

1  **Estuaries**

2  **Define estuary.**

- partially enclosed coastal regions where freshwater (from rivers) meets and mixes with seawater

3  **Explain the basis by which estuaries are classified**

- 4 types based on:
  - geomorphology-geological history of the area
  - prevailing climatic conditions
  - individual physical and chemical conditions

4  **4 main types of estuaries**

- Coastal plain or drowned river
- Bar built
- Tectonic
- fjords

5  **Coastal plain estuary**

- Chesapeake Bay
- Origin end of ice age rising sea level invaded low lying coastal river valleys
- Sea level has risen 120m (394') in last 18,000 yrs Chesapeake bay considered to be a drowned river
- Examples include Narragansett Bay (RI), Chesapeake Bay (MD), Delaware Bay (DE), Thames River (England), Ems River (Germany), Seine River (France), Si-Kiang River (Hong Kong), and Murray River (Australia).

6  **Narragansett Bay and Chesapeake Bay**

7  **Tectonic estuary**

- San Francisco Bay
- Produced by faulting or folding, which causes a restricted down-dropped area into which rivers flow

8  **San Francisco Bay**

9  **Bar built estuaries**

- North Carolina, gulf coast
- Shallow estuaries separated from open ocean by bars composed of sand deposited parallel to the coast by wave action.
- Wind is frequently the most important mixing tool for the fresh and salt water.
- This type of estuary is common along the Texas and Florida Gulf coasts (East Matagorda Bay), in The Netherlands, and in parts of North Carolina (Albemarle Sound and Pamlico Sound).

10  **Outer Banks-Bar built estuary**

11  **Fjords**

- Norwegian, Canadian, New Zealand coastlines
- Glaciated, U-shaped valleys w steep walls, have glacial deposit forming a sill near the ocean

entrance

- usually straight and long
- Depth in mouth shallow ex. 180' depth in fjord-1,500'
- Examples include regions along the coasts of Chile, New Zealand, Canada, Alaska, Greenland, Norway, Siberia, Scotland

12  **fjord**

13  **Explain the criteria by which estuaries may be classified as either positive, negative, or**

**seasonal estuaries.**

- Positive or negative depends on the way the salinity gradients are formed in the estuary

14  **POSITIVE Estuary or River-Dominated or Salt Wedge Estuary**

- Fresh at top,
- Saline wedge at bottom
- Continuum from little mixing and prominent wedges to partial mixing and lesser wedges to HOMOGENEOUS marine dominate and neutral estuaries to complete mixing or an evaporation rate equal to the freshwater inflow giving similar salinities vertically
- Marine dominated estuaries are relatively common neutral few and far between
- Ex of neutral Galveston Bay, Texas and Alligator harbor, Florida

15  **NEGATIVE Estuary or Evaporite estuaries**

- incoming salt water enters at the surface and is diluted slightly with small amounts of freshwater
- High evaporation rate causes surface water to become more saline or hypersaline sinks and leaves bay as bottom current
- Salinity increase as one moves into the estuary (river or freshwater has little or no flow)

16  **SEASONAL or INTERMITTENT ESTUARY**

- formed in area where there is marked wet and dry seasons (like in Mediterranean)

17  **Define isohalines**

- There is usually a gradient from full seawater to freshwater 34.7-0 ppt
- Fresh water is less dense and flows over the seawater; mixing occurs where they come in contact, extent of mixing varies due to: Basin Shape, Tide, River Flow, And Precipitation (run off too)
- Mixing occurs near the top leaving the bottom water more saline
- Cross section of the estuary will show lines of equal salinity or ISOHALINES

18  **explain the significance of isohalines**

- These can move due to evaporation, precipitation, river flow, or tidal flow
- Many ANIMALS and PLANTS cannot move to be in the isohaline best for them
- Affects phytoplankton (base of food chain)
- Occurs often at the turbidity maximum

