Chapter 1 - Coast

- Coast is the zone where the land meets the sea
- Factors affecting coastal environments
    - **Waves : a rising and falling movement of the water surface**
        - Main shaping force of the coastal environment
        - Formed when kinetic energy from winds blowing across seas and oceans is transferred to water surface
        - **Greater wind energy - higher wave energy - stronger and taller waves - more power to shape the landforms**
    - **Tides : daily alternate rise and fall in the sea level**
        - Caused by gravitational pull of moon and sun on earth which produces an alternating low and high tide which changes every 6 hours
        - Tides affect processes such as coastal erosion, sediment transport, sediment deposition as it affects coastal area that can be reached by the waves
        - During high tide, waves reach parts of the coast that may not be subjected to wave action during low tide. Hence, waves erode and transport away larger parts of the coast
        - Intertidal Zone will have more erosion due to continuous drying and wetting
    - **Currents : large scale continuous movement of water in seas and oceans**
        - Play role in **distributing sediments and regulating temperature**
        - Currents carry large amount of energy and shape coast through erosion, transportation, deposition
        - Regulate temperature - carry cool water away from North and South poles towards the Equator and warm water away from the Equator toward Poles
        - Helps create milder climates in coastal environment
        - Longshore current - nearshore current that flows parallel to the coastline
    - **Geology : the arrangement and composition of rock found in the area**
        - Determines the hardness and their resistance to erosion
        - Affects the rate of erosion and the shape of coastline
        - Harder rocks (eg. granite and basalt) will erode more slowly than soft rocks (eg. limestone and shale

        - Granite and basalt (well-jointed rocks) are vulnerable to erosion when the joints are attacked by waves
        - Alternate layers of soft and hard rocks - more vulnerable to erosion
    - **Types of ecosystems : communities of plants and animals interacting with each other (eg. coral reefs and mangrove)**
        - **Reduce the impacts of waves on coast**
        - Natural barriers against coastal erosion and flood
        - Coral reefs - provide natural barrier to slow down the speed and impact of waves on coast
        - Mangrove - help trap sediments and reduce coastal erosion, reduce the effect of floods and tsunami
    - **Human Activities**
        - Built-up coastal areas alter coastline
        - Pollution of coastal environment from dumping waste
        - Affects the condition of the coastal environment
- What are waves and how are they generated?
    - Wave particles move in an orbit, this motion decreases with depth
    - **Factors affecting wave energy**
        - **Wind speed** : the faster the wind blows, the greater the wind energy
        - **Wind duration -** The longer the winds blow, the larger the waves are
        - **Fetch (The distance over which wind has travelled over seas and oceans to form waves) -** the greater the fetch, the greater the wind energy, the greater the wave and the more energy the wave have
        - Wave steepness : ratio of wave height to wavelength
        - Wave period : time waves to travel through one wavelength
        - The higher the wave, the steeper the wave, the shorter the wave period
    - Wave in open ocean have long wavelength and low wave height
    - **How do waves break along the coastline?**
        - **As waves approach a coastline, the base of the wave slows down due to increased friction with sea bed**
        - **Waves pushed forward by waves behind causing wave height to increase and wavelength decrease**
        - **Eventually, waves become too steep**
        - **Thus, wave collapses and breaks onto the coast**

        - **Wave energy released and sometimes air trapped**
    - How do waves affect coastal areas
        - **Swash - the water that washes up shore after incoming wave has broken. It brings materials on the beach and cause light sediments to be transported up the beach** (deposition effect)
        - **Backwash - the water that returns to the sea at right angle due to loss of energy due to friction and gravitational pull as it removes materials from the shore** (erosion effect)
        - **Constructive wave (spilling breakers/swells) - low energy waves of long wavelength that breaks far from shore and gentle slopes created as finer materials deposited**
            - Strong swash that carries sediments onto beach **at oblique angle**
            - Strong swash that deposits sediments and weak backwash that removes only a little material
            - Wave frequency 6-8/min
        - **Destructive wave (plunging/surging breaker) - high energy waves of short wavelength that break violently on shore and steep slopes created as it erodes the coast**
            - Finer materials tend to be transported away, leaving only coarser materials as it erodes coast and transport rocks and beach materials away
            - Carries sediments away from beach into ocean **at right angle due to gravity**
            - Wave frequency 10-14/min
        - **Wave refraction - process by which waves change direction as they approach a coast**
            - **Waves approach an uneven coast with headlands and bays in parallel manner**
            - **Waves converge on headlands and diverge at bays**
            - **Reach the shallower water off the headlands first - waves slow down and break**
            - **When waves converge - increased wave height and greater erosive energy as wave energy is concentrated - headland undergoes more erosion**

