers is known as a food chain. Another definition is the chain of transfer of energy (which typically comes from the sun) from one organism to another. A simple food chain is like the following:

rose plant -- aphids -- beetle -- chameleon -- hawk.
In this food chain, the rose plant is the primary producer. The aphids are the primary consumers because they suck the juice from the rose plant. The beetle is the primary carnivore because it eats the aphids. The chameleon, a secondary carnivore, eats the beetle. The hawk is the tertiary carnivore because it eats the secondary carnivore, the chameleon. The hawk eventually dies and its remains are broken down by decay-causing bacteria and fungi.

Except in deep-sea hydrothermal ecosystems, all food chains start with photosynthesis and will end with decay.

3.2.1 FOOD CHAIN

A food chain describes a single pathway that energy and nutrients may follow in an ecosystem.

There is one organism per trophic level, and trophic levels are therefore easily defined.

They usually start with a primary producer and end with a top predator.
An example of a food chain:

phytoplankton → copepod → fish → squid → seal → orca.
It can also be somewhat a linear sequence of links in a food web starting from a trophic species that eats no other species in the web and ends at a trophic species that is eaten by no other species in the web.

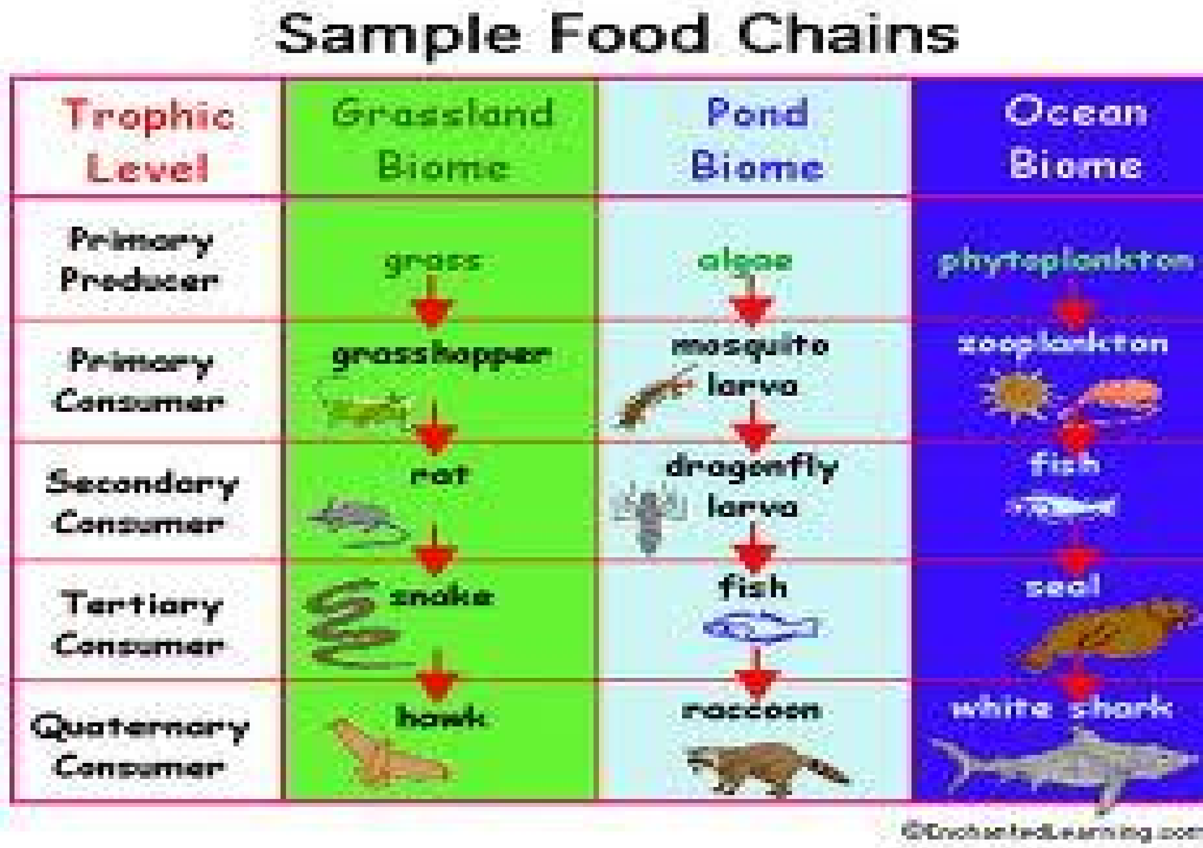
A food chain differs from a food web, because the complex polyphagous network of feeding relations is aggregated into trophic species and the chain only follows linear monophagous pathways.

A common metric used to quantify food web trophic structure is food chain length.

In its simplest form, the length of a chain is the number of links between a trophic consumer and the base of the web and the mean chain length of an entire web is the arithmetic average of the lengths of all chains in a food web.

Food chain studies have had an important role in ecotoxicology studies tracing the pathways and biomagnification of environmental contaminants. Food chains vary in length from three to six or more levels. A food chain consisting of a flower, a frog, a snake and an owl

consists of four levels; whereas a food chain consisting of grass, a grasshopper, a rat, a snake and finally a hawk consists of five levels.
Producers are organisms that utilize solar energy or heat energy to synthesise starch e.g. plants. All food chains must start with a producer. Consumers are organisms that eat other organisms. All organisms in a food chain, except the first organism, are consumers.



Sample Food Chains

Trophic Level	Grassland Biome	Pond Biome	Ocean Biome
Primary Producer	grass	algae	phytoplankton
Primary Consumer	grasshopper	mosquito larva	zooplankton
Secondary Consumer	rat	dragonfly larva	fish
Tertiary Consumer	snake	fish	seal
Quaternary Consumer	hawk	raccoon	white shark

3.2.2 Food Webs

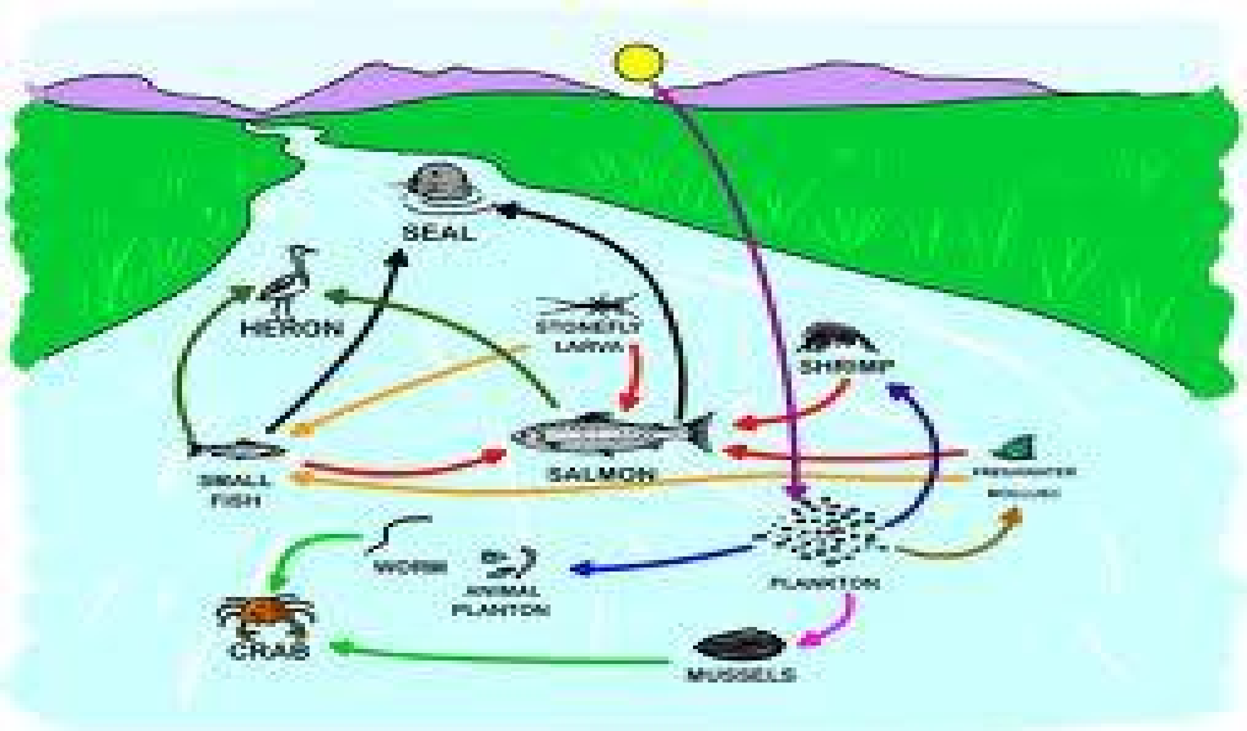
In an ecosystem there are many different food chains and many of these are cross-linked to form a food web. Ultimately all plants and animals in an ecosystem are part of this complex food web.

Food chains and food webs and/or food networks describe the feeding relationships between species in a biotic community. In other words, they show the transfer of material and energy from one species to another within an ecosystem.

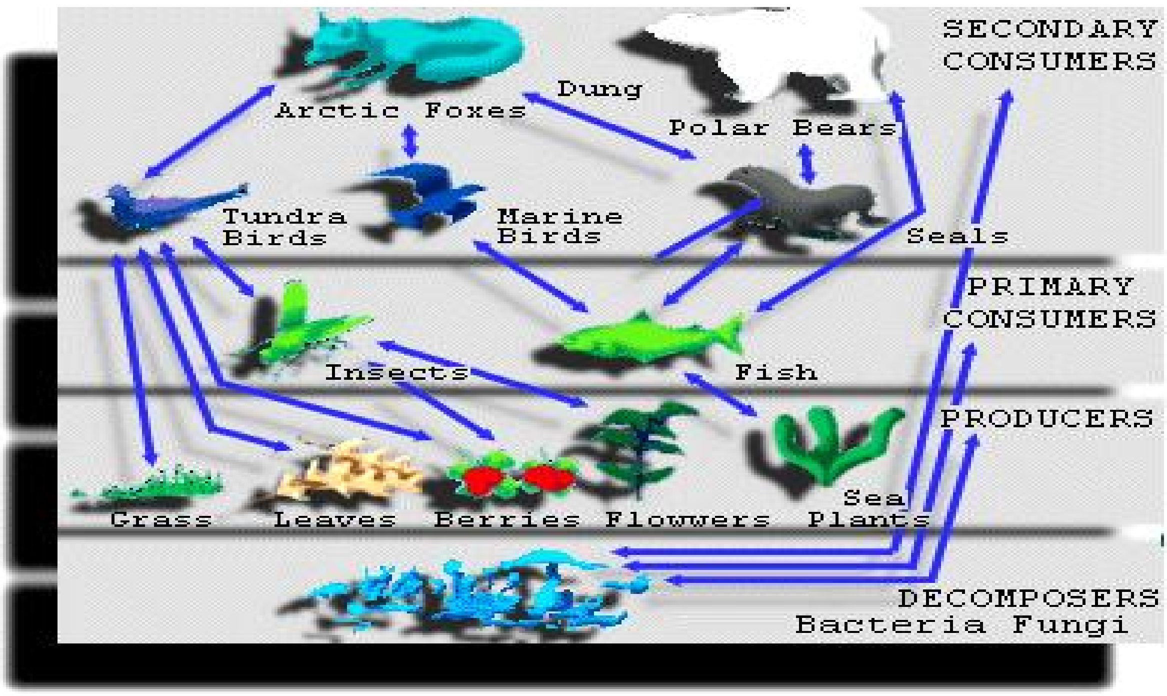
As usually put, an organism is connected to another organism for which it is a source of food energy and material by an arrow representing the direction of biomass transfer.

Organisms are grouped into trophic levels based on how many links they are removed from the primary producers.

Primary producers, or autotrophs, are species capable of producing complex organic substances (essentially "food") from an energy source and inorganic materials.
These organisms are typically photosynthetic plants, bacteria or algae, but in rare cases, like those organisms forming the base of deep-sea vent food webs, can be chemotrophic. All organisms that eat the autotrophs are called heterotrophs. They get their energy by eating the producers.



Aquatic food web



3.2.3 The Trophic level

The trophic level of an organism is the position it occupies in a food chain. The word trophic derives from the Greek (trophē) referring to food or feeding. A food chain represents a succession of organisms that eat another organism and are, in turn, eaten themselves.

The number of steps an organism is from the start of the chain is a measure of its trophic level. Food chains start at trophic level 1 with primary producers such as plants, move to herbivores at level 2, predators at level 3 and typically finish with carnivores or apex predators at level 4 or 5. The path along the chain can form a one-way flow, or a food "web." Ecological communities with higher biodiversity form more complex trophic paths.

Trophic levels are the feeding position in a food chain such as primary producers, herbivore, primary carnivore. Green plants form the first trophic level, the producers. Herbivores form the second trophic level, while carnivores form the third and even the fourth trophic levels. In this section we will discuss what is meant by food chains, food webs and ecological pyramids.

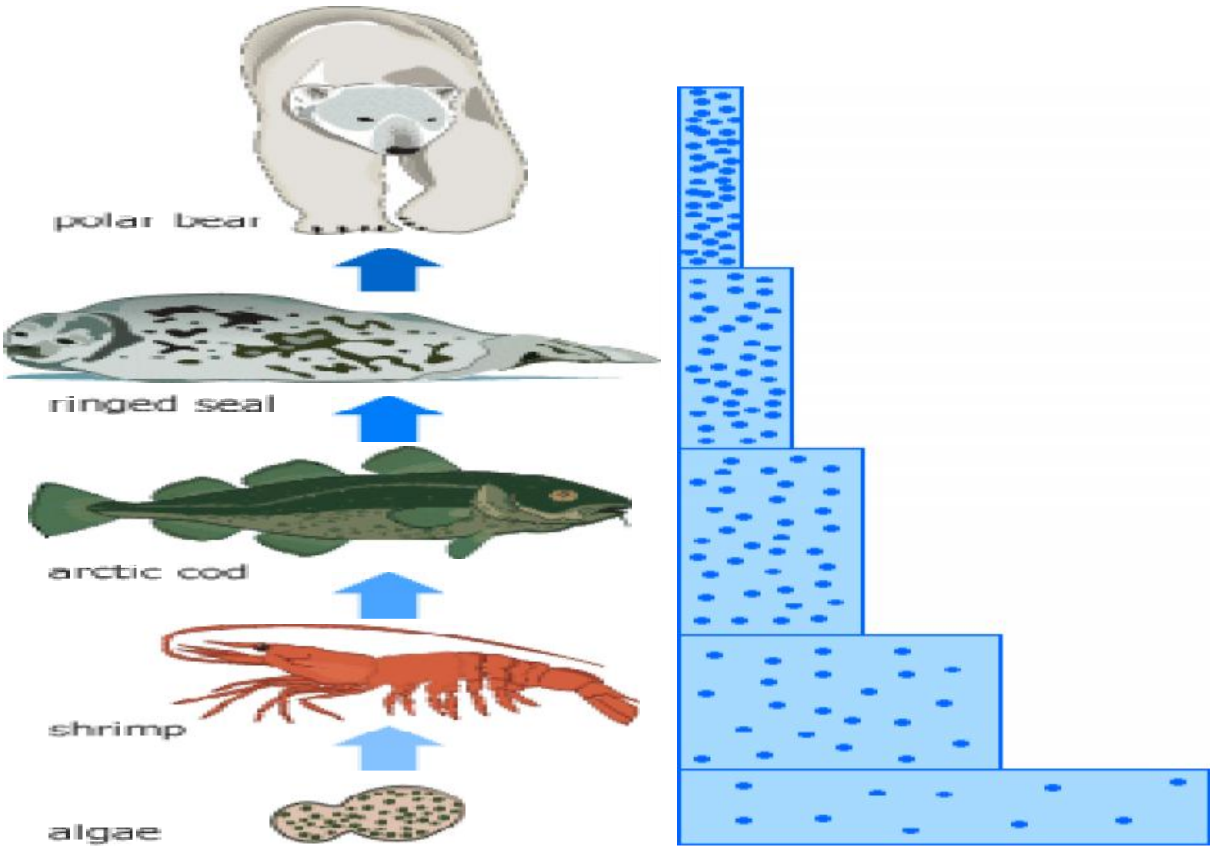
The three basic ways organisms get food are as producers, consumers and decomposers.