19  **Salt Wedge**

20  **Isohalines**

- 21  **Describe other factors that affect salinity in estuaries.**
- Tides
  - Coriolis
  - Seasonal changes
  - Interstitial salinities
- 22  **Tides**
- if tidal range significant, high tide acts to drive the salt water further upstream
  - Low tides displace the isohalines downstream
  - So part of estuary changes with each tidal cycle
  - This area of maximum salinity fluctuation may vary more than salinity range annual pattern for whole estuary
- 23  **Coriolis effect**
- Rotation of earth deflects flowing water N. Hemisphere effect deflects outflowing freshwater to the right as look from estuary to sea
  - S. Hemisphere reversed
  - Consequently, 2 points equidistant from mouth of estuary to either left or right side will have different salinities
- 24  **Coriolis effect**
- 25  **Seasonal changes in estuary**
- Differences in evaporation, precipitation, freshwater flow or discharge may be increased or decreased.
  - Large storms Agnes-freshwater input-loss of organisms
- 26  **Describe temperature variation in estuaries**
- Shallower than adjacent open ocean-so more likely to gain or lose heat
  - Freshwater inputs cause variation because freshwater is subject to seasonal
  - Changes far more than ocean water estuaries colder in winter and warmer in
  - Summer than coastal waters
  - Central part of estuary during tidal cycles shows greatest variation in temperature
  - Vertically: surface greatest variation follows salt wedges deep water least var
- 27  **Explain why there are smaller waves in an estuary than in the ocean**
- Small waves because surrounded by land on 3 sides - no long fetch
  - Shallow so no big waves
  - Slight waves action leads to greater deposition of sediments
  - Leads to rooted plants slower lower wave action
- 28  **Explain the significance of turbidity in an estuary**
- Turbidity: highest turbidities occur during the times of maximum river flow
  - Minimum near mouth
  - The more closed the estuary is the more turbidity is a function of plankton or wind

speed

- Turbidity affects productivity

29  **Explain the concept of flushing time.**

- Flushing time: continual input of freshwater at head some moves down the
- Estuary mixing w seawater, volume of water of sufficient size is eventually
- discharged from estuary or evaporated to compensate for next volume introduced at head
- Interval required to discharge the volume of water is flushing time
- Long flushing times required to maintain estuarine plankton communities

30  **Identify sources of currents and where currents have the greatest velocity**

- Currents due to tides and rivers usually confined to channels fastest In center of channels less friction from sides and bottom

31  **Interstitial salinities**

- between particles of substrate
- Interstitial water changes more slowly than overlying water so organisms living in the substrate are subject to less drastic salinity changes than organisms on the surface of the substrate or in the water column
- Lower littoral zone best buffer high littoral less buffer

32  **Characterize typical estuarine substrates**

- muddy, soft substrates dominate
- Derive from sediments carried into estuary by both seawater and freshwater
- Wind (aeolian) transport of larger sand particles significant in coastal
- Lagoons behind barrier islands

33  **explain the origin of the sediment**

- Freshwater silt suspension mix with seawater, ions in seawater causes the silt to flocculate, creating larger heavier particles which settle out forming mud bottom
- Seawater also has a lot of suspended material which drops out due to the reduction of water motion.

34  **Origins of sediment**

- In N America and Europe the main sedimentary source is sea.
- Particle size and currents affect deposition of particles
- Large currents-coarse calm waters-fine silt
- Large storms-remove deposits or add deposits
- 4 cm silt deposited in Tijuana estuary in S California, same storm took out 40% of volume of magu Lagoon

35  **Significance of sediments and bacteria**

- Particles are often organic origins either terrestrial or marine, rich organic
- Substrate results large food reservoir for estuarine organisms
- Large surface area relative to volume large bacteria inhabitation

36  **Explain why bacteria are significant estuarine organisms**

- Water and mud rich in bacteria because of organic matter to decompose - back

- Again to productivity
- More than 100x bacteria of seawater
- Mud has more than a 1000x times bacteria than overlying water
- Densities of 100-400 million per gram
- Anaerobic or aerobic? Efficiency?

37  **Identify where the estuary is oxygen rich and explain why anoxia occurs in an estuary.**

- Oxygen content: within water column, normal conditions plenty of O<sub>2</sub>
- Strong salt wedges, lower layers not mixing, O<sub>2</sub> depletion
- Substrate and interstitial water-anoxic little mixing due to
- Fine particle size only top few cm affected by burrowing animals

38  **Identify 4 components of estuarine fauna**

- Marine
- Brackish
- Fresh
- Transitional

39  **Stenohaline components**

- Marine
- Fresh water fish

40  **Brackish**

- 5-18 ppt
- some genera appear to be limited in a seaward direction but that could be due more to competition or predation than to just salinity
- Derived from marine stock analogous to intertidal zone being inhabited
- By marine not terrestrial organisms

41  **Transitional animals**

- migratory fishes to breeding grounds (salmon and eels)
- Others only part of life history in estuary-usually juvenile
- Penaeidae
- Birds and fishes that come in only to feed

