INTERTIDAL ZONATION
Introduction to Oceanography
Spring 2017

The Intertidal Zone is the narrow belt along the shoreline lying between the lowest and highest tide marks.

The intertidal or littoral zone is subdivided broadly into four vertical zones based on the amount of time the zone is submerged. From highest to lowest, they are

Supratidal or Spray Zone Upper Intertidal Middle Intertidal Lower Intertidal	Littoral Zone	submergence time influenced by tides
Subtidal	Sublittoral Zone	permanently submerged

The intertidal zone may also be subdivided on the basis of the vertical distribution of the species that dominate a particular zone. However, zone divisions should, in most cases, be regarded as approximate! No single system of subdivision gives perfectly consistent results everywhere. Please refer to the intertidal zonation scheme given in the attached table (last page).

Zonal Distribution of organisms is controlled by

PHYSICAL factors (which set the UPPER limit of each zone):
1) tidal range
2) wave exposure or the degree of sheltering from surf
3) type of substrate, e.g., sand, cobble, rock
4) relative time exposed to air (controls overheating, desiccation, and salinity changes).

BIOLOGICAL factors (which set the LOWER limit of each zone):
1) predation
2) competition for space
3) adaptation to biological or physical factors of the environment

Species dominance patterns change abruptly in response to physical and/or biological factors. For example, tide pools provide permanently submerged areas in higher tidal zones; overhangs provide shaded areas of lower temperature; protected crevices provide permanently moist areas. Such subhabitats within a zone can contain quite different organisms from those typical for the zone.

PHYSICAL FACTORS

Tides

- affect all ocean shorelines, but tidal range varies locally causing wide or narrow intertidal zones (Southern California`s tidal range is about 3 meters).
- Tides affect organisms by periodically submerging and then exposing them to the sun and air.

Waves

- keep organisms moist, increase dissolved oxygen, bring food, and remove wastes;

- rip sessile organisms from the substrate and bury some bottom dwellers in sediment;

- extend intertidal zone above high tide, creating the supratidal zone, a "splash zone";

- are small to nonexistent in protected bays, lagoons, and estuaries. Unique intertidal communities with sharp zone boundaries are found in these environments.

- The greatest diversity and abundance of life in the intertidal zone occurs where wave force is slightly diminished, as at the semiprotected environment of Palos Verdes. Much of the wave energy is dissipated on the headlands to the north.

Substrate: (a substance in or on which an organism lives, grows, or is attached to)

- Different substrates support vastly different communities with varying diversity and population abundances.

Sand or mud support mostly benthic, infaunal species capable of living in turbid water. In such environments, species diversity is moderate and abundances are low.

Cobbles support species hardy enough to resist the action of colliding cobbles in the surf. Diversity and abundances are low.

Rock supports the highest diversity and abundance. The specific community is determined by the rock's texture and degree of hardness. Some substrates are soft enough that some animals can excavate borings, enabling them to live within the rock. Numerous habitats are possible along a rocky shore: tide pools, crevices, overhangs, exposed surfaces, protected surfaces, etc. The degree of habitat diversity tends to be correlated with species diversity (i.e., the greater the number of habitats - the greater the species diversity).

IMPORTANT BIOLOGICAL FACTORS

Predation

Predators often control the lowest depth at which their prey can live. Prey species that can adapt to the harsher physical conditions of a higher zone escape predation, and may become locally abundant, in some cases dominating a zone. Predators eat individuals that live too close to the top of the predators' zone, (which is the highest that the predator can live). For example, the common seastar (Pisaster ochraceus, ochre sea star) feeds on the blue mussel (Mytilus californianus). Pisaster cannot survive above the Lower Intertidal zone; it eats Mytilus that live at the lowest part of the mussel bed. Mytilus is very abundant in the Middle Zone, primarily because it possesses the necessary adaptions for surviving wave shock and prolonged exposure, allowing it to escape predation by moving up.

Competition for space

Space is at a premium in the intertidal zone. If no substrate is available, some species will attach to and live on top of other species; often several layers of organisms live on top of one another. Some species are superior competitors and can squeeze out other species. The limpet (Acmaea) grazes on algae and sometimes "bulldozes" young acorn barnacle (Balanus) right off the rock, leaving areas for more algae to grow.

Physiologic and Morphologic Adaptation

Each species copes with the various physical factors of its particular zone in its own particular way. Some adaptations are physiological (e.g., temperature and salinity tolerance), while others are morphological (e.g., body shape and attachment). Within each zone the general patterns of adaptation are similar between different species. In other cases, markedly different strategies have evolved for surviving the same condition. Some examples follow.