1. Producers (autotrophs) are typically plants or algae. Plants and algae do not usually eat other organisms, but pull nutrients from the soil or the ocean and manufacture their own food using photosynthesis. For this reason, they are called primary producers. In this way, it is energy from the sun that usually powers the base of the food chain. An exception occurs in deep-sea hydrothermal ecosystems, where there is no sunlight. Here primary producers manufacture food through a process called chemosynthesis.
2. Consumers (heterotrophs) are animals which cannot manufacture their own food and need to consume other organisms. Animal that eat primary producers (like plants) are called herbivores. Animals that eat other animals are called carnivores, and animals that eat both plant and other animals are called omnivores.
3. Decomposers (detritivores) break down dead plant and animal material and wastes and release it again as energy and nutrients into the ecosystem for recycling. Decomposers, such as bacteria and fungi (mushrooms), feed on waste and dead matter, converting it into inorganic chemicals that can be recycled as mineral nutrients for plants to use again. Trophic levels can be represented by

numbers, starting at level 1 with plants. Further trophic levels are numbered subsequently according to how far the organism is along the food chain.

Level 1: Plants and algae make their own food and are called primary producers.
Level 2: Herbivores eat plants and are called primary consumers.
Level 3: Carnivores which eat herbivores are called secondary consumers.
Level 4: Carnivores which eat other carnivores are called tertiary consumers.
Level 5: Apex predators which have no predators are at the top of the food chain

The trophic level



3.2.4 Biomass

Biomass is the amount of living or organic matter present in an organism. In ecology, biomass refers to the accumulation of living matter. It is the total living biological material in a given area or of a biological community or group.

Biomass pyramids show how much biomass is present in the organisms at each trophic level, while *productivity pyramids* show the production or turnover in biomass.

3.3 Ecological Pyramids

Ecological pyramids begin with producers on the bottom (such as plants) and proceed through the various trophic levels (such as herbivores that eat plants),

then carnivores that eat herbivores, then carnivores that eat those carnivores, and so on). The highest level is the top of the food chain. An ecological pyramid (also trophic pyramid or energy pyramid) is a graphical representation designed to show the biomass or biomass productivity at each trophic level in a given ecosystem. i.e. Trophic levels and the energy flow from one level to the next, can be graphically depicted using an ecological pyramid.

Three types of ecological pyramids can usually be distinguished namely:

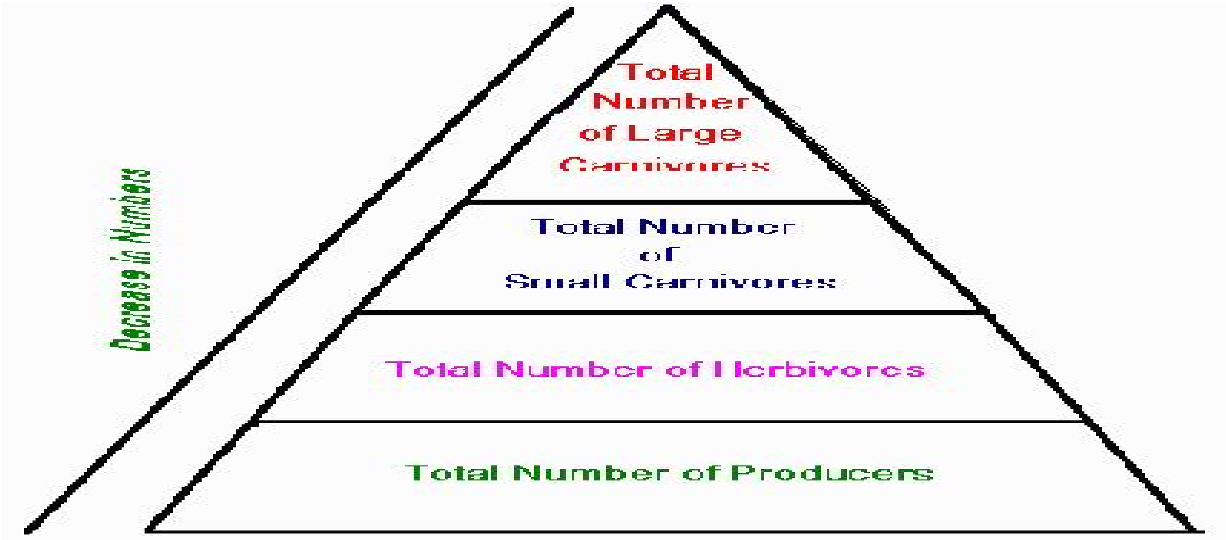
1. Number pyramid.
2. The Biomass Pyramid
3. Energy pyramid.

3.3.1 Number pyramid.

It is easily understood that many grass plants are needed to feed fewer snails on which, in turn, even fewer chickens would be able to feed.
This in turn requires only a few people to eat the chickens that ate the snails.

The Number pyramid shows the number of organisms in each trophic level and does not take into consideration the size of the organisms and over-emphasizes the importance of small organisms.

In a pyramid of numbers, the higher up one moves, so each consecutive layer or level contains fewer organisms than the level below it.

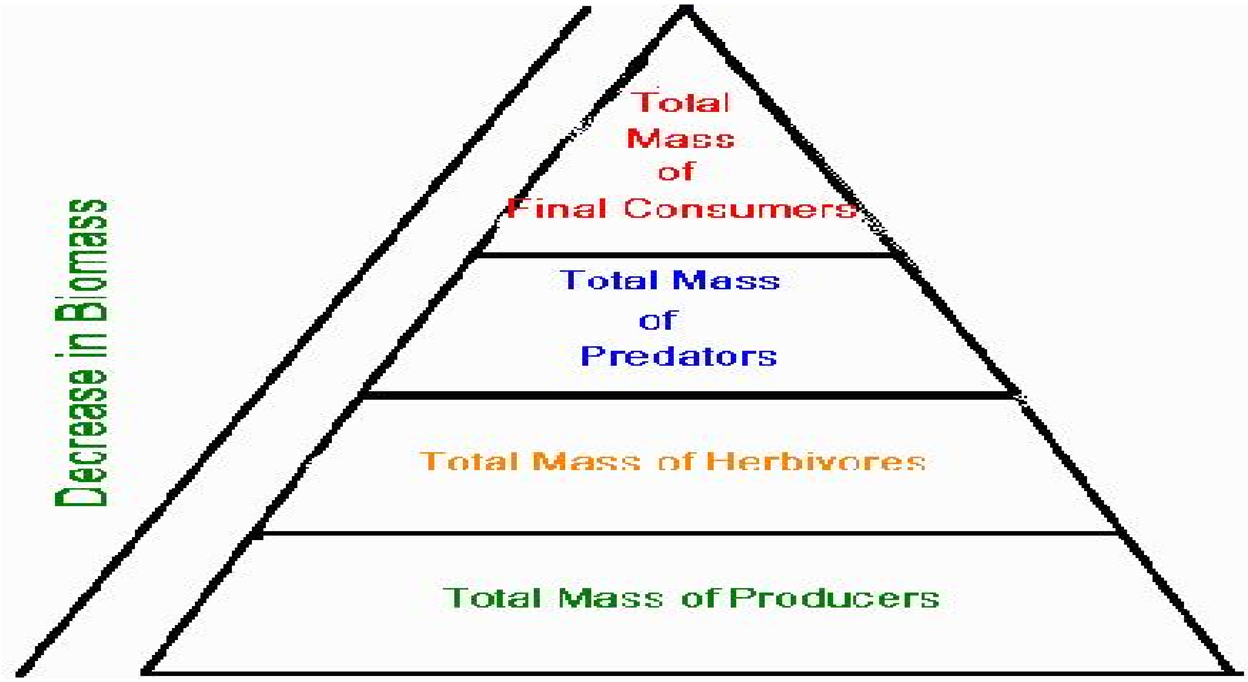


3.3.2 Biomass pyramid.

This pyramid indicates the total mass of the organisms in each trophic level.

The size of the organism is over-emphasized and it can happen that the mass of level 2 is greater than that of level 1, because the productivity of level 1 is not taken into consideration.

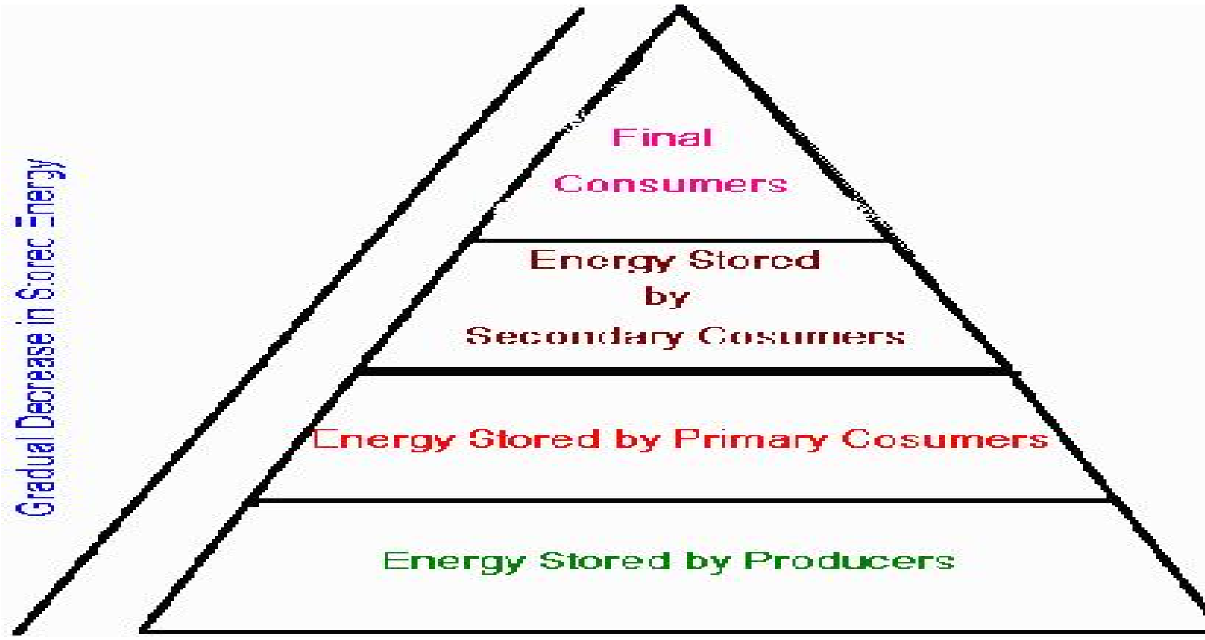
Thus an enormous mass of grass is required to support a smaller mass of buck, which in turn would support a smaller mass of lions.



3.3.3 Energy pyramid.

The Energy pyramid indicates the total amount of energy present in each trophic level. It also shows the loss of energy from one trophic level to the next.

An energy pyramid shows clearly that the energy transfers from one trophic level to the next is accompanied by a decrease due to waste and the conversion of potential energy into kinetic energy and heat energy. The energy pyramid is more widely used than the others because comparisons can be made between trophic levels of different ecosystem. It is, however, more difficult to compile an energy pyramid than it is compile the other types of pyramids.



4.0 CONCLUSION

The dynamics of productivity, transfer of material and energy from one species to another within an ecosystem is highly critical and systemic. The lower organism at the bottom of the feeding pathway are critical to maintaining balance and crucial for starting a food chain as they make their own food.

5.0 SUMMARY

The transfer of energy in the sea results into a pyramid , with most energy concentrated in the photosynthetic organisms at the bottom of food chains and less energy at each higher trophic level. In addition to providing descriptive anatomical accounts, attention is given to describing the food accumulation and feeding pathway as these are important in the discussions of food webs and energy transfer which follow. Ecological communities with higher biodiversity form more complex trophic paths.

6.0 TUTOR MARKED QUESTIONS

1. Explain the term "Energy Transfer" in the aquatic environment".
2. List the various pathway or feeding regimes in the sea.
3. Define the term "food web" and trophic levels.
4. List and draw the ecological pyramids and its uniqueness.

7.0 REFERENCES AND OTHER RESOURCES

Buesseler, K. O. (1998). The decoupling of production and particulate export in the surface ocean. *Global Biogeochemical Cycles,* **12**: 297-310.

Morel, F. M. M. (2008). The co-evolution of phytoplankton and trace element cycles in the oceans. *Geobiology,* **6:** 318-324.

Sarmiento, J. L. and Bender, M. (1994). Carbon biogeochemistry and climate change. *Photosynthesis Research,* **39**: 209-234

Sigman, D. M., Hain, M. P. and Haug, G. H. (2010). The polar ocean and glacial cycles in atmospheric CO_2 concentration. *Nature,* **466:** 47-55.

Weber, T. S. and Deutsch, C. (2010). Ocean nutrient ratios governed by plankton biogeography. *Nature,* **467:** 550-554.

UNIT 7 FACTORS REGULATING PRODUCTION IN THE SEA

CONTENTS

1.0 INTRODUCTION

Some chemical factors are needed in the sea for regulations before organic production can occur in the sea.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- understand the factors responsible for the regulation of production in the sea
- understand the organic production in the different geographical zones of the sea.

3.0 MAIN CONTENT

3.1 Factors Responsible for the Regulation of production in the Sea

3.1.1 Light

The energy of the solar radiation becomes fixed as chemical energy in organic compounds in the process of photosynthesis. The efficiency of the ocean surface in the energy transformation varies with locality and conditions.

On the average, it is about 0.1 and 0.2 % lower than that on the land surface. Photosynthesis is limited to the illuminated surface of the sea and the usefulness measure of the extent of this production layer is the compensation depth.

Compensation depth is the depth at which the production of organic materials by photosynthesis exactly balances the breakdown of organic matters by plants respiration. The compensation depth obviously varies continually with changes of illumination and most be define with respect to time and place.

In the low latitude (in the tropics), the Noon compensation depth usually lies below a 100m throughout the year. In the high latitude, the Noon compensation depth usually lies between 0 – 60m reducing to 0m during the winter when virtually no production occurs.

Photosynthesis varies in proportion to light intensity up to a limit at which plants becomes light saturated and further increase of illumination produces no further increase of photosynthesis. Exposures to strong light is harmful and depresses photosynthesis.

In bright day light, the illumination of the sea surface seems often to be at or above the saturation level for most of the phytoplankton and measurement of photosynthesis in this condition shows that maximum production occurs some distance below the surface usually between 5 – 20m.

The maximum quality of phytoplankton is seldom found very close to the surface and this may be regarded as “Shade Plants”.