- **When waves diverge at bays, decreased wave height and lower erosive energy as wave energy is diffused - deposition at bays**
- **Waves are refracted and break almost parallel to the coast and the impact on the shore is uneven - uneven coastline becomes straightened**
    - This occurs as part of the wave that reach shallow water first slow down while other parts of wave continue at same speed (just read)

- Erosion
    - **Corrasion (Abrasion)**
        - **Rock fragments are carried by the waves and hurled against coast**
        - **They act like chiselling tools to knock, incise, and scrape against the coastal cliff.**
        - **This weakens the surface, resulting in the breaking down of the coast**
        - **Overtime, the impact is powerful enough to undercut a cliff**
- **Attrition**
    - **Eroded rock fragments carried by the waves and thrown against each other, gradually breaking up into smaller, smoother and more rounded pieces**
        - **It occurs at the same time as abrasion.** Usually sediments from beach come from rock particles that have undergone these both processes

- **Solution (Corrosion)**
        - **When waves come into contact with rocks, seawater reacts chemically to dissolve the minerals in the rocks**
        - **The dissolved minerals in solution are then washed out of the rocks , leaving behind minute holes**
        - **Overtime, the rocks are weakened from within, making them susceptible to further erosion by abrasion and hydraulic action**

        - **Hydraulic Action**
            - **When waves break on a rocky coast repeatedly, the force and weight of pounding waves weaken the rocks such that they eventually break off**
            - **Water also surges into cracks, joints and faults of rocks, trapping and compressing air inside tightly. Pressure exerted on lines of weaknesses**
            - **When water retreats, pressure is released and trapped air expands**
            - **Overtime, the lines of weaknesses widens and weakens the rocks causing it to break up and collapse into sea**
    - Coastal Transportation
        - **As waves approach the coast at an angle, swash carries sediments up the coast at an angle**
        - **Backwash carries sediments back to the sea at right angles to the coast due to gravity**
        - **Resultant zig-zag movement along the beach called beach drift**
        - **Longshore current generated in nearshore zone and flow parallel to the coast and move sediments along the shore**
        - **Combined effect of sediment movement of longshore current and beach drift is longshore drift**
    - Coastal deposition
        - When wave energy decreases, waves unable to carry these sediments
        - Large sediments are deposited first, followed by smaller sediments
        - Deposited sediments vary in type and size, resulting in different beaches
    - Condition favourable for coastal deposition
        - Location : Sheltered coast and bend in coastline - mild tides and interrupt longshore drift
        - Shallow offshore water - friction to slow down waves
        - Light winds of short duration with short fetch - constructive wave
    - Coastal Landform
        - **Formation of cliffs (steep and near-vertical rock face along shore)**
            - **Destructive wave attack a rocky coast repeatedly through hydraulic action and abrasion**

- **A shallow hole called notch will be formed along lines of weaknesses in steep slope**
- **Prolonged erosion causes the notch to widen into a sea cave**
- **Overtime, further erosion causes overhanging roof of cave to lose support and collapse, forming steep rocky cliff**
- **Further undercutting at cliff base forms an overhanging portion which eventually collapse**
- **As the cliff retreats landwards, a gently-sloping land surface covered with rocky debris known as shore platform develops at cliff base**

- **Formation of headlands and bays**
  - Bay is a wide inward curve of coastline which surrounds part of sea
  - Headland is protruding area made of more resistant rocks
  - **Headlands and bays develop at an exposed discordant coast where alternate bands of resistant rocks and less resistant rocks are lined at almost right angle to coast**
  - **The continual erosion of different resistant rocks cause coast to be eroded unevenly**
  - **The less resistant areas of rocks curve inwards as they get eroded away by waves, forming bays**
  - **Areas of more resistant rocks will protrude from coastline, forming headlands**
  - What happens after headlands and bays are formed ? (understand)
    - Waves approach the uneven coast with headlands and bays in parallel manner, wave refraction occurs
    - At headland, waves converge due to the shallower water causing waves to break
    - Energy is concentrated and headlands undergo more erosion
    - At bays, waves diverge due to the deeper waters allow wave to break very near shore
    - Energy is diffused and deposition occurs

