PART 1 – MARINE ECOLOGY

Marine ecology is the branch of ecology dealing with the interdependence of all organisms living in the ocean, in shallow coastal waters, and on the seashore. The environment consists of the abiotic - a non-living component, e.g. physical factors such as soil, rainfall, sunlight, temperatures and the biotic - a living component – interactions of the organisms

Abiotic Factors – include factors such as water, salinity, light, pressure, temperature, dissolved gases, pH, tides, currents, waves, stratum, nutrient supply, exposure to air

The Water Cycle - 97 % of the water on earth is **salt water in the ocean**. Of the **3%** of water that is **fresh water**, **2%** is **frozen in ice caps** and only **1%** is usable by **organisms** as liquid water or water vapor found in lakes, rivers, streams, ponds, in the ground water, and as vapor in the atmosphere



The six major processes in the water cycle are

- Precipitation water from the clouds fall to earth rain, snow, hail or sleet
- Surface Runoff water on the surface of the land that flows downhill into bodies of water such as streams, rivers, ponds, and lakes
- Infiltration rain water soaks into the ground through soil and rock layers under the soil with some remaining underground as groundwater
- Evaporation liquid water changes to a gaseous state as water vapor
- **Transpiration** water that has been absorbed by plants will evaporate through the leaves as water vapor
- **Condensation** water vapor is changed into a liquid. Water vapors join dust particles to form clouds

Physical and chemical properties of pure water

- Water is 775 times as dense as air at 0 °C
- Exists in liquid form at normal atmospheric temperature and pressure
- Water only substance on earth to occur naturally in three forms liquid, solid and gas
- Density maximum density is at 4° C not at freeing point of 0° C and expands as it freezes so ice floats
- The boiling point of water is 100 ° C
- The H₂0 molecule is polar and hydrogen bonding is present
- Water molecules are attracted to other water molecules termed cohesion
- Cohesion of water molecules at the surface of a body of water (surface tension) is very high
- Water is attracted to other types of molecules termed adhesion
- Water is an excellent solvent for ions and polar molecules
- Capillary action due to stickiness (cohesion) of water molecules allows water to go up a small tube



A gas becomes solid thought frost formation.

Characteristics of Seawater

- Characteristics due to nature of pure water & materials dissolved in it
- Dissolved solids due to chemical weathering of rocks on land & hydrothermal vents



Surface Tension





Salt Composition

- Sodium chloride accounts for 85% of all solids dissolved
- Major constituents of sea water
 - o 96.5% water
 - \circ 3.0 % sodium and chlorine ions
 - $\circ~0.5$ % other salts as ions of magnesium, calcium, potassium, sulfate, bicarbonate, bromide, boric acid, strontium
- Salt effects the properties of the water
- In seawater, the density increases below 4 degrees Celcius to the freezing point so very cold and dense surface water can be formed and sink to the bottom to form a favorable environment of deep-sea organisms
- Temperatures below zero are possible because seawater freezes at lower temperatures than pure water
- The two important gases dissolved in seawater are oxygen and carbon dioxide.
- Their solubility of oxygen is effected by temperature the lower temperature, the greater the solubility.
- Carbon dioxide reacts chemically in the water to form carbonic acid which dissociates into a hydrogen ion and a bicarbonate ion
- The carbon dioxide-carbonic acid-bicarbonate system functions as a buffer to keep the pH of sea water in a narrow range.

Effects of Abiotic Factors on Organisms in the Ocean

Salinity

- The total salted dissolved in seawater
- Salinity tolerance is also important in limiting distribution
- Salinity fluctuates most in coastal waters due to shifts in river flow
- Organisms that are mobile can *migrate* offshore if they cannot tolerate a certain salinity
- Attached organisms must *cope* with the changes or die clams, oysters, and barnacles manage to survive by closing their shells.

Temperature

- The distribution of species closely follows the shape of *isotherms*
- It controls rates of chemical reactions and thus metabolic rates, growth rates, feeding rates, etc.
- Temperature tolerance varies tremendously among marine organisms
- Young stages are generally less tolerant of large changes in temperature
- Temperature may indirectly effect a species due to a direct effect on its predator

Density

- The sea water gets denser as it gets saltier, colder or both
- The density is controlled more by temperature than salinity

Hydrostatic Pressure

- Hydrostatic pressure is the pressure caused by the height of water
- It is a function of the density of water and the total height of the water column
- Pressure generally increases at a rate of 1 atm per 10 m of water
- Hydrostatic Pressure is enormous in the deep sea yet animals have adapted to live here

- Animals do not contain gases
- Mesopelagic fish have gas-filled swim bladders to help maintain neutral buoyancy so they are unable to move rapidly between depths because the change in pressure could cause bladder explode