3.1.2. Temperature

The rate of photosynthesis increase with rise in temperature up to a maximum beyond which it diminishes sharply with further rise of temperature. Temperature and illumination influence the seasonal variation in rate of production especially in temperate latitude.

But more especially, apart from its small direct influence on photosynthesis, it also influences the production rate indirectly through its effects on movement and mixing of water and hence, the supply of nutrients to the photic zone.

3.1.3. Nutrients

Apart from carbon dioxide dissolve in sea water, there are also present ample quantities of other substances called Nutrients which plants also extracts from the water, which are essential for their growth. Many of these substances are minor constituents of sea water, they are present in very low concentration but their supply exacts a dominate role in the production.

Nitrates and Phosphorus are of very special importance. Iron and Manganese are other essential nutrients while silicon is required by diatoms. Molybdenum and cobalt are also necessary for some plants. The absorption of nutrients by the phytoplankton reduces the concentration of these substances in the surface layer and this limits the extents to which the production of these planktons can increase.

A certain amount of the nutrients absorbed by the phytoplankton may be regenerated and recycled within the photic zone but plants are continuously being lost in the surface layer through sinking and consumption by the zooplanktons.

Therefore, much of the nutrients absorbed from the surface layer are regenerated at the deeper and darker layer of the water. Consequently, the nutrients accumulates at deep layers unless they are returned to the near surface water by vertical movement such as turbulence, upwelling, e.t.c. therefore, the productivity of near surface water over most of the ocean is controlled by the rate at which nutrients rich water returns to the photic zone.

3.2. Production in Different geographical Zones of the Sea

A man known as Raymount in 1980 postulated a table in estimating the production in various zones of the sea.

Table 1: Production in different zones of the Sea

S/ No	Zones	% productivity gClm^2/year
1	Continental Shelf	100 – 160
2	Tropical Ocean	18 – 50
3	Temperate Ocean	70 – 120
4	Antarctic Ocean	100
5	Arctic Ocean (Sub-polar)	Less than 1

Coastal oceans areas are especially productive because nutrients in the deep sub-surface water are mixed back to the photic zone by turbulence caused by tidal currents flowing over irregular shallow ocean bottoms and by storms, winds and waves.

The estuarine circulation of most coastal ocean areas also bring nutrients to the surface water. Estuaries circulations tends to retain particles and planktonic organisms and their associated nutrients in the coastal oceans. Over most of the open ocean in temperate and tropic areas, productivity is relatively very low due to nutrients depletion in surface water.

Along the equatorial however, nutrients are brought to the surface layer by upwelling. Thus, these equatorial upwelling areas are highly productive for phytoplankton and fishes. In the trophic waters, there is always enough light to sustain photosynthesis thus phytoplankton abundance is controlled by the supply of nutrients.

Storms usually cause mixing which causes small blooms but in sub-tropical waters, the phytoplankton bloom occurs in spring followed by the zooplankton bloom. In Sub-polar water, there is too little light during most of the year to support abundant phytoplankton growth.

4.0 CONCLUSION

The understanding of the factors responsible for the production of organic matters in the sea and the rate of exposure of these surface areas determines the presence or absence of phytoplankton.

5.0 SUMMARY

Light, Nutrient and Temperature are basic factors responsible for production in the sea. The Artic Oceans has less than 1% of productivity while the Continental shelf is most productive with about 100 – 160% productivity. There is always enough light in the tropic waters to sustain photosynthesis and thus, phytoplankton abundance.

6.0 TUTOR MARKED ASSIGNMENTS

i. Discuss in details, the factors responsible for the regulation of organic production in the sea.
ii. Using a table ONLY, explain production that takes place in the different zones of the sea.

7.0 REFERENCES AND OTHER RESOURCES

Christensen, J. P. (1994). Carbon export from continental shelves, denitrification and atmospheric carbon dioxide. *Continental Shelf Research* **14**: 547-576.

Dalsgaard, T., Thamdrup, B. and Canfield, D. E. (2005). Anaerobic ammonium oxidation (anammox) in the marine environment. *Research in Microbiology* **156**: 457-464.

Weber, T. S. and Deutsch, C. (2010). Ocean nutrient ratios governed by plankton biogeography. *Nature*, **467:** 550-554.

UNIT 8 BIOGEOCHEMICAL CYCLES

CONTENTS

1.0. INTRODUCTION

Biological oceanography is a field of study that seeks to understand what controls the distribution and abundance of different types of marine life, and how living organisms influence and interact with processes in the oceans.

Biological oceanographers study all forms of life in the oceans, from microscopic plants and animals to fish and whales. In addition, biological oceanographers examine all forms of oceanic processes that involve living organisms. These include processes that occur at molecular scales, such as photosynthesis, respiration, and cycling of essential nutrients, to large scale processes such as effects of ocean currents on marine productivity

Biological Oceanography seeks to understand the life histories and population dynamics of marine organisms and how they interact with their environment. It is an interdisciplinary field that integrates biology with physics, chemistry, and geology. Scientists study organisms ranging in size from bacteria and viruses to fishes and whales that may range over entire ocean basins or be restricted to isolated hydrothermal vents or coral reef communities.

Biological Oceanography (BIO) focuses its research on the planktonic food web structure and dynamics comprising phytoplankton, prokaryotes, micro- and mesozooplankton and viruses. Planktonic food webs and particularly the interactions between the individual functional groups within the food webs are the main driving forces of oceanic biogeochemical fluxes.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- understand the various biogeochemical cycles operating to maintain atmospheric and ecosystem balance.
- understand the concepts of budget associated with every cycle.
- Establish the cycles represent a qualitative description of processes; budgets turn them into quantitative statements.
- distinguish between static budgets and dynamic budgets,

3.0 MAIN CONTENT

3.1 Tools and Technology of Biological Oceanography

Biological oceanographers rely on a variety of tools and use a variety of approaches to aid them in their study of life in the sea.

- Some studies involve laboratory experiments with individual organisms
- The oceanographer must go into the water to directly sample and observe certain types of organisms such as zooplankton.
- Other approaches involve underwater submersible vehicles to gain access to biological communities deep in the ocean, such as those associated with deep-sea hydrothermal vents.
- Many oceanographers use research vessels from which they lower instruments and specialized water sampling gear into the water.

Biological oceanographers employ methods derived from various fields, including molecular biology, immunology, physiology, biochemistry, ecology, and many others.

In addition to making scientific observations, the biological oceanographer uses a variety of models to study the biology of the oceans. Theoretical models are used to examine problems in biological oceanography that cannot be answered through direct observation and measurement.

Major research programs in biological oceanography examine cycles of carbon and other biologically critical elements, such as nitrogen, phosphorus, silicon and iron. These biogeochemical cycles are key in understanding large-scale phenomena such as global warming. Living organisms, particularly phytoplankton (single-celled microscopic plants that utilize photosynthesis), bacterioplankton (marine bacteria), and small animals (zooplankton), play a critical role in biogeochemical cycles.

Other important areas of study include understanding linkages between different levels of the marine food web, from phytoplankton all the way up to fish and marine mammals. Biological oceanographers also study factors that influence biological diversity within the oceans, and the importance of diversity in maintaining biological function.

Understanding and mitigating the decline in biodiversity, such as has occurred with losses of highly diverse coral reef communities, is a primary concern of biological oceanographers.

Researchers also may deal with issues that affect society such as water pollution, overexploitation of fisheries, and harmful algal blooms.

3.2 AIR

Air is a mixture of gases - 78% nitrogen and 21% oxygen - with traces of water vapor, carbon dioxide, argon, and various other components. Air is usually modeled as a uniform (no variation or fluctuation) gas with properties averaged from the individual components.

The water or vapor content in air varies. The maximum moisture carrying capacity of air depends primarily on temperature. The composition of air is unchanged until elevation of approximately 10.000 m. The average air temperature diminishes at the rate of 0.6^{o}C for each 100 m vertical height. "One Standard Atmosphere" is defined as the pressure equivalent to that exerted by a 760 mm column of mercury at 0^{o}C sea level and at standard gravity (32.174 ft/sec^{2})

Other components in air are:

- Sulfur dioxide - SO_2 - 1.0 parts/million (ppm)
- Methane - CH_4 - 2.0 parts/million (ppm)
- Nitrous oxide - N_2O - 0.5 parts/million (ppm)
- Ozone - O_3 - 0 to 0.07 parts/million (ppm)
- Nitrogen dioxide - NO_2 - 0.02 parts/million (ppm)
- Iodine - I_2 - 0.01 parts/million (ppm)
- Carbon monoxide - CO - 0 to trace (ppm)

- Ammonia - NH_3 - 0 to trace (ppm)

Gas	Ratio compared to Dry Air(%)		Molecular Mass - M-(kg/kmol)	Chemical Symbol	Boiling Point	
	By volume	By weight			(K)	(°C)
Oxygen	20.95	23.20	32.00	O_2	90.2	-182.95
Nitrogen	78.09	75.47	28.02	N_2	77.4	-195.79
Carbon Dioxide	0.03	0.046	44.01	CO_2	194.7	-78.5
Hydrogen	0.00005	~ 0	2.02	H_2	20.3	-252.87
Argon	0.933	1.28	39.94	Ar	84.2	-186
Neon	0.0018	0.0012	20.18	Ne	27.2	-246
Helium	0.0005	0.00007	4.00	He	4.2	-269
Krypton	0.0001	0.0003	83.8	Kr	119.8	-153.4
Xenon	$9\ 10^{-6}$	0.00004	131.29	Xe	165.1	-108.1

Many elements cycle through ecosystems, organisms, air (Air is a mixture of gases - *78%* nitrogen and *21%* oxygen - with traces of water vapor, carbon dioxide, argon, and various other components.), water, and soil. Many of these are trace elements. Other elements, including carbon, nitrogen, oxygen, hydrogen, sulfur, and phosphorus are critical components of all biological life.

Together, oxygen and carbon account for 80 percent of the weight of human beings. Because these elements are key components of life, they must be available for biological processes. Carbon, however, is relatively rare in the Earth's crust, and nitrogen, though abundant in the atmosphere, is in a form that is not useable by living organisms.

3.3 Bio-Geo-Chemical Cycles

This term describes everything on Earth. The cycles we discuss will all fall into the big group of biogeochemical cycles.

BIO: Biology - Study of Life / Living things. These cycles all play a role in the lives of living things. The cycles might limit the organisms of Earth or they might happen alongside, changing the environment.

GEO: Earth (third planet from the Sun). Rocks / Land. This refers to the non-living processes at work. Oxygen cycles through many systems. It's

in you and plants for the 'bio' part of the cycle. Oxygen might also wind up in rocks. The 'geo' part of its cycle.
CHEMICAL: Molecules / Reactions / Atoms. All cycles include these small pathways. Complete molecules are not always passed from one point to the next. Sometimes chemical reactions take place that changes the molecules and locations of the atoms. Think about oxidation as an example of the 'chemical' part of these pathways. To sum it up, these pathways are all made of different biological, geological, and chemical processes that help make the world go 'round and life exist on Earth.

Biogeochemical Cycle: the cycling of chemical elements required by life between the living and nonliving parts of the environment. Some examples of these chemical elements are H2O, P, S, N2, O2 and C.

These elements cycle in either a gas cycle or a sedimentary cycle; some cycle as both a gas and sediment.

In a gas cycle elements move through the atmosphere. Main reservoirs are the atmosphere and the ocean.

Gas Cycles:

- Carbon
- Nitrogen
- Oxygen
- Phosphorus
- Sulfur

In a sedimentary cycle elements move from land to water to sediment. Main reservoirs are the soil and sedimentary rocks.

The biogeochemical cycles transport and store these important elements so that they can be used by living organisms.

Each cycle takes many different pathways and has various reservoirs, or storage places, where elements may reside for short or long periods of time. Each of the chemical, biological, and geological processes varies in their rates of cycling. Some molecules may cycle very quickly depending on the pathway.

Carbon atoms in deep ocean sediments may take hundreds to millions of years to cycle completely through the system. An average water molecule resides in the atmosphere for about ten days, although it may be transported many miles before it falls back to the Earth as rain.

3.3.1 The concept of cycles and budgets

Meteorology and oceanography are physical sciences which aim to understand processes in the environment and describe, analyze and predict them in a quantitative manner.

A common way of expressing processes quantitatively is through the concept of cycles and budgets.

On time scales of geological history, all processes on earth are based on a constant reservoir of materials. The forms in which the materials are present change constantly. In a state of equilibrium this change has to be cyclic.

3.4 The Nutrient Cycle

Nutrients are essential for plant and animal life. They undergo a terrestrial and an oceanic cycle. On land nutrients are taken up from the soil by plants and return to the soil by decomposition of dead organic matter. This is a closed cycle on a relatively short time scale, determined by the process of decomposition and life spans of plants, animals and humans. In developed human societies it is only broken by the uptake of nutrients by populations of large cities, which do not return the nutrients to the land but dispose of them in sewage systems. The resulting nutrient loss in agriculture is compensated by the importation of mineral fertiliser from the reservoir of minerals in the geosphere.

This human influence introduces a link with a nutrient cycle of a much longer time scale, determined by the formation of mineral deposits. The situation is similar to the situation discussed with the carbon cycle below but does not have the same immediate consequences; the increase of nutrients available for the fast nutrient cycle on which life processes and agriculture depend is very gradual, and much of the mineral input is removed from the rapid nutrient cycle through the oceanic component.

In the ocean nutrient uptake by plants occurs in the surface layer reached by sunlight where photosynthesis takes place. Most nutrients are removed from the euphotic zone and transferred to the deeper ocean as dead organisms sink to the ocean floor, where they leave the rapid nutrient cycle. In the deeper layers organic matter is remineralized, i.e. nutrients are brought back into solution. Thus, the ocean cannot support highly productive ecosystems except where nutrients are returned to the euphotic zone from below in so called upwelling regions.

3.5 The Nitrogen Cycle

Nitrogen is in a sense the most informative phytoplankton nutrient. That is because its oxidation states give information about the biological transformations to which given atoms have been subjected in the immediate past. Because of this information content, early studies of nutrient-uptake kinetics and regulation of phytoplankton growth focused on nitrate and ammonium utilization. Physiological and ecological studies have since broadened to include trace metals, co-limiting factors, and organic forms of nitrogen and phosphorus. Nitrogen is a fundamental constituent of proteins, nucleic acids, enzyme cofactors and at least one key, marine carbohydrate, chitin. Thus, it must be acquired and incorporated by phytoplankton for the initial synthesis of organic matter, and it remains essential at all steps in all food chains.

However, very few organisms are capable of directly reducing and incorporating N2, the form of nitrogen in the atmosphere that is abundant as dissolved gas in the ocean. This capability is restricted to an array of bacteria, some of which are photosynthetic cyanobacteria ("blue-green algae"). The biochemical transformations are referred to as "nitrogen fixation." They require a high energy input for reduction of N2 to ammonium, which then can be incorporated in amino acids, purines, glucosamine, and so forth. Ammonium in marine systems can serve as an energy source for bacteria and archaea, which oxidize it to nitrite (NO2 −), then nitrate (NO3 −). Both NO2 − and NO3 − are available for uptake by most phytoplankton and many bacteria. Because they are biologically available, all these reduced and oxidized forms are referred to as "fixed" nitrogen.