        - Eventually, coastline becomes straightened
- **Formation of caves, arches and stacks**
    - **Increased wave erosion at headlands due to wave refraction, resulting in more rapid erosion of the less resistant rocks through hydraulic action, abrasion, solution**
    - **Waves attack lines of weaknesses at headland base and undercut it. Continuous wave action hollows out a sea cave**
        - **The caves may enlarge till it finally cuts through headland or caves may develop on each side of headland and erosion join caves together. This forms a bridge of rock called arch above opening of headland**
    - **Overtime, roof of the arch may collapse due to active undercutting, leaving behind a pillar of rock known as stack**
    - **Stack undergo further erosion and weathered, wearing down to a stump which may be covered during high tide**
- **Formation of beach** (sediments are deposited more quickly than they are eroded) - a zone of sediment deposition
    - Finer grain tend to result in gentle slopes while materials of coarser grain form steep-sloped beach
    - **Wave refraction causes dissipation of wave energy in bays**
    - **Materials eroded from headlands and other materials carried by waves are deposited at head of bays, forming beaches**
    - **Deposited materials sorted by swash and backwash**
    - **Finer materials transported back to edge of sea by backwash**
- **Formation of Spit and Tombolos**
    - **Spit is a long, narrow ridge of sediments with one end attached to land**
    - **Tombolo is spit that extend seawards to join coast to an offshore island**
    - **When the direction of coastline change abruptly, longshore drift will continue transport materials in original direction for some distance before laying them on sea floor**

        - **Overtime, accumulation of deposits may rise above water surface, forming an extension to mainland known as spit**
        - **Wave refraction may cause free end of spit to curve and form hooked spit**
        - **As free end of spit extends seawards, it may connect offshore island to mainland, forming tombolo**
- How do People use Coastal Areas?
    - **Fisheries and Agriculture**
        - **Fisheries are areas where fish are bred and raised to meet the growing demands for fish**
        - Aquaculture is farming of fish in cages or ponds close to coasts, in rivers or converted wetlands
        - Camau, Vietnam - shrimp production (Coastal mangroves which are waterlogged are favourable for shrimp production. Mud and concrete ponds have replaced the mangrove shrimp ponds. Profitable but at a cost where coast becomes more vulnerable to erosion. New alternative - organic shrimp farming must grow in mangrove forest within a balanced ecosystem)
    - **Housing & Transportation**
        - Coastal areas are used to build houses
        - Water as a means of transport (eg. relying on daily tides to remove household waste)
        - Kukup, Malaysia - Stilt house communities of 180 houses in which boats (fishermen) and scheduled ferry services (visitors) are used as a mode transport
    - **Tourism & Recreation**
        - Sentosa, Singapore - Holds 2 golf courses, a marina, a residential area and an integrated resort
        - It has attracted 19 million people in 2011, 600% increase from 2003
- Coral Reefs
    - Develop at or slightly below sea level. Built by and made up of thousands of coral polyps

- Distribution - widely distributed but are mostly found between the Tropic of Cancer in Northern Hemisphere and Tropic of Capricorn in Southern Hemisphere. Most concentrated in Southeast Asia
- **Conditions affecting coral growth**
  - **Average seawater salinity of 34-37 parts per thousand**
  - **Sea surface temp of no lower than 17-18 degree Celsius**
  - **The level of murkiness is low enough to allow sufficient sunlight to penetrate**
  - **A moderate amount of water movement ensures that coral receives sufficient level of O2**
  - **Sediments may suffocate living coral**
- **Values of Coral reefs**
  - **Habitat for marine creatures - support the natural ecosystem, allowing marine creatures to breed and grow**
  - **Coastal protection - absorb wave energy thereby protecting the adjacent land masses from erosion**
- **Pressure to coral reefs**
  - **(MISSING)**