Diffusion

- Molecules move from high to low concentrations
- internal fluids of marine organisms also contain salts
- chemical gradient salts inside the body relative to the surrounding seawater
- salts will diffuse from an area of high concentration to low concentration-nutrient uptake and the elimination of waste products.
- Diffusion is also the mechanism by which water molecules pass through cell membranes. This is called osmosis
- **Osmoregulation** is the ability of organisms to control the concentration of salts or water in their internal fluids. This is extremely important for organisms living in areas where the salt concentrations vary such as estuaries

Ocean Circulation

- Currents move and mix ocean waters and transport heat nutrients, pollutants and organisms
- Surface circulation is driven by wind
- The *Coriolis Effect* Since the earth is rotating, anything that moves over the surface tends to turn a little rather than moving in a straight line and it deflects large-scale motions like winds and currents to the right in Northern Hemisphere and to the left in Southern Hemisphere

• Wind Patterns

- Winds driven by heat energy from sun
- Polar Easterlies at high latitudes are the most variable winds
- Westerlies at middle latitudes move in opposite direction
- *Trade winds* warmer at equator
 - wind at equator becomes less dense and air from adjacent areas gets sucked in to replace it creating winds
 - wind bent by Coriolis Effect
 - approach equator at 45° angle where there is no land
 - steadiest winds



• Surface Currents

- Winds push the sea surface creating currents
- \circ Surface current moves off 45°
- Top layer pushes on layer below & again Coriolis Effect come into play
- o Second layer moves slightly to right and slower and is repeated down the water column
- o (Ekman spiral)- lower waters move progressively at greater angles from the wind
- \circ Effect of wind decrease with depth 100 m no wind is felt
- o Produces Ekman transport- upper part of water column moves perpendicular to wind
- o Direction to right N. Hemisphere & left in S. Hemisphere
- Trade winds move toward equator & the equatorial current move parallel
- Currents combine into huge gyres



• Waves

- Parts of a wave are the *Wave crest* moves up & forward *Trough* moves down and back
- $\circ~$ Waves are mechanical energy that has been transferred by wind, earthquakes, landslides, or other waves to the ocean water
- o Most of the energy transfer is by wind and the waves travel outward from the energy source
- The greater the energy supplied, the larger the wave.
- The size of a **wave** also depends on its **fetch**. The **fetch** is the distance a **wave** travels. The greater the **fetch**, the larger the **wave**



Tides

- Influence marine organisms
- Organisms are exposed & submerged on shore
- Drive circulation of bays and estuaries, trigger spawning
- Gravitational pull of sun & moon & rotation of Earth, moon, & sun
- Moon's influence gravity strongest on side of earth closest pulls water in ocean toward it
- Opposite side furthest from moon pull is weakest
- earth's rotation is like unbalanced tire (wobble) creates a centrifugal force makes the
- oceans bulge out toward the moon & away from moon
- 2 high tides and 2 low tides in 24 hours and 50 minutes
- extra 50 min because for earth to catch up to moon
- Sun ½ as strong as moon because so far away
- Full & new moon (sun moon in line)
- Tidal range (difference between high and low tide) is large
 Spring tides
- First and third quarter
- Sun & moon at right angles partially cancel each other out – tidal range small **Neap tides**
- Tides vary depending on location and the shape and depth of the basin
- East coast of N. America & most of Europe & Africa have semidiurnal tides (2 highs and 2 lows)
- West coast of USA & Canada mixed semidiurnal tide- successive tides of different height
- Diurnal (1 high and 1 low) rare on Antarctica and parts of Gulf of Mexico, Caribbean, & Pacific
- Tide tables give predicted time and height of high and low tides
- Determined by local geology
- Weather like strong winds can cause water to pile on the shore creating higher tide than normal





Biotic Factors are interactions among living organisms



Zonation - major divisions of marine ecosystems

- **Pelagic zone** include **neritic zone-** the productive coastal waters.- and **oceanic zone-** deep waters of the open ocean- Another division in the pelagic zone is related to light penetration. *(see below)*
- The **benthic zone** extends from the seashore to the deepest parts of the sea. The material that makes up the bottom is the **substratum** and the organisms living there are the **benthos**



Classification of Organisms by Environment

- Horizontal: Neritic and Oceanic zones
- Vertical:
 - *Epipelagic* (top) is *euphotic* (good-light = enough for photosynthesis)
 - o <u>Mesopelagic</u> (middle) is <u>disphotic</u> (low-light= too weak for photosynthesis)
 - **Bathypelagic** (deep) is **aphotic** (without-light)
 - *Abyssopelagic* ("bottomless")
 - Deep sea layers **bathypelagic** 1000-4000m and the **abyssopelagic** zone (below 4000m) have limited food supplies although bacteria have been found that can make their own food



Classification of Organisms Based on Lifestyle

Plankton (floaters)