The nitrogen cycle represents one of the most important nutrient cycles found in terrestrial ecosystems (below). Nitrogen is used by living organisms to produce a number of complex organic molecules like amino acids, proteins, and nucleic acids. The store of nitrogen found in the atmosphere, where it exists as a gas (mainly N_2), plays an important role for life. This store is about one million times larger than the total nitrogen contained in living organisms. Other major stores of nitrogen include organic matter in soil and the oceans. Despite its abundance in the atmosphere, nitrogen is often the most limiting nutrient for plant growth.

This problem occurs because most plants can only take up nitrogen in two solid forms: ammonium ion (NH_4^+) and the ion nitrate (NO_3^-). Most plants obtain the nitrogen they need as inorganic nitrate from the soil solution. Ammonium is used less by plants for uptake because in large concentrations it is extremely toxic. Animals receive the required nitrogen they need for metabolism, growth, and reproduction by the consumption of living or dead organic matter containing molecules composed partially of nitrogen. In most ecosystems nitrogen is primarily stored in living and dead organic matter. This organic nitrogen is converted into inorganic forms when it re-enters the biogeochemical cycle via decomposition.

Decomposers, found in the upper soil layer, chemically modify the nitrogen found in organic matter from ammonia (NH_3) to ammonium salts (NH_4^+). This process is known as mineralization and it is carried out by a variety of bacteria, actinomycetes, and fungi. Nitrogen in the form of ammonium can be absorbed onto the surfaces of clay particles in the soil. The ion of ammonium has a positive molecular charge is normally held by soil colloids. This process is sometimes called *micelle fixation* (see Figure). Ammonium is released from the colloids by way of cation exchange.

When released, most of the ammonium is often chemically altered by a specific type of autotrophic bacteria (bacteria that belong to the genus *Nitrosomonas*) into Nitrite (NO_2^-). Further modification by another type of bacteria (belonging to the genus *Nitrobacter*) converts the nitrite to nitrate (NO_3^-). Both of these processes involve chemical oxidation and are known as nitrification. However, nitrate is very soluble and it is easily lost from the soil system by leaching. Some of this leached nitrate flows through the hydrologic system until it reaches the oceans where it can be returned to the atmosphere by denitrification.

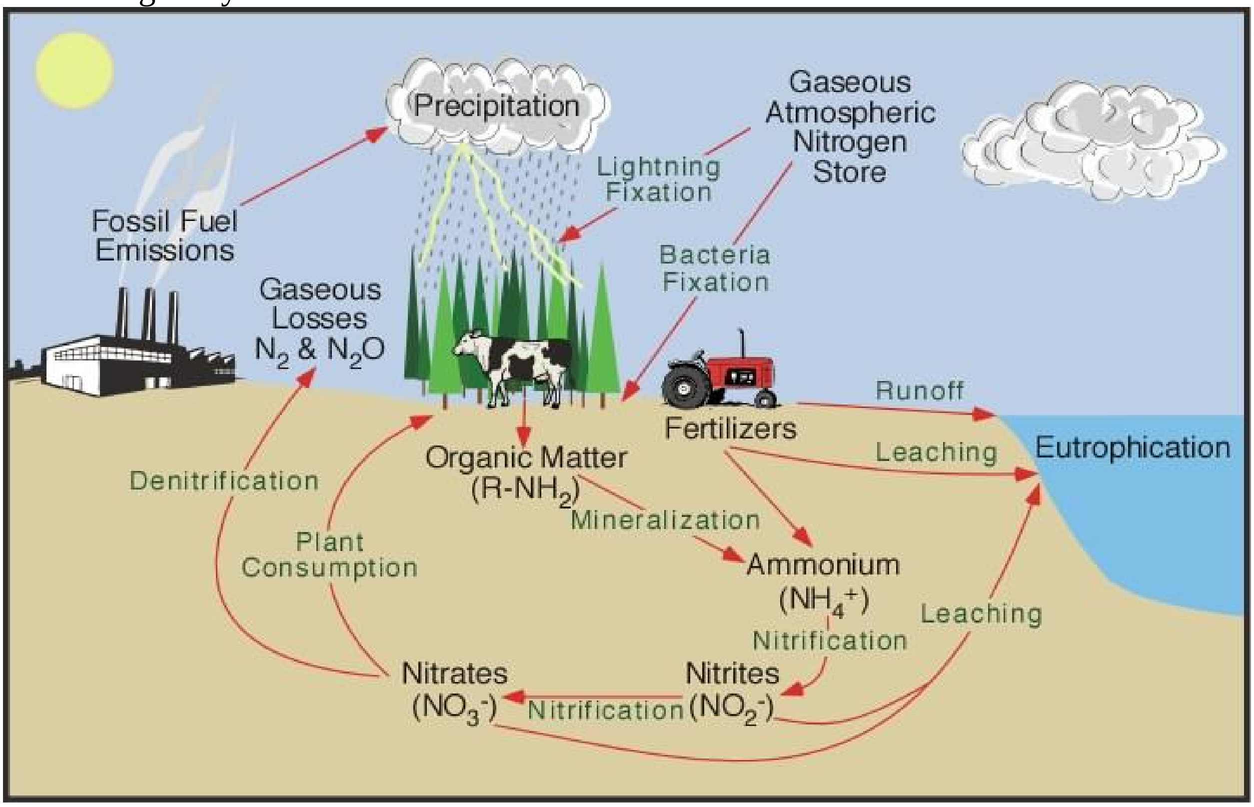
Denitrification is also common in anaerobic soils and is carried out by heterotrophic bacteria. The process of denitrification involves the metabolic reduction of nitrate (NO_3^-) into nitrogen (N_2) or nitrous oxide (N_2O) gas. Both of these gases then diffuse into the atmosphere. Almost all of the nitrogen found in any terrestrial ecosystem originally came from the atmosphere. Significant amounts enter the soil in rainfall or through the effects of lightning. The majority, however, is biochemically fixed within the soil by specialized micro-organisms like bacteria, actinomycetes, and cyanobacteria.

Members of the bean family (legumes) and some other kinds of plants form mutualistic symbiotic relationships with nitrogen fixing bacteria. In exchange for some nitrogen, the bacteria receive from the plants carbohydrates and special structures (nodules) in roots where they can exist in a moist environment. Scientists estimate that biological fixation globally adds approximately 140 million metric tons of nitrogen to ecosystems every year.

The activities of humans have severely altered the nitrogen cycle. Some of the major processes involved in this alteration include:
The application of nitrogen fertilizers to crops has caused increased rates of denitrification and leaching of nitrate into groundwater. The additional nitrogen entering the groundwater system eventually flows into streams, rivers, lakes, and estuaries. In these systems, the added nitrogen can lead to eutrophication.

Increased deposition of nitrogen from atmospheric sources because of fossil fuel combustion and forest burning. Both of these processes release a variety of solid forms of nitrogen through combustion. Livestock ranching. Livestock release a large amounts of ammonia into the environment from their wastes. This nitrogen enters the soil system and then the hydrologic system through leaching, groundwater flow and runoff. Sewage waste and septic tank leaching.

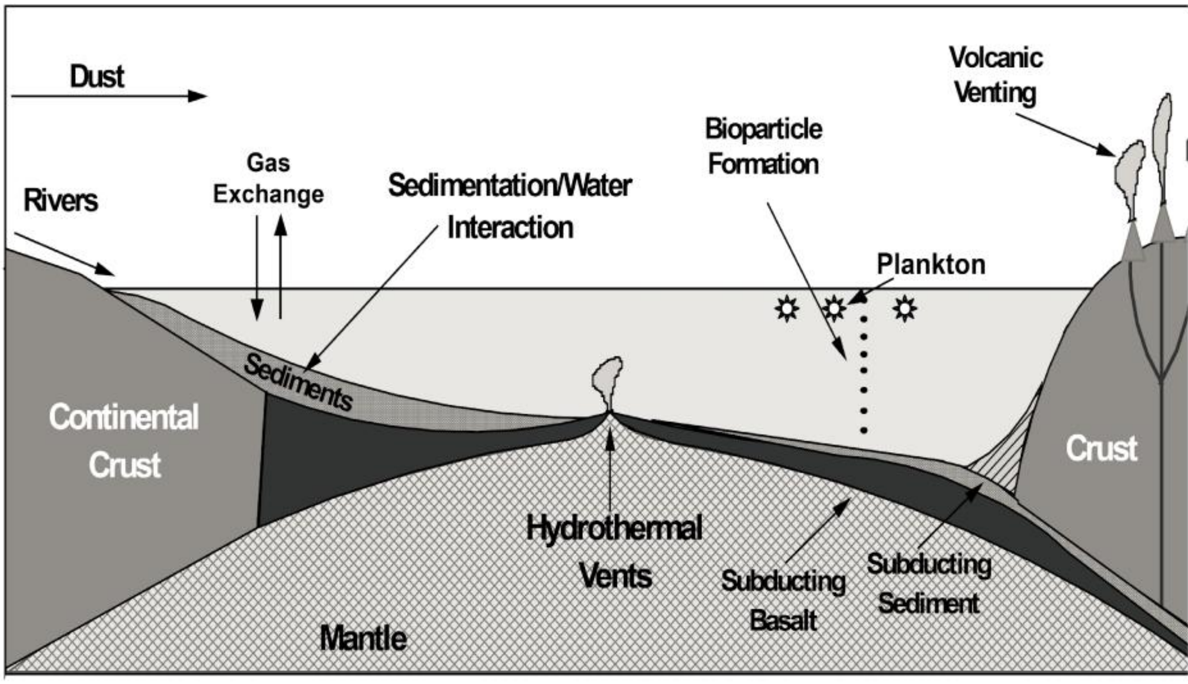
The Nitrogen Cycle



3.6 THE CARBON CYCLE

The inventory of dissolved inorganic C in the oceans is 50-60 times greater than that in the atmosphere, so a small perturbation of the ocean carbon cycle can result in a substantial change in the concentration of CO2 in the atmosphere. The ocean carbon cycle influences atmospheric CO2 via changes in the net air-sea CO2 flux that are driven by differences in the partial pressure of CO2 between the surface ocean and atmosphere. This exchange process is dominated by two interdependent “carbon pumps” that deplete the surface ocean of total CO2 relative to deep water. Because the solubility of CO2 increases with decreasing temperature, the SOLUBILITY PUMP transfers CO2 to the deep sea during formation of cold deep water at high latitudes. This is a link of the ocean carbon cycle to physical processes (circulation). At the same time the BIOLOGICAL PUMP removes carbon from surface waters by settling of organic and inorganic carbon derived from biological production to the deep sea. This is a link of the ocean carbon cycle to biological processes.

Understanding the natural processes that affect the global carbon cycle is an important requisite for correctly predicting the effects of global warming. For this we need a sound descriptive and quantitative background in all aspects of chemical oceanography and a good understanding of the coupling between chemical oceanography, tectonics, climate, and physical, and biological oceanography. As illustrated in the figure below the oceans are in continues contact with the atmosphere, lithosphere and biosphere.



In addition to the major role the ocean plays in the global carbon cycle the world’s ocean is also a resource for minerals, energy (gas and petroleum), fisheries, and is the ultimate water source.

All life is based on the element carbon. Carbon is the major chemical constituent of most organic matter, from fossil fuels to the complex molecules (DNA and RNA) that control genetic reproduction in organisms. Yet by weight, carbon is not one of the most abundant elements within the Earth's crust. In fact, the lithosphere is only 0.032% carbon by weight. In comparison, oxygen and silicon respectively make up 45.2% and 29.4% of the Earth's surface rocks.

- Carbon is stored on our planet in the following major sinks:
- as organic molecules in living and dead organisms found in the biosphere;
- as the gas carbon dioxide in the atmosphere;
- as organic matter in soils;
- in the lithosphere as fossil fuels and sedimentary rock deposits such as limestone, dolomite and chalk
- in the oceans as dissolved atmospheric carbon dioxide and as calcium carbonate shells in marine organisms.

Ecosystems gain most of their carbon dioxide from the atmosphere. A number of autotrophic organisms have specialized mechanisms that allow for absorption of this gas into their cells. With the addition of water and energy from solar radiation, these organisms use photosynthesis to chemically convert the carbon dioxide to carbon-based sugar molecules. These molecules can then be chemically modified by these organisms through the metabolic addition of other elements to produce more complex compounds like proteins, cellulose, and amino acids. Some of the organic matter produced in plants is passed down to heterotrophic animals through consumption.

Carbon dioxide enters the waters of the ocean by simple diffusion. Once dissolved in seawater, the carbon dioxide can remain as is or can be converted into carbonate (CO_3^{-2}) or bicarbonate (HCO_3^{-}). Certain forms of sea life biologically fix bicarbonate with calcium (Ca^{+2}) to produce calcium carbonate ($CaCO_3$). This substance is used to produce shells and other body parts by organisms such as coral, clams, oysters, some protozoa, and some algae. When these organisms die, their shells and body parts sink to the ocean floor where they accumulate as carbonate-rich deposits.

After long periods of time, these deposits are physically and chemically altered into sedimentary rocks. Ocean deposits are by far the biggest sink of carbon on the planet. Carbon is released from ecosystems as carbon dioxide gas by the process of respiration. Respiration takes place in both plants and animals and involves the breakdown of carbon-based organic molecules into carbon dioxide gas and some other compound by products.

The detritus food chain contains a number of organisms whose primary ecological role is the decomposition of organic matter into its abiotic components. Over the several billion years of geologic history, the quantity of carbon dioxide found in the atmosphere has been steadily decreasing. Researchers theorized that this change is in response to an increase in the Sun's output over the same time period. Higher levels of carbon dioxide helped regulate the Earth's temperature to levels slightly higher than what is perceived today. These moderate temperatures allowed for the flourishing of plant life despite the lower output of solar radiation.

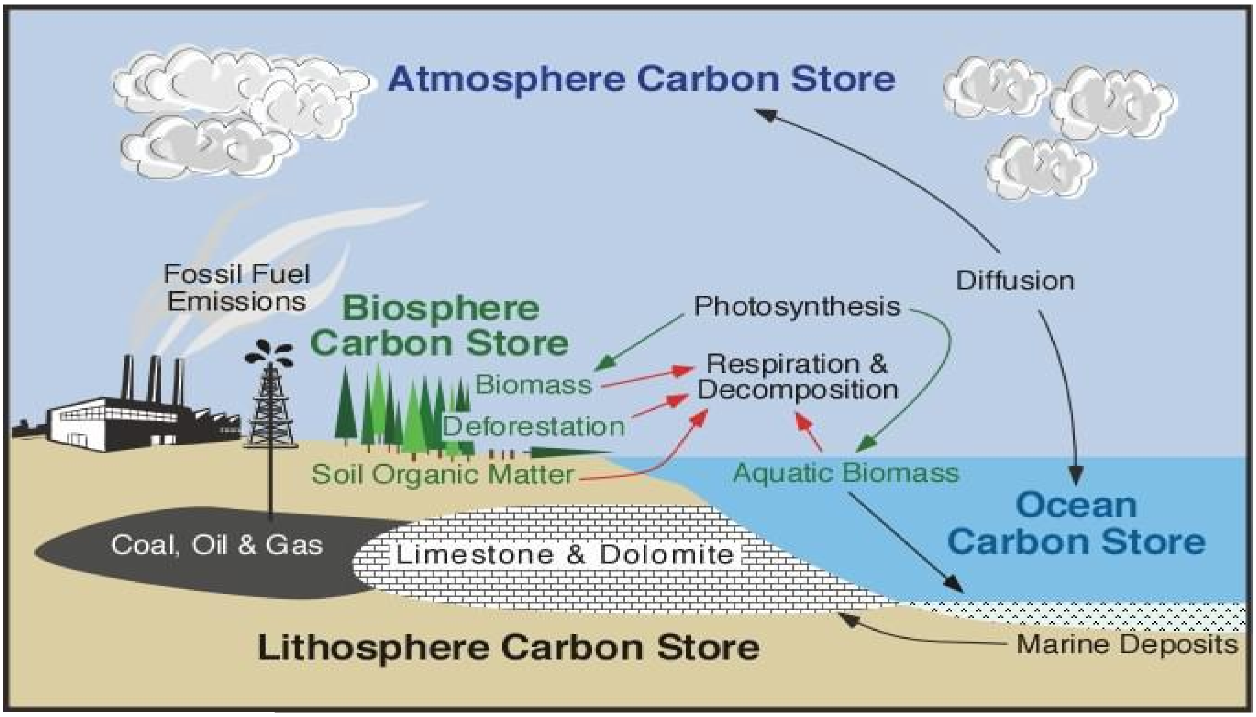
An enhanced greenhouse effect, due to the greater concentration of carbon dioxide gas in the atmosphere, supplemented the production of heat energy through higher levels of longwave counter-radiation. As the Sun grew more intense, several biological mechanisms gradually locked some of the atmospheric carbon dioxide into fossil fuels and sedimentary rock.