INTERTIDAL ZONE OF THE PACIFIC COAST OF NORTH AMERICA

This section is an introduction to the diverse intertidal communities of western North America. This shoreline encompasses one of the richest intertidal zones in the world in a band extending all the way from Alaska to Baja, Mexico. Similar groups of species live in the same zones all along its 8500 km length.

The coastline of western North America is especially diverse because (1) the intense coastal upwelling of nutrient-rich bottom waters occurs here, seasonally providing an abundance of nutrient-rich bottom water; (2) there is almost complete freedom from winter sea ice as far north as Alaska; and (3) a low diversity of herbivorous-fish species allows algae to grow in abundance, thus supporting large numbers of invertebrate herbivores.

The high diversity of the intertidal zone also reflects the large number of habitats created along the interface of the sea and land in this tectonically active coastline. Many of the organisms that live in this zone are illustrated in Figure 2 (Intertidal Food Chain). You don't have to learn this food chain (web) - use this figure to help to identify lab specimens.

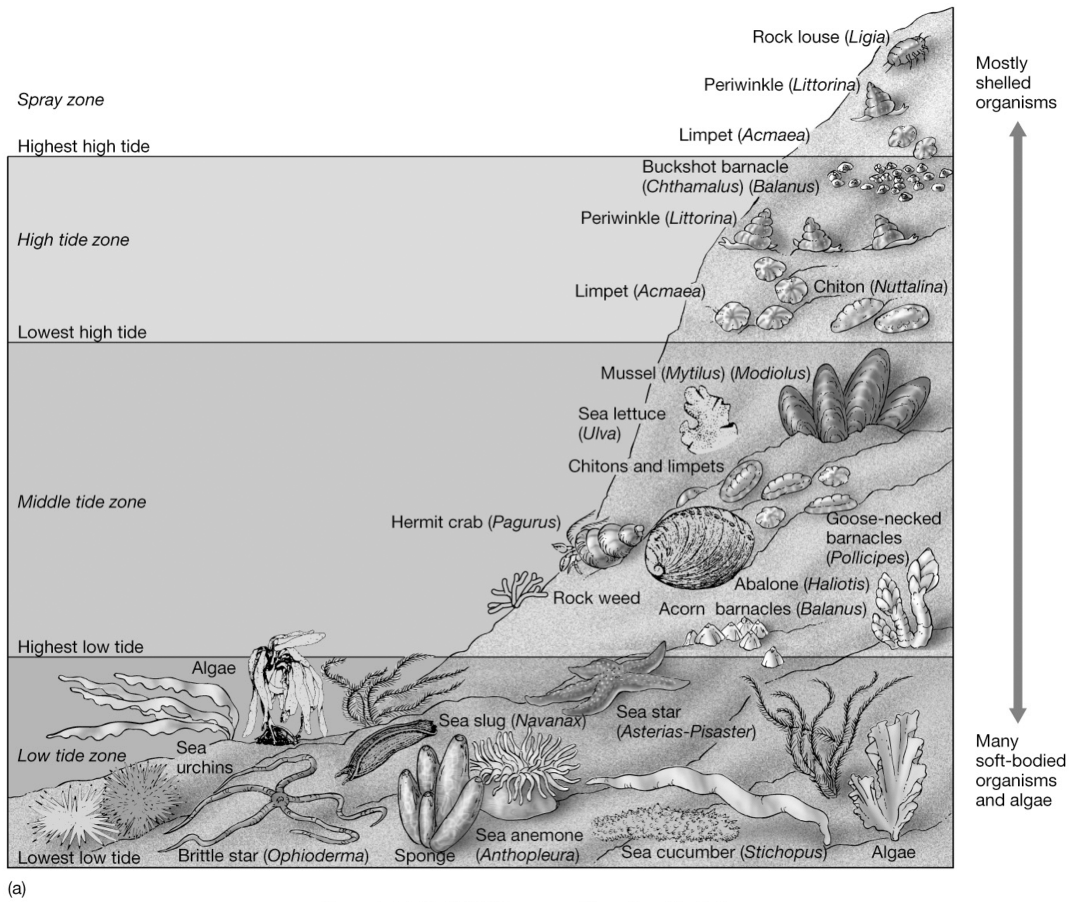


Figure 1. A typical rocky intertidal zone, much like those found in southern California, with some organisms typically found in each subzone (not to scale).

ADAPTIVE STRATEGIES OF INTERTIDAL-ZONE LIFE

The intertidal zone is a highly productive but harsh environment. Species that have successfully adapted to the intertidal zone tend to share certain morphological and physiological traits that represent adaptive solutions to the problems of survival and reproduction in this extreme environment. The most important problems facing intertidal organisms include remaining attached to the substrate where waves and currents are strong, and avoiding dessication as a result of exposure at low tide. The following examples reveal the range of adaptive solutions to these problems among some common intertidal organisms of western North America.