42  **Defend the component that is considered to be true estuarine fauna.**

43  **Give 3 reasons why there are so few estuarine species**

- Fluctuation environmental conditions: salt, temp, etc few organisms have specializations it takes to live in these conditions
- Estuaries have not existed long enough in geological time to permit estuarine fauna to develop
- Estuaries have little topographic diversity-lots of broad expanses of mud fewer

niches and therefore, fewer species

- 44  **Compare abundance and diversity of estuarine vegetation**
- Not abundant: mud substrates unsuitable for macroalgal attachment
  - Turbid water restricts light penetrations to narrow upper layer
  - Deepwater barren of plant life
  - Seagrasses *Zostera marina*, *Ruppia maritima* *Thalassia*, *Cymodocea* subtidal communities
  - Mudflats have few green algal species: *Ulva*, *Enteromorpha*, *Cladophora*
  - May be SEASONAL abundance
  - Not diverse: very few species dominant vegetation is emergent species *Spartina* and *Salicornia*

- 45  **Describe some morphological adaptations of animals that live in the estuary.**

- . Result of adaptations to a given habitat such as burrowing into mud
- A. Presences is advertised by various shapes and sizes of holes
- B. Burrow or form tubes-tubes stabilize fine substrates
- C. Fine fringes of hair or setae-protect respiratory passages or sift for food
- D. Snails have bipectinate gills
- E. Siphons
- F. Worms with paddle feet to swim that can also burrow
- G. Worms, clams, with siphons to reach overlying water
- 

- 46  **Fauna adaptations cont.**

- 2. Smaller body size
- 3. Reduced number of vertebrae in fishes
- 4. Lower reproductive rate and lower fecundity
- 5. Abyssal threads in mussels
- 6. If don't burrow, may develop heavy bodies to keep from washing away

- 47  **Describe some morphological adaptations of plants that live in the estuary.**

- Aerenchyma-open tissue similar to parenchyma that brings O<sub>2</sub> to roots
- Hollow stems
- Trichomes-hairs
- *Spartina* structures analagous to glands to remove salt
- Waxy layers to prevent dessication
- Extensive carbohydrate stores in roots to cope w salinity fluctuations
- High lignin add strength to cope w high internal salinity
- Abundant stomata, lenticels

- 48  **Define osmoregulation**

- ability to control the concentrations of salts or water in internal fluids

- 49  **Compare osmoconformers with osmoregulators**

- Osmoconformers: do not have the ability to control their internal salt content
- most marine animals are osmoconformers
- Limited ability to penetrate estuaries can't tolerate changes in internal fluids
- Osmoregulators: have physiological mechanisms to control the salt content of

their internal fluids

- 50  **How osmoregulate**
- Some fishes control how dilute their urine is: Use gills, kidneys, specialized salt glands
  - Either excrete excess water or absorb differentially solutes
  - HOW DO: May move water; May move ions; Adjust internal water-ion balance
  - Polychaete worms, mollusks, and crustaceans
  - Crabs have exoskeleton that reduces permeability and has ability to regulate ion concentrations of internal fluids
  - Work off of changes in amino acid balances
  - Additional physio: blood of some invertebrates is loaded or packed with hemoglobin to pick up all available O<sub>2</sub>
- 51  **Explain how vascular plants adapt to osmotic stress**
- Plant physiology
  - If ion concentration increases around roots, plants increase ion concentration in tissues
  - To get rid of salt before lethal levels accumulate, may actively excrete salt, depend on rains or transpiration to wash off salt on outside of plant, or may drop leaves with high salt content
  - Succulents store lots of water to dilute salt waxy outside to prevent excess salt from entering
- 52  **Describe behavioral adaptations of estuarine animals**
- 1. Burrowing in to mud-- mud water buffer; less likely eaten by surface feeder
  - 2. Adults may be able to osmoregulate=like crabs, young can't, so show migratory pattern breed in seawater; larvae float in zooplankton; return to estuary as mature
  - 3. Lots of food in estuary, few predators, fishes migrate in to use as nursery
    - Mullet, striped bass, flounder, shrimp
- 53  **Shallow Habitats**
- Borders of Chesapeake Bay comprise thousands of miles of shallow waters
  - Sublittoral zone
  - Seasonal variations of temperature extremes
  - Rain or lack of rain has immediate impact on salinity
  - Winds and storm activity increases turbidity by displacing sediment
  - Sediment deposition is great year round
- 54  **Tides and Shallow Habitats**
- At high tide, rock jetties, piers, marshes all become part of shallow water habitats
  - Many invertebrates that live in the littoral zone are abundant in shallow water: clams, worms, snails
  - Semiterrestrial invertebrates will not be seen in shallow water: fiddler crabs, wharf crabs, and sea roaches
- 55  **Chaetopterus, Nereis, Paleomonetes, Rangea, Nassarius**
- 56  **Hemigrapsus, Callinectes, Crassostrea, Geukensia**
- 57  **Sesarma, Uca, Ligia are semiterrestrial**
- 58  **Chrysaora, Aurelia, Copepods, Diatoms, Crab Zoea**
- 59  **Little fishes call this home**
- 60  **Morone, Anguilla, Micropogonias, Pleuronectes**