In summary, this regulating process has kept the Earth's global average temperature essentially constant over time. Some scientists suggest that this phenomenon is proof for the Gaia hypothesis. Carbon is stored in the lithosphere in both inorganic and organic forms. Inorganic deposits of carbon in the lithosphere include fossil fuels like coal, oil, and natural gas, oil shale, and carbonate based sedimentary deposits like limestone. Organic forms of carbon in the lithosphere include litter, organic matter, and humic substances found in soils. Some carbon dioxide is released from the interior of the lithosphere by volcanoes. Carbon dioxide released by volcanoes enters the lower lithosphere when carbon-rich sediments and sedimentary rocks are subducted and partially melted beneath tectonic boundary zones.

Since the Industrial Revolution, humans have greatly increased the quantity of carbon dioxide found in the Earth's atmosphere and oceans. Atmospheric levels have increased by over 30%, from about 275 parts per million (ppm) in the early 1700s to just over 365 PPM today.

Scientists estimate that future atmospheric levels of carbon dioxide could reach an amount between 450 to 600 PPM by the year 2100. The major sources of this gas due to human activities include fossil fuel combustion and the modification of natural plant cover found in grassland, woodland, and forested ecosystems.

Emissions from fossil fuel combustion account for about 65% of the additional carbon dioxide currently found in the Earth's atmosphere. The other 35% is derived from deforestation and the conversion of natural ecosystems into agricultural systems. Researchers have shown that natural ecosystems can store between 20 to 100 times more carbon dioxide than agricultural land-use types



The Carbon Cycle

The carbon cycle operates naturally on two vastly different time scales. It involves the ocean, the atmosphere, the geosphere and the biosphere.
On the geological time scale carbon is released into the atmosphere and ocean through the weathering of carbonate rocks such as limestones. It returns to this vast storage reservoir as new rocks are formed through sediment deposition. On the much shorter climate timescale carbon is exchanged between the atmosphere, the ocean and living and dead organisms.

The carbon cycle includes both timescales, but for most practical purposes the carbon budget and the carbon flux budget usually exclude the geological timescale. This separation between the timescales has been significantly disturbed through the burning of fossil fuel. This adds carbon dioxide to the atmosphere and increases its ability to retain heat energy received from the sun (the greenhouse effect).

The following tables give some current estimates for the carbon budget and the carbon flux budget:

THE CARBON BUDGET

Region	Amount (Gt Carbon; 1 Gt = 10^{15} G)	
	Before Anthropogenic Change	After Anthropogenic Change
Land Plants	610	550
Soil And Humus	1,500	no change
Atmosphere	600	750 (+3.4 per annum)
Upper Ocean	1,000	1,020 (+0.4 per annum)
Marine Life	3	no change
Dissolved Organic Carbon	700	no change
Mid-Depth And Deep Ocean	38,000	38,100 (+1.6 per annum)

THE CARBON FLUX BUDGET

From	To	Amount (Gt Carbon Per Year; 1 Gt = 10^{15} G)	
		Natural	Anthropogenic
Atmosphere	Land Plants	100 (a)	
	Ocean	74 (d)	18
Land Plants	Atmosphere	50 (a)	
	Soil And Humus	50 (a)	
Soil And Humus	Atmosphere	50 (a)	
Deforestation	Atmosphere		about 1.9
Fossil Fuel	Atmosphere		about 5.4

Ocean Sink	Upper Ocean		0.4
	Mid-Depth And Deep Ocean		1.6
Rivers	Ocean	0.8	
Upper Ocean	Atmosphere	74 (d)	16
	Marine Life	about 40 (b)	
	Mid-Depth And Deep Ocean	90 (c)	5.6
Marine Life	Upper Ocean	about 30 (b)	
	Mid-Depth And Deep Ocean	4 (b)	
	Dissolved Organic Carbon	6 (b)	
Dissolved Organic Carbon	Mid-Depth And Deep Ocean	6 (c)	
Mid-Depth And Deep Ocean	Upper Ocean	100 (c)	
	sediment	0.13	

3.7 The Water Cycle / Hydrologic Cycle

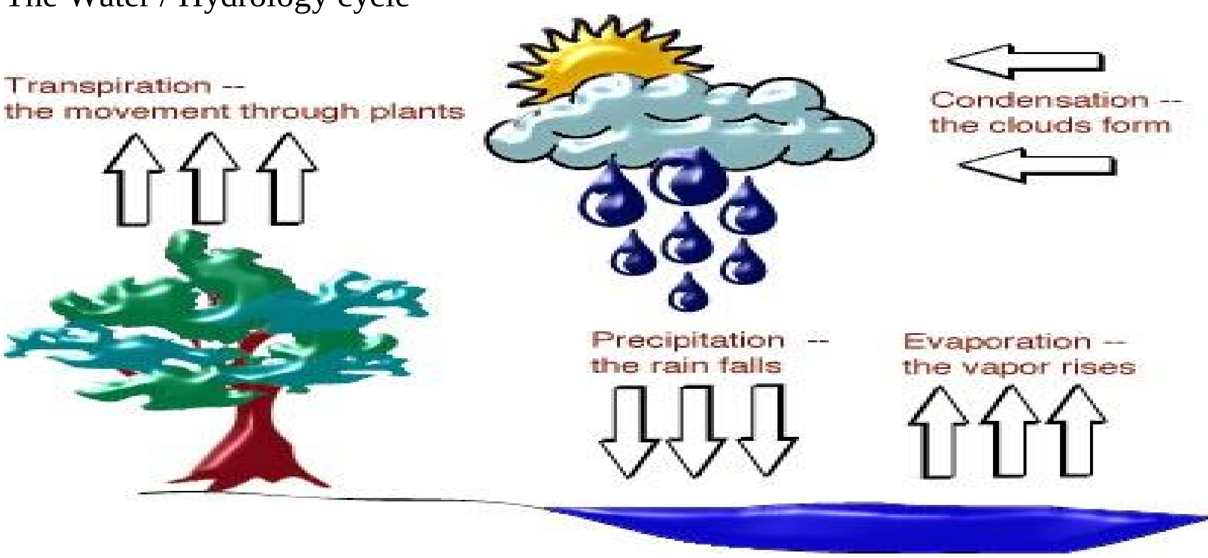
The earth is the only planet in the solar system where liquid water is found on the surface. Water is the only substance which, under the ranges of pressure and temperature experienced on earth, is present in solid, liquid and gaseous phase. The water cycle is therefore of fundamental importance to many processes unique to earth. In comparison, the outer planets of our solar system (Saturn, Jupiter, Uranus, Neptune and Pluto) and their moons are too cold to contain water in any form other than ice, the inner planets (Mercury and Venus) are too hot to hold water in any form other than water vapour, and Mars is presently too cold but may have had liquid water on its surface at some point in its history. In the current stage of development of the solar system Earth is the only planet that contains water in all its phases.

Like many other cycles, the water cycle links processes acting in the living and non-living world: Precipitation and oceanic evaporation link ocean and atmosphere; evaporation from land and transpiration from vegetation link the atmosphere with the biosphere. In the context of meteorology and oceanography the effect of the biosphere is quantitatively expressed as a single process, evapo-transpiration. The water cycle then describes a basic component of the combined system ocean-atmosphere.

Associated with every cycle is a budget. Cycles represent a *qualitative description* of processes, budgets turn them into *quantitative statements*. We distinguish between static budgets, which summarize how much of a material is available and how it is distributed between the different compartments, and dynamic budgets, which quantify how rapidly the material is moved between compartments. Cycles define the process; budgets allow answers to questions such as; "How is the water cycle affected if a given percentage of the existing bushland in Western Australia is cleared and replaced by wheat farming?"

The cycle includes precipitation, evaporation, condensation, and transpiration (PECT). Earth's water keeps changing from liquid water to vapor and then back again. This cycle happens because of the sun's heat and gravity. Water is constantly being cycled between the atmosphere, the ocean and land. This cycling is a very important process that helps sustain life on Earth. As the water evaporates, vapors rise and condense into clouds. The clouds move over the land, and precipitation falls in the form of rain, ice or snow. The water fills streams and rivers, and eventually flows back into the oceans where evaporation starts the process anew. Water keeps moving and changing from a solid to a liquid to a gas, over and over again. Water's state (solid, liquid or gas) is determined mostly by temperature. Although water continuously changes states from solid to liquid to gas, the amount of water on Earth remains constant.

The Water / Hydrology cycle



The earth is the only planet in the solar system where liquid water is found on the surface. Water is the only substance which, under the ranges of pressure and temperature experienced on earth, is present in solid, liquid and gaseous phase. The water cycle is therefore of fundamental importance to many processes unique to earth. In comparison, the outer planets of our solar system (Saturn, Jupiter, Uranus, Neptune and Pluto) and their moons are too cold to contain water in any form other than ice, the inner planets (Mercury and Venus) are too hot to hold water in any form other than water vapour, and Mars is presently too cold but may have had liquid water on its surface at some point in its history. In the current stage of development of the solar system Earth is the only planet that contains water in all its phases.

Like many other cycles, the water cycle links processes acting in the living and non-living world: Precipitation and oceanic evaporation link ocean and atmosphere; evaporation from land and transpiration from vegetation link the atmosphere with the biosphere.

In the context of meteorology and oceanography the effect of the biosphere is quantitatively expressed as a single process, evapo-transpiration. The water cycle then describes a basic component of the combined system ocean-atmosphere.

Associated with every cycle is a budget. Cycles represent a qualitative description of processes; budgets turn them into quantitative statements. We distinguish between static budgets, which summarize how much of a material is available and how it is distributed between the different compartments, and dynamic budgets, which quantify how rapidly the material is moved between compartments. Cycles define the process; budgets allow answers to questions such as; "How is the water cycle affected if a given percentage of the existing bushland in Western Australia is cleared and replaced by wheat farming?"

3.6.1 The Water Budget

The distribution of water on earth (the static budget); this budget shows where the water is found:

Region	Volume (10^3 Km^3)	% of Total
Oceans	1,350,000	94.12
Groundwater	60,000	4.18
Ice	24,000	1.67
Lakes	230	0.016

Soil Moisture	82	0.006
Atmosphere	14	0.001
Rivers	1	-

The static budget demonstrates the importance of the ice sheets to the global water cycle: Any change in the atmospheric or oceanic conditions that releases a significant part of the water that is presently stored in the ice, will produce a major shift in the water cycle. The atmosphere seems insignificant in comparison. However, the important role of the atmosphere becomes clear when the dynamic budget is considered.

3.6.2 The Water Flux Budget

The branches of the water cycle on earth (the dynamic budget); this budget shows how water moves between atmosphere and hydrosphere:

Process	Amount (M^3 Per Year)
Precipitation On Ocean	$3.24 \cdot 10^{14}$
Evaporation From Ocean	$-3.60 \cdot 10^{14}$
Precipitation On Land	$0.98 \cdot 10^{14}$
Evaporation From Land	$-0.62 \cdot 10^{14}$
Net Gain On Land = River Run-Off	$0.36 \cdot 10^{14}$

The flux budget demonstrates that most of the water exchange between the compartments is between the ocean and atmosphere, so the atmosphere is an extremely dynamic element in the system despite of its small water content at any one time. The turnover of water between ocean and atmosphere over a few decades is equivalent to the total amount of water stored in the ice sheets.

3.8 The Salt Cycle

The salt cycle involves the ocean, the geosphere and to a very minor extent the atmosphere. Minerals are leached from rocks through flowing groundwater and surface erosion. They enter the rivers and from there the ocean where they accumulate, making sea water salty. They are removed from the water and enter the sediment by chemical action.

The sediment is used to form new rock which brings the minerals back into the geosphere. Salt gets into the atmosphere as spray from wind waves. This may be carried on to land, constituting a minute pathway from sea to land in the global salt cycle.

Because the salt cycle operates on such large time scales, establishing a static salt budget is of no relevance to oceanography.

3.8.1 Elements of the Salt Flux Budget

The salt cycle operates on such long scales that establishing a salt flux budget is not an important task for oceanography. The following table gives an idea of the time scales involved:

Element	Crustal Abundance (%)	Residence Time (Years)
Some Major Constituents Of Sea Salt:		
Sodium (Na)	2.4	60,000,000
Chlorine (Cl)	0.013	80,000,000
Magnesium (Mg)	2.3	10,000,000
Some Trace Constituents Of Sea Salt:		
Lead (Pb)	0.001	400
Iron (Fe)	2.4	100
Aluminium (Al)	6.0	100

3.9 Impact of humans on the balance

Biogeochemical cycles are subject to disturbance by human activities.

1) Humans have significantly altered the carbon cycle by clearing vegetation that stores carbon, materials that release a huge amount of carbon into the biosphere
2) altered the nitrogen and phosphorus cycles by adding these elements to croplands as fertilizers, which has contributed to over-fertilization of aquatic ecosystems when excess amounts are carried by runoff into local waterways.

4.0 CONCLUSION

Air is a mixture of gases with traces of water vapor, carbon dioxide, argon, and various other components. Ecological cycles links processes acting in the living and non-living world expressed quantitatively through the concept of cycles and budgets.

5.0. SUMMARY

Each cycle takes many different pathways and has various reservoirs, or storage places, where elements may reside for short or long periods of time. Each of the chemical, biological, and geological processes varies in their rates of cycling. Some molecules may cycle very quickly depending on the pathway.

7.0 TUTOR MARKED ASSIGNMENTS

i. Discuss in details, any 3 of the following ecological cycles.

a. Nitrogen cycle
b. Carbon Cycle
c. Water Cycle
d. The Salt Cycle
e. The Nutrient Cycle

ii. Using a table, explain the carbon budget and the carbon flux budget
iii. What are the tools and technology of a biological oceanographer?
iv. Highlight the impact of humans on the ecological balance

7.0 REFERENCES AND OTHER RESOURCES

Christensen, J. P. (1994). Carbon export from continental shelves, denitrification and atmospheric carbon dioxide. *Continental Shelf Research* **14**: 547-576.

Dalsgaard, T., Thamdrup, B. and Canfield, D. E. (2005). Anaerobic ammonium oxidation (anammox) in the marine environment. *Research in Microbiology* **156**: 457-464.