- **Mangrove**
  - Salt-tolerant tropical or subtropical plants which grow in tidal mud and sheltered coast
  - Distribution - found on coast of countries located between Tropic of Cancer and Tropic of Capricorn like Malay Peninsula, New Guinea, Northern Australia
  - Environmental Conditions affecting growth
    - **Found along low-lying, sheltered coast where rivers constantly deposit clay or silt where the soil is waterlogged making it soft and muddy and where the soil is anaerobic (oxygen-deficient), where there are inter-tidal zones as there is flow and ebb of tides**
  - Adaptations
    - **Prop roots (eg. Rhizophora) - grow from lower part of stem and anchors trees firmly in the muddy ground and provide firm support thus prevent from toppling over / washed away by coming and outgoing tides**

        - **Aerial Roots (eg. Avicennia) - roots that emerge from below water and exposed during low tides to allow to take oxygen so that mangrove can continue breathing as mud is anaerobic**
        - **Kneed roots (eg. bruguiera) - provide stability in soft soil**
        - **Salt regulator leaves (eg. Rhizophora) - absorb salt and store it in old leaves which then drop off**
        - **Some fruits are buoyant so that when they drop into water, waves and currents will carry them away to new coastal location and take root, ensuring coastal propagation of mangroves**
    - Values
        - **Dense network of roots to stabilise shoreline as they can absorb wave energy and slow down flow of water and allows sediments from river or coast to build up amongst mangrove roots**
        - **Improves water quality - mangroves trap fine sediments like heavy metals and act as natural filters**
        - **Provide fuelwood for coastal communities**
    - **Pressure**
        - Clearing of mangroves for fuelwood and charcoal – fish breeding grounds are reduced and coast becomes more vulnerable to storm waves eg. Indonesia
        - Conversion to other land uses like paddy fields and shrimp farms – mangroves are cleared and largely disappear from the environment as a result of human activities **eg. Vietnam**
        - Coastal development where land is reclaimed for housing, industry and recreational uses – mangroves largely disappear and coast becomes more vulnerable and polluted **eg caribbean island**
        - Rising sea level and extreme storm activity that might endanger living things – mangroves will have problems colonising areas further inland eg gulf of Thailand

How can we manage coastal areas in a sustainable manner

1. Laws and Regulations

Laws and Regulations	Explanation	Example & Benefits	Limitations
Limit damaging activities	Damaging activities like clearing mangroves are activities that interrupt the functioning of the natural system. These lead to negative impacts such as reduced biodiversity, water pollution. As banning these activities might be costly and ineffective, many national and local government try to limit these activities instead. This is done through management that aligns the needs and demands of the people together with the nature of the coastal environment thus helping to manage the negative impacts of damaging activities	Sand dunes were often trampled by people visiting the beach in Port Philip, Australia. Dune vegetation were destroyed and sand dunes were left exposed to wind erosion. To allow the dunes to recover, authorities fenced off the dunes and build access paths to beach thus allowing the coastal environment to recover	Not all damaging activities are easy to be limited like anchoring of boats. Thus, this may not be welcomed by tour operators possessing economic interest in these areas
Protect coastal resources	Protecting coastal resources is a management strategy that aims to prevent resources like fish from being exploited. Areas close to the coastline where most marine fish are caught are vulnerable to overfishing	The declining fish population in Wakatobi National Park, Indonesia has fuelled community-led initiatives in collaboration with park authorities to close fishing on ‘fish banks’ allowing for the reversal of the declining population of fishes	Local fishermen see their access to a valuable resource and a possibly major source of food being denied. The benefits of protecting coastal resources may then be insignificant to local fishermen who can no longer fish in the area that has supported them for a long time
Restrict Development	Coastal areas attract a multitude of people because of its ability to	Authorities have developed management policies to deal	-

in areas prone to natural hazards (a bit different - not so important)	provide natural resources and a substantial range of built services despite the occurrence of natural hazards. Residents and investors of these areas may have to spend more in construction and maintenance and will also need to be prepared for emergencies	with the threats of natural hazards in coastal areas • Relocation of property - land use plans and development guidelines • Avoidance of Development - enforce laws to ban building development on coastal areas • Defending Development in coastal areas - coastal protection measure	

Thus, limiting damaging activities is easier as it is more acceptable to the people than to completely outlaw resource extraction as the people's livelihood are at stake

2. Measures to protect the coast from erosion - controlling the development and change in the coastal zone according to agreed principles and criteria
    a. **Soft Engineering (protecting the coast using natural processes. It does not involve the construction of any physical structures**