Avoiding Desiccation

1. Periwinkle snail (Littorina) commonly lives in the Upper Intertidal Zone. The species Littorina scutulata lives at the top of the zone, and typically has a larger shell volume than its cousin, L. planaxis which lives lower in the zone. The larger volume allows the organism to hold more water to avoid desiccation longer. When exposed, Littorina secretes a mucus which cements it to the substrate forming a hard seal which slows drying.

2. Bivalves (like Mytilus, the blue mussel, and Haliotis, abalone) and barnacles have tightly closing valves that prevent water loss and large internal body cavities which hold seawater during times of exposure.

3. Limpets (Acmaea) and chitons are molluscs that create suction against the substrate using their muscular foot and mucus to form a watertight seal between their shell and the substrate.
4. Various crab species (like Pachygrapsus) store water in their gill chambers which are protected by their hard carapace.

5. Sea anemones (Anthopleura) and sea urchins (Strongylocentrotus) secret mucus and cover themselves with shells, sand grains, or dead algae to slow desiccation and reflect sunlight. Sea anemones retract their tentacles and mouths at low tide to minimize surface area.

6. Crustaceans like rock lice (Ligia) and crabs actively seek cool, shaded, moist environments during the day under boulders or within crevices to slow desiccation.

Notice in the above examples that similar strategies are shared by unrelated species. For example, mucus secretion is extremely important in many groups as a means for preventing desiccation.

Attachment

Organisms respond to the effects of wave action in a variety of ways. The species living on exposed rocky headlands are dominantly those better adapted for staying attached, while species common to semi-protected shores often lack such features. There are several common adaptions for remaining attached to the substrate:

1. Vacuum suction is used in conjunction with mucus by the anemones (with their basal disk), echinoderms (sea urchins and starfish with tube feet), and gastropods (snails and limpets with a muscular foot) for staying attached.

2. Cementation of organisms to hard substrate keeps some species attached. One adaptation involves a flexible structure, the other, a rigid structure cemented to the substrate:

    A) Flexible: some macroalgae (Laminaria) cements their flexible and whip-like stalks with a massive holdfast. Blue mussel (Mytilus) attaches itself with organic threads (byssal threads) and organic cement. Gooseneck barnacle (Pollicipes) cements a thick, fleshy integument to rocks using organic cement. These species dissipate the energy of wave shock by being flexible.

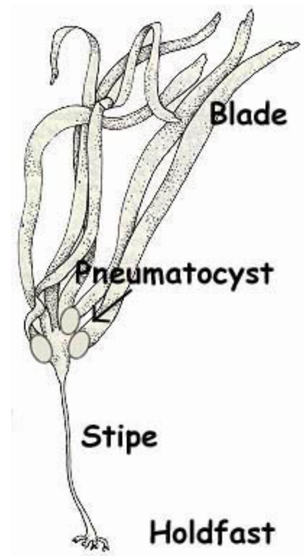
    B) Rigid: Barnacles, some bivalves, tube worms (Serpula), tube-building snail (Vermicularia) and other "encrusters" cement rigid shells or other hard parts directly to the substrate. These species typically present low profiles to currents and survive by resisting wave shock.

3. Boring into rock is effective in shielding some species like the rock-boring clams, sea urchins, and chitons from waves. These species typically use a combination of mechanical and chemical means to excavate their borings into the bedrock.

4. Leverage between rocks or in crevices is used by crabs and other arthropods, octopuses, and sea urchins, which wedge themselves into available openings.

Notice that some organisms may use more than one strategy.

MARINE MACROALGAE



Benthic **Algae** are abundant in nearshore environments, and are mostly concentrated in the Lower Intertidal and Subtidal zones. **Algae** are plant-like protists. They are primary producers that perform photosynthesis using chlorophyll in chloroplasts that are found in their cells. **Macroalgae** (Seaweeds) are complex multicellular algae that are structurally similar to plants, but lack the specialized tissues of plants. It is important to note that while a blade, stipe and holdfast of seaweeds perform structurally like the leaf, trunk, and roots of terrestrial plants, they do not perform their specialized functions i.e. roots extract nutrients from soil, while holdfasts only keep kelp in a fixed location. There are three distinct phyla of macroalgae: Chlorophyta (Green algae), Phaeophyta (Brown algae) and Rhodophyta (Red algae).

Chlorophyta (Green algae)

Green algae appear bright green because there is no pigment masking the chlorophyll. It is more common in the upper intertidal zones along the rocky coasts of California than red and brown algae. It is believed that a green algae-like ancestor evolved into the earliest terrestrial plants. Green algae builds it's cell walls from cellulose just like terrestrial plants.