Weber, T. S. and Deutsch, C. (2010). Ocean nutrient ratios governed by plankton biogeography. *Nature*, **467:** 550-554.

UNIT 9 PHYSICS AND CHEMISTRY OF THE OCEAN

CONTENTS

1.0 INTRODUCTION

Chemical and physical properties of water are often discussed together. These properties are fundamentals of many disciplines such as hydrology, environmental studies, chemical engineering, environmental engineering, etc. they are of interest to chemist and physicists of course.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Understand that the color of an object as a result of the absorption of wavelength;
- Understand the importance of light to the marine environment;
- Understand the presence or absence of other physical parameters to the chemistry of the ocean.

3.0 MAIN CONTENT

3.1 Colour

The colour of an object is the end result of the differential absorption of the wavelength of the light spectrum. The colour of the ocean water ranges from a deep - indigo blue in the tropical and equatorial regions of little biological productivity to a yellow – green in a coastal water of high latitude areas.

The many forms of electromagnetic energy radiated by the Sun include amongst others: Cosmic rays, Gamma rays, X-rays, ultraviolet rays, visible rays, infrared rays, microwaves, etc. the very narrow segments of a visible ray may be broken down on the basis of wavelength into the following:

- Red
- Orange
- Yellow
- Green
- Blue
- Indigo
- Violet

When all these colours combine together, they produce the white light (visible). The reason we see things in color is because objects reflects wavelengths in lights of the visible spectrum. In the ocean, the absorption of visible light is greater for the longer wavelength colour, thus the shorter wavelength portion of the visible spectrum is transmitted to greater depth.

As a result of this condition, the red wavelengths are absorbed within the upper 20m, the yellow disappears before a depth of 100m has been reached but the green light can still be seen down to 250m. Only the blue and some green wavelengths extends beyond this depth and their intensity becomes low. This is because of this pattern of adaption that objects in the oceans usually appear blue – green.

In general, the intense blue colour of the ocean water is indicting on the high reflection of the blue color of the ocean water and is also an indication of very little suspended matters. The colour of the ocean water varies directly with the amount of suspended materials present and also varies inversely to the depth to which light penetrates.

C ἀ s/d

Intensive blue water is also very poor to the amount of organic matter present. In fact, intensive blue water is associated with areas where living is very poor. The part of the Atlantic Ocean known as the SARGASSO sea is usually referred to as the desert of the sea because, this is an area with very high salinity, very narrow suspended matter and very intensive coloration.

However, the ocean is not always blue, there are other colors that dominant the ocean water and these are due to the reflection of the particles present in the Ocean. The yellow and brown particles bought into the sea through the land especially at the mouth of major rivers combine with the already blue- color to produce green color.

We found out that the green colour dominates the coastal water, sometimes however, the yellow color dominates as a result of organisms which have an intensely yellow color especially zooplankton. A few oceans of the world have been singled out for having particular colors, for example, the Red Sea, The Black Sea. The predominant color of the red sea is not really red but the red color is associated with the red color of the dinoflagellates which as a result of its abundance, tends to change its color to the ocean water.

3.2 Light:

Among the various factors, light is the most essential factor for the marine environment. It is essential because it provides the heat energy and is also important for its role in PHOTOSYNTHESIS. The source of light energy is the SUN and this energy is released as a result of nuclear processes. It is this light energy that reaches the surface of the earth haven travelled a total number of 150 x 10^6km distance from the sun that the heat energy is radiated uniformly but due to the spherical shape of the earth, the heat energy receives decreases from the equator to the pole.

Actually, it is a variation in the in-coming solar radiation that produces the climate in both land and sea. It is estimated that the average amount of light energy that is received on each square/centimeter of the ocean surface is approximately 0.433cal/sec. the reason for this low amount of energy compared to what comes from the sun is that, a great deal of it is absorbed, some are reflected and so on and so forth.

3.3 Illumination

This is the measure of the intensity of light penetrating into a column. The variability in illumination depends on the variability of the incident light. If the amount of incident light is low, then the amount of light that passes through the water column is even smaller. The incident light varies with cloud condition, seasons, latitudes, rate of atmospheric reflection as well as absorption. It also depends on the turbidity.

Table 1: Absorption of Radiation in The Atmosphere and Ocean

	Clear Sky (%)	Cloudy Sky (%)
Incoming radiation	100	100
Scattering back to space by air	7	7
Absorption in upper atmosphere	3	3
Absorption in lower atmosphere	10	10
Reflection in space	-	10
Clouds	-	45
Absorption that reaches Ocean surface	80	25
REACHING 10M DEPTH FOR:		
Oceanic water	8	2.5
Coastal Water	0.4	0.125

3.4 Transparency

This is defined as the measure or amount of reflected light at a given depth of water. In order to measure transparency, we use a light disc called SEECHI DISC. A Seechi disc is a wide plate painted in various colors and is usually weighted. When the Seechi disc is dropped into the water, the depth at which the disc is out of sight is measured and the depth at which the disc becomes visible at the process of bringing it out; these two measurements are added and divided by 2 (two) to get the depth. The disadvantage is the the various measurements observed at the same ocean.

3.5 Turbidity

This is the amount of suspended particles in the water. It is usually referred to as the inverse of transparency. The higher the turbidity, the lesser the transparency. The direct measure of turbidity is by filtration. A sample of water is filtered, dried and the residue is measured.

3.6 Temperature

The temperature of ocean water is of paramount importance. The temperature of the ocean at any time is a function of so many factors. These include:

- Air temperature
- Relative humidity
- Rate of evaporation
- Air and Water currents
- Speed of the wind, e.t.c.

As a result of all these, the temperature of the ocean water usually varies in 3 (three) ways:

3.6.1 Diurnal Variation of temperature is the variation between the night and day i.e. day variation.

3.6.2 Seasonal Variation of temperature involved changes seasonally like rainy, sunny, harmattan seasons.

3.6.3 Latitudinal Variation of temperature varies from the N-pole to the S-pole; high latitude at 0° i.e. at the equator.

In spite of all these obvious variations, it is correct to state that these variations are relatively less to the ocean water than on land. With respect to temperature, there is greater stability in the ocean than on land. These are as a result of the following:

- Sea water has very high specific heat capacity compared with fresh water and land
- Light penetrates more easily in the sea water than on land mass
- There is a tendency of heat to be transferred to the atmosphere by convection current when the sea is warmer than the air whereas when the air is warmer, very little heat is transferred to the sea water.

The temperature at various places in the ocean would depend upon the rate at which heat flows in and out of these area. Qualitative consideration of heat transfer in ocean water masses constituents the heat budget. The heat budget for any locality in the Ocean is expressed by the following equation:
The rate of heat loss - the rate of heat loss = net rate of heat loss/gain. This is measured in Langley / unit time.

1 Langley = 1g cal/cm2
This can be denoted by the equation;

$$(Qs + Qc) – (Qr + Qe + Qb) = QT$$

Where:
Qs = rate of heat gained from solar radiation
Qc = rate of heat gained / loss through ocean current
Qr = rate of heat loss through radiation into space
Qe = rate of heat loss through evaporation

Qb = rate of heat loss through conduction to the atmosphere
QT = net rate of heat loss / gain in the locality
If QT = positive value, the temperature of the ocean water of the locality is raising,
QT = negative value, the temperature of the locality is decreasing,
QT = zero value, the temperature of the locality is constant
Symbolically, the heat budget of the world ocean is expressed using average values:
IF Qs = Qr + Qe + Qb is 100% = 41% + 53% + 6%, it is considered that the Qc and QT of the world ocean is zero.

4.0 CONCLUSION

Most people come in contact with the Ocean only near its surface and usually near its edges. In the huge part of the ocean that remains hidden, sea water is salty, cold, dark and deep. Average salt content in the ocean is 35g/kg of sea water, composed mostly of 6 constituents: Sodium (Na^+), Chloride (Cl^-), sulfate (SO_4^{2-}), Magnesium, (Mg^{2+}), calcium (Ca^{2+}) and Potassium (K^+). These are often referred to as conservative elements because their ratios to each other remain constant throughout the Ocean.

5.0 SUMMARY

In this unit we have leant that:

i. Color of an object is a result of the absorption of its relevant wavelength;
ii. Light is an essential factor because it provides the heat energy for photosynthesis to occur.; and
iii. Illumination, Transparency, Turbidity and Temperature are also major factors that are considered for the physical and chemical units of water.

6.0 TUTOR MARKED ASSIGNMENTS

1. Appraise the narrow segments of the visible ray.
2. In what ways are the following factors relevant in the physical and chemical constutuents of the water:
   - Color
   - Turbidity
   - illumination

7.0 REFERENCES AND OTHER RESOURCES

Carl, N. and Jonny, O. (2006). *Physics Handbook for Science and Engineering.* (8th ed.). Studentliterature. 263pp.

Lamb, H. (1994). *Hydrodynamics* (6th ed.). Cambridge University Press. 367pp.

Roemmich, D (2007). "Physical Oceanography: Super Spin in the Southern Sea". *Nature*, **449** (7158): 34 – 35.

UNIT 10 OCEANOGRAPHIC SURVEYING TECHNIQUES

CONTENTS

1.0 INTRODUCTION

Survey, monitoring, assessment and similar measurements are only a means to an end. They achieve little in themselves except, maybe add a quantum of knowledge and some understanding. What is even more important, is the use of the results of survey and monitoring - how and when to use the information and knowledge obtained through survey and monitoring. Since survey and monitoring can consume a great deal of time, staff and funds, it is essential to establish clear objectives before survey and focus on those objectives throughout. Survey, monitoring, assessments and measurement can turn into an expensive "black hole" into which resources are poured at ever increasing amounts. It is often the view that more data are needed and that there is not enough information - in effect, there are never “enough” data and the important thing is to make the judgment as to how much data and information are “essential” in order to meet the objectives.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Understand the various oceanographic survey technique, and;
- Understand the various methods of ecological survey

3.0 MAIN CONTENT

3.1 Navigation:

The collection and monitoring of oceanographic usually takes place on-board research vessels. The accuracy of such information depends on the ability of the vessels to locate its exact position either to repeat previous stations where data have been collected in the past or undertake new investigations. To undertake this research, special navigation system has been developed. These include the following:

3.1.1 Shore-based Radio Navigation System:

In Coastal areas, the shore-based radio transmission can be used for more accurate position. The receiving board determines the distance between the vessels and two (2) pairs of responder on shore.

3.1.2 Transmit Satellite Navigation System:

Transmit Satellites circle the earth at an altitude of 1100km corresponding to a revolution time of about 108minutes. They transmit electro-magnetic waves and every 2(two) minutes, the satellite also transmits accurate time signals with orbital parameters of their parts and elevation. The Satellite receiver on the ship decodes this information and compute the position of the ship.

3.1.3 Global Position System (GPS):

This satellite navigation project developed by the US Department of Defence was originally conceived as a target control for weapon systems. Its use has however been extended to civilian land, marine and air navigation, providing incredibly accurate, world-wide navigational capabilities. The GPS overcomes the limitation of other navigational systems, such as the frequency problems of electrons, signal interference due to weather storms, etc. The GPS consists of 21 atomic satellites and 3 spares with each orbiting the earth twice daily. Each GPS satellite transmits precise time and position data. Land based control stations constantly monitor the GPS satellites to ensure accuracy of information. GPS operates 24 hours a day without delays between fixes that are commonplace with transit satellite navigation.

3.1.4 Speed Logging System:

This system utilizes Doppler sonar and inertial aids. For modest accuracy, the standard ship speed log, in combination with the gyro compass, can be used for positioning. The Doppler sonar system is a sonar transducer containing four crystals which generate supersonic sonar beams in the fore, aft, port and starboard directions. After transmission of a pulse train, the crystals receive the back scatter and part of the signal. The observed frequency shift serves to determine the velocity vector of the ship in relation to the sea bed or, in water deeper than about 400m, relative to a layer in the water column which scatters a sufficient percentage of the wave.

3.1.5 Integrated navigation systems

An integrated navigation system combines the output of several systems. The main advantage of this is that it combines sensors with different navigational characteristics, with the weak points of one subsystem as the strong parts of another. For example the Transit system can be used in conjunction with Doppler sonar. The Transit satellite provides accurate fixes every few hours while the Doppler sonar enables dead reckoning between fixes.

3.2 Oceanographic Techniques

Instruments for oceanographic measurement and data gathering must have certain qualities like:

- Able to withstand hydro-static pressure,
- Resistance to corrosion by salt,
- Must be able to cope with rough field work, and;
- The data must be interpretable and re-producible.

3.2.1 Bathymetric

This is the distance between the water surface and the sea bottom. To measure it, we use an echo sounder for special measurement. The echo sounder sends a pulse through the water to the sea bed and this pulse returns to the receiver where convention of the speed and time is made to obtain the depth based on the formula:

$$D = 0.5VT$$

Where: D = depth
V = velocity of the pulse which is 1500m/s (k)
T = travel time of the pulse

3.2.2 Tide

There are 2 types of gauges for measuring tidal variations:

Non-registering gauges require the presence of an observer to measure and record the height of the tide. Self-registering, or automatic gauges, automatically record the rise and fall of the tide while unattended. Non-registering gauges include the tide staff, the simplest kind of which consists of a plain staff or board about 2-5cm thick and 5-15cm wide and graduated. The length of the staff should be sufficient to extend from the lowest to the highest tide in the locality where the staff is to be used. The staff is secured in a vertical position by fastening it to a pile or other suitable support. The height of tides can be read from the graduations on the staff.

Self-recording tide gauges include:

- Float gauges - with direct mechanical registration of the water level.
- Pneumatic gauge - in which a diving bell lies on the sea floor at such a depth that pressure variations due to surface waves can be ignored. By means of an air-filled tube, the hydrostatic pressure is connected with a recording manometer on shore on a measuring pole.
- Acoustic gauge - by means of acoustic signals sent to the seabed, the depth being determined by the time required for a sound wave to travel from the ship or boat (acoustic transmitter) to the bottom and for the echo to return.

A depth recorder can also be used to measure tides from submerged capsules and platforms. For accuracy, tidal readings must be related to a datum, the commonest being the chart datum.

3.2.3 Ocean’s Surface Wave

Waves can be measured from the sea floor, at the sea surface or from an aircraft. The most important method of measuring waves from the sea floor is the recording of bottom pressure fluctuations that reflect surface waves and which can be used to calculate surface displacements in accordance with the linear wave theory. In pressure gauges, the pressure sensor reacts exclusively on any variations of the hydrostatic pressure. Another method, though of less importance, is the measurement with a reversing echo sounder. Float gauges and electrical measuring devices are suited for measurement from the sea surface. They are deployed from fixed platforms, like bridges at the coast or pole research towers. Float gauges are similar to those used for the measurement of tides. With electrical devices, variations of water level are converted into changes in electrical resistance capacitance. In the capacitive method, an insulated wire is stretched in a vertical position with a cylindrical capacitor in the range where it is wetted with water. The variation in length of wetted clinger, or the variations in size of the capacitor respectively, correspond to the variations in water level. Wave observations from a ship can be carried out visually, photographically or by means of built-in measuring devices (slip burner recorders). Accelerometer instrumented buoys are often used for wave measurements in deeper waters where pressure sensors cannot be used and where structures are not available for attachment of other types of wave sensors. Accelerometers can transmit wave measurements to a shore-based receiving station where wave data are recorded or monitored in real time. Aircraft and satellites which orbit the earth carry sensors which can measure sea waves. However, the resolution and accuracy of wave data from atmospheric measurements is still poor when compared with that from sea-based instruments described above. A promising recent development permits recording of the state of the sea from simultaneous measurements of the sea surface temperature through infrared and microwave radiation.