- Plankton are weak swimmers, and are known as drifters, unable to counteract currents.
- Made up of **Phytoplankton** (plant plankton) the primary producers in the pelagic region and **Zooplankton** (animals) which range from bacteria size to 15 m jellyfish
- Diatoms (cooler water) and Dinoflagellates (warmer water are major types of phytoplankton
- Other algae include coccolithophores, silicoflagellates, blue-green algae and green algae (usually in coastal waters)
- Occupy the first two or three links in the marine food chains
- Adaptations which keep them in upper sunlight layers include small size, structure, shape, decreased density due to oil droplets in cytoplasm
- Zooplankton can be as numerous as **500,000 per gallon**
- The most common are Copepods who along with other zoo plankton have **vertical migrations** moving up toward the surface to feed in the evening as light diminished as light, shadows, and pigment colors help them locate food this assists phytoplankton with photosynthesis in daylight
- Holoplankton are permanent members of the zooplankton community and have evolved special adaptations as special appendages, droplets of oil and wax, ability to tread water, jell-like layer, and gas-filled float to remain adrift
- **Meroplankton** are temporary members of the zooplankton community because they are part of the plankton for only part of their life cycle usually larvae of sea urchins, sea stars, crustaceans, some marine worms, gastropods and most fish.
- A majority of the invertebrates and many vertebrates have a planktonic state as meroplankton
 - They use the water mass to feed and disperse their planktonic young to new habitats
 - The reproductive cycles often coincide with maximum concentrations of food and favorable currents such as spring phytoplankton blooms that increase zooplankton coincide with migration patterns of whales, penguins, and seals

Nekton (swimmers)

- Nekton are active swimmers capable of counteracting currents eg. Fish, Squids, Reptiles, Birds, and Mammals
- Planktivouous Nekton are animals that feed on plankton as baleen whales and some fish
- Herbivorous Nekton feed on large seaweeds and sea grasses as turtles and manatees
- Carnivorous Nekton are the dominant animals of the nekton and they migrate great distances for food
- Nekton animals use their ability to swim as their means of locomotion, to find food and to escape predators so they have many adaptations as fins, jets of water, strong flippers, flukes and flippers to swim through the water
- Many of the Nekton animals are the top of the trophic levels as carnivores or herbivores without natural predators except man



Benthos (bottom dwellers) – live on the bottom

- Resides primarily in or on the substrate and doesn't swim or drift for extended periods as an adult
- They either burrow, crawl, walk, (motile) or are sessile-permanently affixed to the substrate or each other
- **Epiflora** or **epifauna** live *on* the sea bottom while **infauna** live *in* the sea bottom where the substrate could be a source of food
- Benthic plants are restricted to shallow waters because they need light for photosynthesis
- Benthic animals occur everywhere from shallow depths to the deep sea
- Divided by size:
 - Microbenthos (<100 mm) includes bacteria & protests
 - Meiobenthos (100-500 mm) includes small metazoa and larger protists
 - Macrobenthos (>500 mm) includes larger metazoa and megabenthos
 - Megabenthos (very large) large crustaceans, mollusks, etc.
- Divided by what they eat:
 - Herbivores- feeds on plant material
 - Carnivores/predators- feeds on other benthic organisms
 - Detritivores- feeds on dead plant and animal material
- Divided by how they eat:
 - Suspension feeders- eats using a mucus-covered appendage that catches particles in water column
 - Filter feeders- strain particles from the water column
 - Deposit feeders- ingest sediment and removing the nutrients
- **Demersal organisms**, usually fish and invertebrates, alternate between swimming and feeding near the bottom and resting on the bottom

TROPHIC (FEEDING) RELATIONSHIPS

- Energy transfer is accomplished in a series of steps by groups of organisms known as **autotrophs**, **heterotrophs**, and **decomposers**
- Each level on the **pyramid** represents a **trophic** level.
- AUTOTROPHS absorb sunlight energy and transfer inorganic mineral nutrients into organic molecules.
 - The autotrophs of the marine environment include algae and flowering plants and in the deep sea are chemosynthetic bacteria that harness inorganic chemical energy to build organic matter
 - AUTOTROPHIC NUTRITION supplies food molecules to organisms that can't absorb sunlight.
- **HETEROTROPHS** Consumers that must rely on primary producers as a source of energy...heterotrophic nutrition.
 - The energy stored in the organic molecules is passed to consumers in a series of steps of eating and being eaten and is known as a **food chain**.
 - Each step represents a trophic level and the complex food chains within a community interconnect and are known as a **food web**.
- **DECOMPOSERS--** The **final trophic** level that connects consumer to producer is that of the decomposers.
 - They live on dead plant and animal material and the waste products excreted by living things.
 - The nutritional activity of these replenish nutrients that are essential ingredients for primary production.