Measure	**Explanation**	**Example and Benefits**	**Limitations**
Beach Nourishment	Slows down the erosion It involves the replenishment of large quantities of sand to the beach. When longshore drift removes sand from the beach and carries it further down the coast, people bring in sand from other areas and deposit the sand onto the beach again. This measure	Sand has been added to widen the beach on Gold Coast, Australia	It can adversely affect wildlife in the coastal environment thus disrupting coral reef ecosystem and thus biodiversity It is expensive and thus not feasible for less-developed countries with low finances

	can successfully change a coast into a wide, sandy beach that offers protection to the immediate inland area. Beach can also be extended seawards and improved beach quality		
Planting vegetation and stabilising dunes	Dense root system of coastal mangroves absorb wave energy, trap sediments, reduce coastal erosion thus stabilising the coastlines as Roots of mangroves anchor soil firmly in place. / Sand dunes can be stabilised by planting grasses as they anchor the sand and prevent erosion. Roots of grasses trap and bind the sand together thus preventing it from being blown inland. These ridges of sand found along the coast defend the coast from flooding and coastal erosion as they act as barriers against floodwater and storm surges as well as extend the coast	Marram grass is planted to stabilise the sand dunes at Omaha Beach in New Zealand + : more labour-intensive and cheaper thus suitable for developing countries with limited finances	Human activities must be minimized or else erosion will still take place
Encouraging coral reef growth	Coral reefs acts as undersea barriers that protects against coastal erosion by reducing the speed of waves and weakening the energy of waves approaching the coast. Artificial reefs can be created by placing long-lasting concrete or steel onto the sea floor and overtime it will be colonised by	Maldives operate a coral-growing programme to help curb beach erosion. As a result, the island now sustains a large marine biodiversity in terms of corals, marine animals.	Coral growth may be slow taking 20-30 years before the results appear by then the coral growth may not be significant

	corals and marine creatures thus help enhance fishing opportunities		

b. **Hard Engineering Measure -** The construction of physical structures to protect the coast from erosion

Measure	**Explanation**	**Examples and Benefit**	**Limitations**
Seawalls	Seawalls are made of concrete or stone that are built parallel to the coast. They protect the coast from the onslaught incoming waves by absorbing and reflecting the incoming waves before they can erode the loose materials thus protecting the coast against strong waves especially during storms	The coastal settlement of Pondicherry in India was protected by the 2004 Indian Ocean Tsunami by a French colonial seawall	Costly to build and maintain as constant repairs have to be made to maintain them thus not feasible for less developed countries with limited resources
Gabions	Gabions are wire cages filled with crushed rocks. They are piled along the shore to prevent or reduce coastal erosion by weakening the wave energy as the gaps between the rocks allow water to filter through thus dissipating wave energy	Gabions constructed along the Andaman Coast in Thailand, successfully protecting the coast from erosion + : Cheaper to construct and maintain than other coastal protection measure	Small stones filling up the wire cages can be eroded over time and fall through the gaps of the wire cages
Breakwaters	Concrete or rocky structures constructed at some distance away from the coast or with one end linked to the coast. They break the force of oncoming waves at some distance away from the coast thus slowing down erosion. As waves are deflected,	Offshore breakwaters at Almeria, Spain to protect the coast from erosion	They are costly and may not be viable for less developed countries

	breakwaters also create a zone of calm water behind them, allowing beach to form		
Groynes	Groynes are low walls made of pipes, woods constructed at right angles to the shore to retain the sediments that might otherwise be removed by the longshore drift. These structures absorb or reduce the energy of the waves and cause materials to be deposited on the updrift side of the groyne facing the longshore drift, thus adding to the beach	Beaches have been successfully sustained by building and maintaining a series of groynes along the coast of Eastbourne in UK	They are low in aesthetic value and spoil the natural beauty of the coastal environment which may limit access to beach goers thus affecting the tourism activities on the coast The downdrift side of the ground may be eroded as it is not replenished by the materials carried by the longshore drift
Tetrapods	Tetrapods are four-pronged concrete structures stacked offshore in an interlocking position, allowing water to pass through them, reducing strong backwash and dissipating wave energy. They are designed to dissipate the force of incoming waves by allowing water to flow around rather than hitting against them thus reducing coastal erosion	Crescent City, California has used tetrapods to defend against coastal erosion and the impact of tsunamis which occurred several times	Aesthetically unappealing for beach goers as it ruins traditional coast scenery which may reduce tourism activities on the coast