3.2.4 Currents

Two quantities must be determined by sensors for current measurements. These are the absolute value and the direction of the velocity or its components in a right angled coordinate system. The absolute value is usually obtained by measuring the rotation rate of mechanical sensors such as propellers, rotors, paddle wheels, or turnstiles with hemispherical bowls. The direction is determined by means of a current vane relative to the north direction (magnetic compass, induction compass) or to the bearing of a fixed measuring stand. The acoustic current metre, which makes use of the fact that sound is carried along with moving seawater, consists of two sonar paths for each coordinate direction through which the sound propagates in opposite directions. The difference in the travel times is a measure of the carrier velocity. Measurements of currents can also be made from a moored vessel with the current metre lowered into the water. Currents measurements can be made using Acoustic current meter and are measured at 3 (three) depths level from the water surface. These depths are:

- Near the surface (within 1.0m from the surface),
- mid depth, and
- near the bottom (within 1.0m from the bottom

3.2.5 Drift measurements

Drift measurements are made on the surface by a variety of floats. Systematic drift measurements in the near surface layers are carried out with drift bottles or with drift cards in plastic envelopes they drift ashore. This method only gives the starting and final points and a rough estimate of the time span of the drift. Parachute buoys used for drift measurements carry a mark, a radar reflector or a radio transmitter. The buoys are connected by a thin rope with a floating body at the selected depth to be measured. A parachute or another structure with high flow resistance is fixed to the float. Its trajectory can be tracked by taking the bearings of the surface buoys by means of optical, radar or radio direction finding either from a ship or a coastal station. Fluorescent dye is also used to measure surface currents. Powdered dye is released on the surface, often in packets, and it dissolves leaving a readily visible patch. Its propagation can be traced visually and photographically from an aircraft or by the use of a fluorimeter from a ship. Drift measurements in the bottom current can be performed with specially designed mushroom shaped floats made out of plastic. The “foot” which is weighted to result in a minimum degree of negative buoyancy, touches the sea floor slightly and the mushroom is carried along in small hops by the bottom current. Distance and time are obtained when they are retrieved in bottom trawls.

3.2.6 Water Sampling devices

Properties of seawater are best measured “insitu”. If this is not possible, the water has to be collected and analysed in the laboratory. In such situations, 3 precautions are necessary:

- the sample must be taken at known depth and position,
- the sample must be protected from falsification
- the sample should be adequately preserved by keeping in the freezer till analysed.

The water samplers at different depth can be triggered by any of the following devices; a messenger, a propeller or an electric remote control.

3.3 Living Resources Assessment Methods

Living resources include all living things from mangroves to manatees to microbes. They also include ecosystem functioning, health and integrity and, for the purpose of coastal survey, they include also subsistence fishing as well as commercial, economic use of various resources. Living resources also include the living landscape - whatever gives a particular part of the globe its unique ecological and aesthetic character.

3.3.1 Ecological Survey Method

One of the most important reasons for ecological survey is to document the ecological situation and to establish a baseline of what needs to be managed and their conditions. An ecological survey is basically the description of the environment including all its biota, trophic relationships, various life stages and seasonal variations, presence of rain and endangered species and the presence of special population or ecological communities such as mangrove and maybe coral reefs in wet-land systems. The methods of surveying ecological environment are:

3.3.1.1 Micro – Scale

Macro scale surveys utilize visual representations of data, often in a coarse format. Topographic maps, bathymetric charts and thematic maps (e.g. geology, vegetation) are the most common of the coarse data summaries. When coupled with local knowledge which can be superimposed on the base maps and after some validation by rapid checking in the field, they are often more than adequate as macro surveys. Better definition and detail can be provided by aerial photographs whether taken vertically or obliquely. Particularly when they are taken as a time series, aerial photographs can provide accurate information on trends in mangrove distribution, the migration of sand spits, the extent of sea grass meadows.

3.3.1.2 Rapid Rural Appraisal

This is an excellent survey technique which can provide a quick preliminary assessment of the situation for comparatively little cost. It provides mainly a good "gut feeling" and may require follow-up, however, after an effective rapid rural appraisal, any follow-up can be targeted much better. The techniques employed in rapid rural appraisal can include any combination of: review of existing data, direct personal observations, semi-structured interviews with local people, community meetings, relating of personal stories and experience, drawing of diagrams, etc. Rapid rural appraisal can be used successfully to establish a baseline of the existing situation. It can then be repeated to record historical changes, particularly those within the collective living memory of a community.

It can also provide a comprehensive analysis of single events such as a cyclone, a flood or an oil spill. It is also extremely valuable to provide an insight into the seasonal variability of a particular environment, especially when the investigator is limited to one particular time of the year. A typical rapid rural appraisal would start with the investigator familiarizing himself/herself with the main body of information already existing." This could mean a desk review of reports, study of aerial and other photographs, familiarisation with any published material. Armed with this preliminary information, the investigator could then convene a village meeting at which he/she will prompt information on whatever aspect of the environment is important. During this flexible approach, a skilled investigator will use "peer review" of the information which is volunteered and note consensus and dissent.

An effective approach is to use felt pens on a map base and record the information as it is provided and agreed to by the meeting participants. It is also possible to take one or two knowledgeable local people into the field to validate the critical information through spot checks. The data can then be refined and converted onto annotated maps, cross-sections of the environment, time sequences, etc. These will serve as a strong basis for any more thorough assessment or survey that is deemed necessary Rapid rural appraisal techniques include daily combination of review of existing data, direct personal observations, semi-structure interviews with local people, communities' meetings and relating of personal stories and experiences. This is the least costly and the most basic ecological study.

3.3.1.3 Remote Sensing

While rapid rural appraisal is usually the least costly and most basic ecological survey methodology, remote sensing is often the most sophisticated and most expensive. However, it can also be the most objective and most accurate and, depending on the environment that is being surveyed, it can also be very cost-effective. It can be defined as the obtaining of data about a target without the sense of being in contact with the target.

This is most sophisticated and expensive. There are many sensor and recording systems and they include photographic cameras (sometimes with specialized type of film), radiometers and radar systems which can record in photographic form or in digital form. Digital data, which depends on image processing systems to be transformed into useable imagery, is very versatile and can make corrections for radiometric and geometric “noise” and can also be enhanced using specialized spectral techniques.

3.3.1.3.1 Advantages of Remote sensing using space satellites are:

- Have been used to provide data on ocean color (reflects productivity of the water, interpreted to present the sediments loads, plankton blooms, etc).
- It can be used to get the sea surface temperature and after analysis, give the upwelling areas.
- Used for surface wind and waves conditions. This is important in dealing with oil spills.
- Give information on land use and even vegetation.

3.3.1.3.2 Some of the limitation of Remote sensing using space satellites are:

- Interpretation of the satellite images is often hinder by tidal fluctuations and storm surges.
- Cloud cover in humid tropical environment is a big problem.
- Light penetration in water is limited and therefore the deeper one tries to read below the water surface, the less reliable the data becomes.

3.3.1.4. On the ground survey

This is the most common and relies on standard methodologies usually employing sampling approach such as:

- Transects: this is recording the presence and absence of biota and the nature of environment along a linear part.
- Quadrant: usually a square meter use in conjunction with a transect. Can consist of a photograph (e.g. to record the extent of cover by algae).
- Deep Cores: to penetrate beneath the surface of the sub-stratum.
- Trawling: usually for a set period of time and set speed to record large biota.
- Planktonic net: can be used for a set period of time at a set speed and level in the water column.
- Gill net: the standard length of net with a standard mesh size set for a specific period of time at a specific depth level.

4.0 CONCLUSION

All the above methodologies rely on samples in order to interpret the overall situation. If the data from samples is to be extrapolated to the whole, the samples must be known to be representative according to reliable statistical techniques. The minimum number of replicate samples required to obtain representativeness, is the number at which a 100% increase in sample numbers will only lead to a 5-10% improvement in accuracy. It is also essential that samples are replicable so that results from different sites can be compared and contrasted, and so that repeat samples of the same site can be taken over time in order to observe any changes. The only way to ensure replicability is to record the approach and methodology used right from the planning stages, through to field work and subsequent analysis.

5.0 SUMMARY

In this unit the students have learnt that:

i. The various navigation systems and oceanographic techniques used for survey in the Ocean.
ii. The methods of documenting the ecological situation and establishment of living resources assessment.

6.0 TUTOR MARKED ASSIGNMENTS

i. What are the methods used as survey techniques in the ocean?
ii. Explain in details five (5) methods used for living resources assessment.

7.0 REFERENCES

Awosika, L. F., Ibe, C. E., Nwankvvu, E. O., Balogun, A. and Adekoya, E. A. (1992) Physical and Geological Factors Affecting the Transport, Dispersion and Deposition of Pollutants in the Lagos Lagoon, Nigeria. WACAF II Phase 2 Project. A Progress report for IOC.

Cook, P (1994) Offshore Mineral Resources. In: Proceedings International Conference on Oceanography. Lisbon. 23pp.

Herold, M., Gardner, M. E. and Roberts, D. A. (2003). Spectral resolution requirements for mapping urban areas. IEEE Transactions on Geoscience and Remote Sensing.

UNIT 11 MANAGEMENT OF DATA

CONTENTS

1.0 INTRODUCTION

What should be done with the results of survey and monitoring? There is a distinction between data and information. Survey and monitoring produce data which are most often screeds of figures and raw observations of very little use to anyone in their crude state. These data must be transformed into information which is an accessible, retrievable and user-friendly product. The transformation of data into information comprises processing, analysis, interpretation and eventfully application and this process can be referred to as data or information management.

2.0 OBJECTIVE

By the end of this unit, you should be able to:

- Understand the various methods used to conserve data received from the field;

3.0 MAIN CONTENT

3.1 Data and Information management

The type and format of information depends on the needs of the user or users, and this relates back to the objectives of survey and monitoring in the first place. The various formats for information management and display can be grouped loosely into six categories:

3.1.1 Simple Tabulation

This is probably the most commonly used format for displaying numerical data. By using rows and columns in logical manners and tables, it can provide visual relationship and connections and transformation of raw data into information.

3.1.2 Matrix

Almost by definition, a matrix is expected to be more complex than a simple tabulation. It provides an analytical relationship between data in a visual display - a cumulative visual summary of all impacts on all resources. For example, a matrix can be used to assess the impacts on coastal resources of an activity such as dredging. In such a matrix, all resources (including amenity values, uses, etc) are listed on the vertical axis, together with a numerical weighting factor (say from 1 to 5) to reflect the perceived significance or value. All impacts (from various phases, activities and processes) are listed on the horizontal axis, together with a weighting factor reflecting the expected duration of the impact (1 = short term, 2 = long term, 3 = irreversible).

In fact, the preparation of these two lists is already a very useful exercise providing a mental checklist of areas of contention. Having listed all the resources and all the impacts, the next stage is to relate, in an analytical manner, the items on the vertical axis with those on the horizontal axis. This relationship can in most cases be translated into a numerical impact index. Wherever the grid intersects, a judgement is made of the severity of the particular impact on the particular resource, and this can range from O (no impact, not applicable) to 3 (high impact). The numerical value representing impact severity is multiplied by the figure for impact duration and the result is multiplied further by the figure representing the resource significance or value. The resulting figure can be called the impact index and it provides an excellent comparative picture of where the problem areas of a development are likely to arise.

It must be stressed that the impact index is not an absolute figure but only a comparative one within the same impact assessment exercise. Although it is not able to be used for comparison across projects, it can certainly provide useful information on the comparative costs and benefits of various mitigation measures proposed within a project, as well as a good picture of cumulative impacts. Although it is only relative and indicative, rather than absolute, it can be a very useful and inexpensive data analytical tool in the hands of an experienced assessor.

3.1.3 Graphics

Graphic presentation of the results of survey and monitoring can range from common graphs to complicated illustrations. The latter can be hand drawn or photographic images. Although they are not expected to have a degree of accuracy that will enable them to be used as identification guides, all illustrations of plants and animals should depict what they are trying to represent as accurately as possible. It is important for graphic representations to be kept simple, avoiding clutter and avoiding the need for interpretation - if they cannot convey the information without resorting to explanatory text,

3.1.4 Data Base

A data base can be defined as a collection of data related to a particular topic or for a particular purpose. Simple data bases can range from a few note book to a filing cabinet, a card index, a photo collection or an electronic data base by computer. A computerized database management system is a software programme used to store and retrieve data or information on computer. Much has been made of electronic databases in recent time and it is worth remembering that the database is made up of what the user puts in - the computer only provides the system that stores and retrieves data. However, a relational database management system has the added ability to manage the system in a related manner.

This means that changes or updates in one cluster of data, will be reflected in a related cluster. Before investing time and money in setting up a database, especially if it is a sophisticated electronic one, it is essential to determine at the outset the purpose of the database, who will use it, what are his/her needs, which are the most important parameters or fields or data sets, and the relationship between them.

3.1.5 Maps and Plans

Maps and plans of coastal resources represent a significant advance from tabulations, matrices and graphic presentations of the results of survey and monitoring. Maps and plans truly transform data into information since they present the results within a spatial, geographic context, giving them an added dimension. Maps and plans allow the user to collate, analyse synthesize and apply; large amounts of information, in a simple, visual representation. They can juxtapose resource data and demands on resources; and they can indicate conflicting demands and potential impacts before they occur. Maps and plans are a versatile and sound basis for decisions on resource use.

They are an excellent tool for professional managers of coastal resources. They can expose weaknesses in the available information base and help focus research efforts. They can inform members of the public, making them more sensitive to the multiple issues that need to be resolved. They are a good early guide for developers and a good departure point for any assessment of the potential impacts of a proposed development. They are a very good source of formal educational material both at the secondary and tertiary levels. Finally, they are an excellent record and a subsequent measure, for policies, objectives and goals for coastal area management. Maps and plans can accommodate an enormous amount of information, but they need to be designed by a professional cartographer in order to finish up as a good, useful product

3.1.6 Geographic Information System (GIS)

A GIS is a computer-based system that can input, retrieve, analyze and display geographically referenced information. It is often erroneously regarded as synonymous with, or closely tied to remote sensing, database management, computer aided design (CAD), and computer cartography. In fact, it is allied to all these and has some common elements with some of them. However, it is a unique tool, very sophisticated, and comprising elements of all except perhaps, remote sensing. There are a number of benefits and advantages GIS in resource management:

- it integrates data of various types (graphics, text, digital, analogue);
- it has an enhanced capacity for data exchange among disciplines or departments;
- it can process and analyse data very efficiently and effectively;
- it can apply models, testing and comparing alternative scenarios;
- it has a facility for efficient updating of data (including graphic data);
- it has the ability of handling large volumes of data.

The dimensions of integrated coastal area management are very broad and encompass the maritime influence on land as well as the terrestrial influence on water. They also include a third dimension of depth, taking in water volume with vertical variability. Coastal areas have fuzzy boundaries both physical (land and sea interface) and administrative (coastal area limits for management purposes).