- The dead and partially decayed plant and animal tissue and organic wastes from the food chain are **DETRITUS**.
- \circ $\;$ This contains an enormous amount of energy and nutrients.
- \circ $\,$ Many filter/deposit feeding animals use detritus as food.
- \circ $\,$ Saprophytes decompose detritus completing the cycle

Food Chain

- Producer
- 1st order Consumer or *Herbivore*
- 2nd order Consumer or 1st order Carnivore
- 3rd order Consumer or 2nd order Carnivore
- 4th order Consumer or 3rd order Carnivore
- **Decomposers** consume dead and decaying matter as bacteria (often not shown on food chains or food webs but essential to the ecosystem



Food Web – multiple food chains in an ecosystem



Energy vs. Nutrients

- Nutrients are **cyclic** biogeochemical cycles
- Energy flow is **one way**



Ecologic Pyramids

- Ecological pyramid a graph representing trophic level numbers within an ecosystem.
- The primary producer level is at the base of the pyramid with the consumer levels above
 - *Numbers pyramid* compares the number of individuals in each trophic level. *May be inverted due to size of individuals*
 - *Biomass pyramid* compares the total dry weight of the organisms in each trophic level.
 - *Energy pyramid* compares the total amount of energy available in each trophic level. This energy is usually measured in kilocalories.



ENERGY TRANSFERS IN MARINE ENVIRONMENTS

- Primary producers usually outnumber consumers and at each succeeding step of the food chain the numbers decrease
- The numerical relationship is called the **numbers pyramid**
- The energy pyramid is the energy distribution at each trophic level as it passes from producers through the consumers.
- Some energy is lost as it passes to the next level because
 - \circ consumers don't usually consume the entire organism
 - o energy is used to capture food
 - o organisms used energy during their metabolism
 - o energy is lost as heat
- Ecological Efficiency = efficiency of energy transfer between trophic levels:
 - \circ ~20% for herbivores
 - \circ 10-15% for carnivores
- 80-90% of energy is lost due to respiration Number of trophic levels will determine how much energy and food is available to top predators (whales, fish, birds)
- Number of trophic levels:
 - High in open ocean waters
 - Low in upwelling regions
- Phytoplankton size: If phytoplankton is small (pico-, nanoplankton), then more trophic levels (protozoa) because larger animals (copepods) are unable to graze such small food particles; upwelling regions – large phytoplankton
- Generally only **10%** will pass on to the next level (**10% Rule**)



- **Scavengers** feed on dead plants and animals that they have NOT killed...crabs ripping chunks of flesh from fish on the beach are scavengers.
- Most scavengers consume detritus rather than flesh and deep sea animals can feed on both

Recycling of Nutrients in Marine Environments

Recycling of nutrients is key to productivity in marine environments.

- Food Production occurs mainly through photosynthesis with some chemosynthesis in lower depth without light
- Primary productivity varies seasonally and geographically and is measured as carbon/m²/year
- The more vertical mixing that occurs in an area, the higher the primary productivity
- It decreases as depth increases due to less light for photosynthesis
- Accessory pigments in algae enables them to make the most of the light that gets to them
- Key nutrients are necessary along with energy to sustain life and allow reproduction and growth of organisms

Important Nutrient Cycles include carbon, nitrogen, and phosphate cycles in addition to the water cycle.



Sediments



Imbalances in Marine Environments

- Nutrient over-enrichment: eutrophication such as Algal Blooms eg. the Red tide
- Ecosystem Alteration
- Climate Change and Sea Temperature Rise
- Acidification of the Oceans
- Pollution as pathogen contamination and toxic chemicals
- Alteration of freshwater inflow
- Loss and degradation of habitat
- Declines in fish and wildlife populations
- Introduction of invasive species
- Accidental spills as Oil Spills

Pollution

Sources of water pollution may include **point source pollution** from a clearly identifiable location or **nonpoint source pollution** that comes from many different places.

- Sources of pollution usually fall into four main categories industrial, residential, commercial, and environmental
- Some types of pollution may include
 - o *organic pollution* decomposition of living organisms and their bi-products
 - o *inorganic pollution* dissolved and suspended solids as silt, salts, and minerals
 - o *toxic pollution* heavy medals and other chemical compounds that are lethal to organisms
 - o *thermal pollution* waste heat from industrial and power generation processes

Threats to Marine Water Quality and Marine Environments

- Oil spills and their ecological disasters
- Marine dumping of wastes plastic and other wastes
- Dredging Wastes
- Overfishing
- Ocean acidification
- Population displacement
- Mangrove Destruction
- Bycatch marine wildlife unintentionally caught as sea turtles, porpoises, albatross, crabs, starfish & fish
- Whaling is still a problem though strides are being make
- Overfishing and Exploitation
- Climate Change
- Sea Temperature Rise
- Invasive Species
- Ocean Dead Zones