- 61  **Grass Beds**
- Grow BELOW mean low tide to depths of 9 feet
  - Rapid dense growth provides habitat and food for a variety of organisms
  - Greatly affected by light availability and changes in salinity
  - Plants themselves are not usually grazed, but provide structure for microinvertebrates that are grazed and detritus when they decompose
- 62  **Eel grass meadows**
- 63  **Widgeon grass**
- 64  **Turtle grass**
- 65  **Sea grasses in Chesapeake Bay**
- *Zostera marina*-eel grass
  - *Ruppia maritima*-widgeon grass
  - (*Thalassa* grows more in SE in FI and more subtropical areas)
  - Eel grass does better in higher salinities and colder weather
  - Widgeon grass does better in lower salinities and warm weather
  - Alternate in same areas
- 66  **There are many freshwater grasses.**
- *Potamogeton*- redhead grass and sago pondweed
  - *Zannichellia*-horned pondweed
  - *Myrophyllium*-milfoil
  - *Vasineria*-wild celery
  - *Elodea*-waterweed
  - *Ceratophyllum*-coontail
  - *Hydrilla*
- 67  **Animals attached to plants**
- Substrate for many invertebrates
  - Microscopic algae and protozoans
  - Barnacles, sea squirts, lacy crust and coffin box bryozoans, annelids, sea anemones, green bead tunicates, hydroids, convex slipper shells, pill clams
- 68  **commensals**
- 69  **Grasses provide habitat at the base of the plants**
- Whip worms, tube worms, mussels, red beard sponge
  - Stabilize sediment
  - Protection from predation
- 70  **Grazers and other small organisms in grass beds**
- Ribbon worms, flatworms, pill bugs, isopods, amphipods, skeleton shrimp, snails

and sea slugs, scuds

- Juvenile blue crabs use as a nursery
- Grass shrimp, mantis shrimp
- Mud crabs and spider crabs live here
- Seahorses, pipefish, stickleback

71  **Larger predators of grass beds**

- PEOPLE: grass bed scrapes for blue crabs
- Cownose ray and bluntnose ray some eagle rays
- Sandbar sharks
- Some larger predatory fish (stripers)
- Some dabbling ducks

72  **Oyster Bars(reefs, rock, beds)**

- *Crassostrea virginica*
- Depths of 8-25 feet
- Salinities of 8 to 35 ppt
- Temp >6C to grow
- Requires hard surface to attach to as larvae

73  **Ecological Functions**

- Filter water in the historical past every 7 days of entire C.B.
- provides large surface area and spaces for other organisms, both sessile and mobile

74  **Human Services**

- Food
- (not eaten in months that end w "r"-due to lack of refrigeration and spawn those months so oysters are thin and watery having used up reserves)
- Harvest used to be in millions of bushels and now in thousands of bushels
- Oyster rock used for road beds

75  **Oysters have different shapes**

- Softer bottom habitats-elongated narrow shells
- Hard bottom habitats-rounded
- Reproductive age is around 2 years or 2 –2.5 inches

76  **Life on the shells and in the shells**

- Hydroids, bryzoans, anemones, sea squirts, calcareous tube worms
- Boring sponge and *Polydora*, boring worm
- Red beard sponge
- Oyster crabs live on gills (and cause some damage to the gills)

77  **Between the shells**

- All sorts of worms
- Mud crabs
- Snails including oyster drills
- Skeleton shrimp and amphipods
- Barnacles
- Jingle shells
- Blue crabs, spider crabs, and hermit crabs
- Toad fish, gobies, blennies, and skillettfish

78  **Blenny, Skillettfish, Toadfish, Goby**

79  **Why oysters beds are declining**

- 2 diseases: MSX and dermo
- Overharvesting
- Development
- Both overharvesting and development lead to higher levels of sedimentation which reduces suitable habitat and suffocates oysters