Finally, the coastal area has a wide array of scales and processes - from the microscopic biological processes, to chemical ones, from the spread of the Exclusive Economic Zone (EEZ) to the millimeters of sea level rise. An ideal GIS would be able to deal with these requirements and complexities, but none does as yet, at least not completely. Most good GIS programmes can handle the third dimension (depth), but a fourth dimension (time) is still beyond existing software. GIS therefore has limitations, but in spite of these limitations, it is an excellent tool for coastal area planning and management and an efficient mechanism for handling data and transforming it into information.

3.2 Community Structure Indices (Analysis and Interpretation of Organisms)

The community structure approach examines the numerical abundance of each species in a community. Example of this include the following:

3.2.1 Biotic Indices

These are generally specific to a geographical area as well as to a particular type of pollution. They are used to classify the degree of pollution by determining the tolerance of an indicator organisms to a pollution. Indicator species are assigned scores for their tolerance level. Biotic indices assume that polluted sites or systems would contain fewer species than un impacted site or system.

3.2.2 Diversity Indices

This is a measure of the richness or number of distinct taxa at a site and the evenness which is the relative abundance of different taxonomic group determined by the counts of all organisms collected. A diversity index attempts to combine the data of species abundance in a community into a single number.

3.2.2.1 Types of Diversity Indices

Species diversity measures can be divided into 3 main categories namely:

- Species richness indices
- specie abundance models
- indices based on the proportional abundance of specie.

3.2.2.2 Margalef's Index

This is a diversity of species richness which does not take into account dominant diversity but is largely dependent on specie richness. The more the species present in a sample, the greater the diversity. The formula goes thus:

$D = S – 1/ Log_e N$

Where:

D = Diversity

S = Number of species

Log_e = Natural log

N = Number of individual

3.2.2.3 Menhinick index

They are usually very easy to calculate. This index formula goes thus:

$D = S / \sqrt{N}$

The specie abundance models include:

- the log normal distribution,
- the geometric series, and;
- the logarithmic series

3.2.2.4 Indices based on the proportional abundance of species

This include information statistics indices or the Shannon Wiener diversity index. It is sometimes incorrectly referred to as the Shannon Weiner index. The value of Shannon Weiner diversity index usually range between 1.5 and 3.5 and only rarely surpasses 4.5. These index takes into account the evenness of abundance of species and the evenness written as (e) is the ratio of the observed diversity to maximum diversity.

4.0 CONCLUSION

The understanding of the various methods in interpreting data collected from the filed would go a long way to ensure that efforts of researchers on the field and raw data collected from such trips would be used judiciously.

5.0 SUMMARY

In this unit we have leant:

i. the various formats used for the information management of raw data collected from the field, and;
ii. the community structure approach to examine the numerical abundance of each species in a particular community.

6.0 TUTOR MARKED ASSIGNMENTS

i. Explain these following methods used for data management
   a). Simple Tabulation
   b). Maps and plans
   c). Graphics
   d). Geographic Information System
ii. Discuss the following diversity indices and include equation(s) where necessary:
   a). Menhinick Index
   b). Margalef Index
   c). Indices based on the proportional abundance of species.

7.0 REFERENCES AND OTHER RESOURCES

Kam, S. P., Paw, J. N. and Loo, M. (1998). The use of remote sensing and geographic information systems in coastal zone management. In: Integrative Framework and Methods for Coastal Area Management. ICLARM, Manila. 66pp.

Tortell, P. (1992). Coastal Zone Sensitivity Mapping and its Role in Marine Environmental Management. *Marine Pollution Bulletin*, **25** (14): 88-93.

Tortell, P., Collins, D., DuBois, R., Gwyther, D. and Sedlak, O. (1992) Environmental Guidelines for Dredging and River Improvement. United Nations Food & Agriculture Organization (FAO), Rome. 169pp.

UNIT 12 OCEAN RESOURCES

CONTENTS

1.0 INTRODUCTION

Resources are the geologically proven stocks of an energy carrier which are not yet regarded as recoverable economically because recovery requires new and expensive technology. The term “resources” also applies to stocks which are not yet proven but can be assumed to exist in a region based on its geological characteristics. The distinction between reserves and resources is sometimes fluid. The oil sand industry in Canada is the latest example of a transition from resources to reserves. Only a few years ago, these deposits were not recoverable economically. Today, thanks to its oil sands, Canada appears near the top of the list of countries with the largest oil reserves. These deposits can now be exploited, but as this requires new and complex technology, they are still classed as “unconventional

2.0 OBJECTIVES

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

- understand the various types of oceans in the world
- understand the state of resources found in the ocean
- understand the importance of the minerals from the Sub-Sea beds to humans.

3.0 MAIN CONTENT

An ocean is a very large sea which usually separate continents. They are four large Oceans in several seas, in order of size. They are:

- Pacific Ocean (32.4%),
- Atlantic Ocean (16.2%),
- India Ocean (14.4%),
- Arctic Ocean (2.8%)
- Other Sea (5.1%)

Together with the seas, bays and gulf, these oceans cover about 71% of the earth’s surface. The other seas include the North Sea, Black Sea, Gulf and Mexico, Mediterrean Sea and the Caribbean Seas, which forms about 5.1% of the earth surface.

3.1 Resources

This term is generally applied to plants, animals, solid, liquid or gaseous minerals in the sea that can be exploited by man. The resources are either renewable or non-renewable. The Oceans and seas contains enormous quantities of fishes and fisheries of which the rapidly expanding world's population must depend. The sea also contains other raw materials which are not inexhaustible but with enormous reserve.

3.1.1 Renewable Resources

This include all living organisms because they can reproduce which include phytoplankton. Some higher plants and animals. The animals include mammals (whales, dolphins); reptiles (sea turtle, sea snakes); fin fish and shell fish. Nigeria have a diversity of fin fish consisting of about 199 species and they are all edible except for the puffer fishes which are poisonous. The fin fishes are further divided into Bony (Bonga, tilapia) and Cartilaginous (sharks, rays, skates) fishes. The shelled fishes include the shrimps, crabs, lobsters, oysters, etc.

3.1.2 Non-Renewable Resources

These are the non –living. The most important is the oil and gas. In Nigeria, oil and gas constituent 90% of the foreign exchange earnings, other are Silica and gravels. The sand are pure quartz which are used in industries for glass making, capacitors, computers, etc. we also have refractory clays which are used in furnance for steel manufacture. We have heavy minerals which are used in industries for raw materials. Salt is also an important resource from the sea and can be extracted in large quantities.

3.2 The resources in the Ocean

3.2.1 Food:

FAO (1998) gave the total world's catch of fish and fisheries at about 500 metric tonnes. China is the leading fish producing country in the world followed by Peru, Japan, Chile, USA and Russia. For growth, vigor and general health, the human body is dependent to a very large extent on quantities and quality of protein availability because these are substances that make up the muscles and other body mass, hence the need to take in fish and aquatic products.

In addition, the minerals that are essential components of the skeleton and the vitamins that controls the chemistry of the body are derived from these aquatic organisms. Fishes whether whole or reduced to meal (processed) is one of the best source of these food components. Proteins are among the most complex chemical substances, although they occur in many kinds of food, only fish protein contain the essential Amino Acids which are missing in grain proteins and poultry.

These essential Amino Acids are Lysine, Methionine and cysteine. The rapidly rising use of fish meal for animal feeds take place because it is rich in essential Amino Acids. Other fishery products of high protein contents include shrimps, squids, Krill, Lobsters, etc.

3.2.2 Aquaculture/Mariculture

Though, fish and fishery products falls under renewable resources, it is paramount to maintain the maximum sustainable yield (MSY) in order to avoid overfishing and over exploitation. This could be done through aquaculture or mariculture.

Mariculture is the application of farming techniques to grow, manage and harvest marine animals and plants in the ocean or ponds of ocean water for food. This may be hatchery reared or intensive captive maintenance throughout the life span of the organisms.

Aquaculture is the rational rearing of aquatic animals in man-made ponds, reservoirs or enclosures in lakes or coastal waters.

3.2.3 The Biologist Place in Fishing Industries

The biologist objectives of fishing management were to find out what level of fishing efforts will produce the maximum sustainable yield for each resources and to develop scientific management measures which will maintain the maximum sustainable yield.

Fishery biologists have made many valuable contributions to our understanding of oceanic and fresh water ecology. They are pioneered in the study of population dynamics in the natural environment. They have equally been productive in biological research, they have made important contributions to the literature of plankton especially in taxonomy and the distribution of fish eggs, larvae and adult fish. Thus, the existence of the ocean provides Job opportunities to scientists and related discipline if given the adequate training, good exposure, financial backing and machinery to carry out research.

3.2.4 Power from the tide (Ocean Energy)

The tide can be harnessed or manipulated to produce energy, although it has been emphasized how very small the tide generating forces are, compared to other forces. Energy of the tide is continuously being disintegrated at a rate whose order of magnitude is a billion horse power.

The ability to generate power from the tide (although, very small) can still be research into for proper utilization as source of energy in addition to those sources of energy presently used. The temperature differences between warm surface and cool deep water could also be used to power machines such as electrical generators. Hydro - electric power uses the energy of water, flowing down rivers and streams back towards the oceans. The electrostatic attraction between water molecules and soft ions can be used to provide energy at places where fresh water runs into the oceans.

However, the manufacture of appropriate membrane have being troublesome. Fuels can also be produced from biomass such as seaweed in the oceans, forests or land. However, the ocean biomass is in even greater demand for food.

3.2.5 Mineral Resources

Mineral deposits found in land are usually cheaper and easier to extract than those on the ocean floor, hence we explore them first. The ocean mineral resources fall into 3 (three) categories:

3.2.5.1 Minerals removed from underlying bedrocks:

The minerals removed from underlying bed rocks are removed through bore holes and some from mines. By catch value, the most important ocean resources are oil and natural gas removed through bore holes ie drilling. Also removed through boreholes but of less important are sulphur and potassium salts. Resources dredged from ocean floor include sand and gravels (which are used for filling and concrete), calcite (use for cement production) and to lesser extent, heavy metals enrich sediment and manganese nodules (for metals). Resources removed from the water include various salts and water itself. These minerals found in water are:

3.2.5.1.1 Recovering of chemicals from the sea

a) **Salts**: the oceans have been used as source of slats for thousands of years. In addition, magnesium salt and bromine are also extracted in commercial quantities. The most obvious chemical recovered in large quantity is NaCl (Sodium Chloride) from the sea. As the sea water evaporates, various dissolve salts begins to sequentially crystalize out.

CaSO4 crystallizes out first followed by the brine which is concentrated until NaCl begins to precipitate.

Finally, when specific gravity exceeds 1.28, Magnesium salts begins to precipitate, the remaining concentrated brine solution is called bitterns and may be further processed to recover Magnesium compounds, halides and other salts.

b) **Magnesium**: next to Sodium, Magnesium is the most abundant metallic cation in the seawater, since World War 11, the magnesium metal consumed in USA have come largely from the sea. In addition to the metal, we have MgO, $Mg(OH)_2$ and $MgCl_2$ are also produced from seawater and brine. Magnesium is chemically similar to Calcium but it is more soluble. Hence, Magnesium is a light weight metal like Aluminum but much stronger than Aluminum. Magnesium is used in construction where light weight and strength are important, when solubility is important and when solubility is important such as in Medicines.

c) **Halides**: the elements, iodine was first discovered than bromine in bitterns prepared from salt marshes water. Bromine is principally used for anti-knock compounds in gasoline. Iodine is used to prevent goiter.

d) **Gold**: the oceans of the world are said to contain enough gold. The recovery of gold from the sea water curiously enough appear to be particularly appear to the Germans who were avid alchemists who discovered that the gold concentration is far too small and the quantity of the seawater that we have to be processed far too large to make the extraction profitable.

e) **Bio – materials**: the marine biosphere yields many materials useful to many. The most obvious of cause is food materials. But also seaweed as a source of Sodium alginates and fertilizers as well as food. Not well known but increasing scientific attraction in the marine biosphere is now as a source of physiologically active substances ranging from toxins to antibiotics i.e. Drugs from the sea.

f) **Desalination**: the ability or process of removing salt from water is not an easy task and the process designed to accomplish this aim have been pushed from research and development into engineering and production. The main categories of desalination are:

- Process involving a phase change, this include evaporation, distillation and freezing.
- Processes involving semi-permeable membrane. This will involve electro dialysis and reversed osmosis (hyper- filtration).

- Process involving chemical equilibrium; this involves ion exchange and hydration.

3.2.5.1.2 World Sub-Seas Mineral Resources

a) **Petroleum**: Sea bed petroleum (oil and gas) produced off-shore. 25 countries presently contribute 17% of the world outputs and makes up nearly 90% of the total value of current sub-sea mineral productions. So, very soon, sub-sea petroleum productions may probably exceed that of other marine resources combined including sea water, chemicals and fish. Petroleum resources are largely confined to continental shelfs, continental slopes, continental ridges and small ocean basins. The separation of petroleum will produce kerosene, diesel, Vaseline and gasoline.

b) **Potash and other saline minerals**: most of the world deposits of anhydrates and gypsum (Calcium and sulphates), common salts and potash – bearing minerals are formed by evaporation of sea water and other natural brines in basins of restricted circulation. Important deposits of Magnesium bearing salts are also deposited in such basins and elemental sulphates formed in some of them by biological processes involving the alteration of anhydrides.

c) **Sulphur**: nearly 60% of world productions of sulphur comes from deposits associated with anhydrites; either embedded deposits of salts. Growth in demand for Sulphur have exceeded supply in recent years and while new discoveries are helping to ease out world's shortage, new sources are needed.

d) **Heavy metals concentration**: coal and some sub-sea minerals are currently being mined by dredging and some some underground methods. The production potential of heavy minerals concentration, sand, garvel, shell and lime muds. These are mined by dredging while coal, iron ore, copper, limestone and other minerals are mined from underground of land or artificial island where entering is limited to shallow near-shore parts of the continental shelfs.

e) **Phosphorites**: is widely distributed on the continental shelf and upper slope in the areas of upwelling. There are sufficient and abundant in areas such as off the coast of Southern California and East of New Zealand but in many places consists of scattered nodules, too sparsely distributed to be recovered.

4.0 CONCLUSION

Resources from the ocean are renewable and non-renewable materials. Marine resources have great potential for profitably exploitation. However, their extraction is fraught with risks and could potentially cause severe degradation of the marine environment.

5.0 SUMMARY

In this unit; you have learnt that:

i. Resources from the sea are either renewable or Non –renewable;
ii. Minerals are embedded in the ocean floor, and;
iii. Valuable chemicals can also be drilled from the seabed.

6.0 TUTOR MARKED ASSIGNMNETS

i. Define the following and give practical examples:
a). Renewable Resources
b). Non-renewable Resources
ii. List 5 chemicals extracted from the ocean floor and state their uses.
iii Explain how energy is generated from the ocean body.
iv how do we mitigate the effect of severe degradation on the marine environment

7.0 REFERENCES AND OTHER RESOURCES

FAO (1998). Food and Agricultural Organization Annual Report. Rome, Italy. 32- 35.

Hannington, M. D., Jamieson, J., Monecke, T., Petersen, S. and Beaulieu, S. (2011). The abundance of seafloor massive sulfide deposits. *Geology*, **39**: 1155–1158.

Hinrichsen, D. (2011). *The Atlas of Coasts and Oceans: Ecosystem, threatened Resources, Marine Conservation.* University of Chicago. 72pp.

Ray, G. C. and McCormick-Ray, J. (2009). *Coastal Marine Conservation: Science and Policy*. John Wiley Sons Press. 102pp.

Soule, M. E. (2005). *Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity.* Island Press. 127pp.