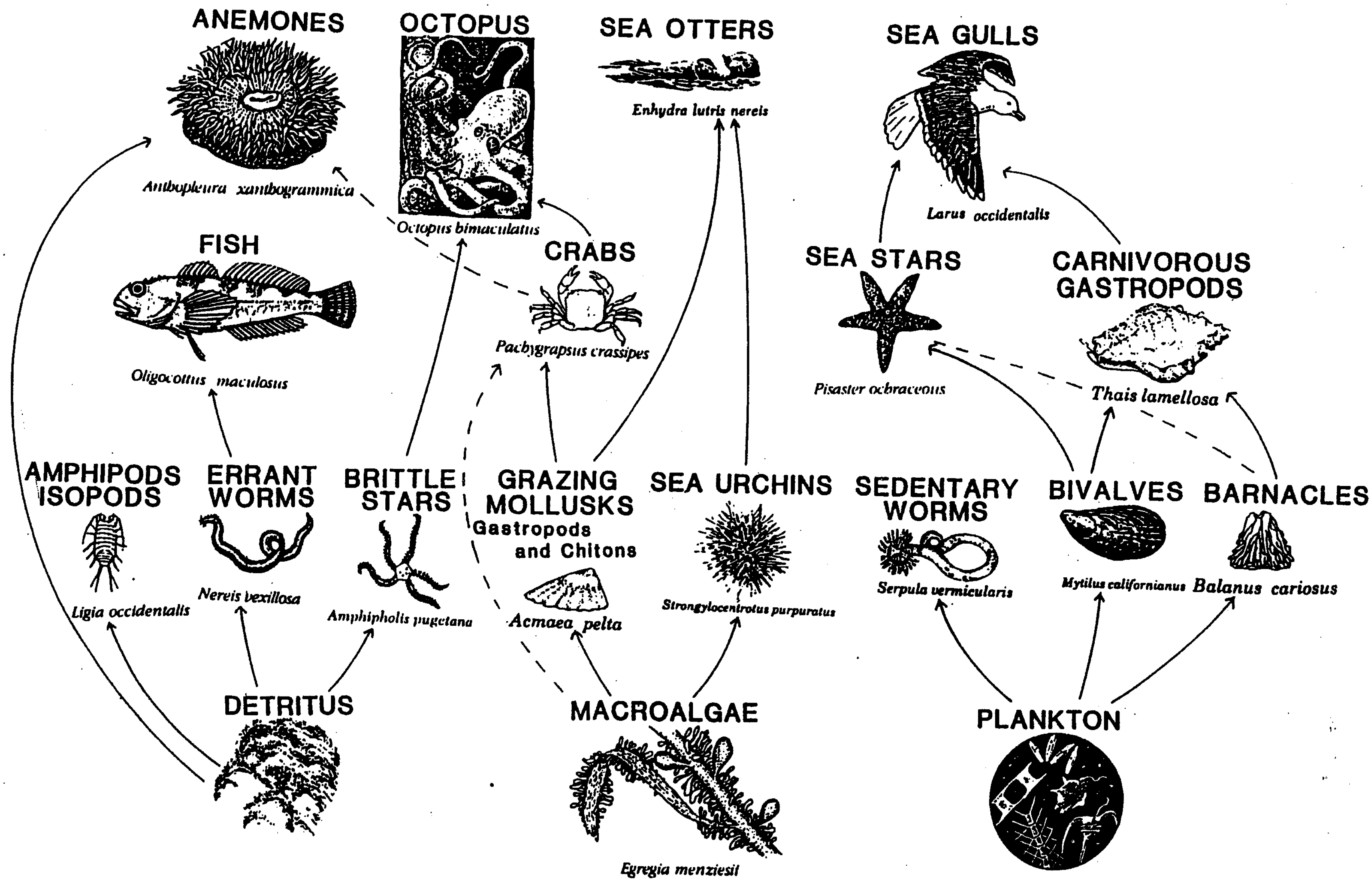
Phaeophyta (Brown algae)

Brown algae are the largest and most structurally complex of all seaweeds. Many species use pneumatocysts (gas bladders or floats) to maintain upright posture. A particular group of brown algae called kelp is abundant in temperate subtidal zones and is extremely important to its marine ecosystem. Kelp create huge 'kelp forests' which support over 800 distinct species of marine animals. Much like the destruction of tropical rainforests, the destruction of these kelp forests can quickly lead to ecological collapse of an entire region.

Rhodophyta (Red algae)

Red algae are incredibly diverse as there are more species of red algae than green and brown combined. The pigments in their cells promotes more efficient absorption of blue light which penetrates deeper in the water column than other wavelengths, and so allows red algae to survive at greater depths than other algae. Some red algae (coralline algae) deposit $CaCO_3$ in their cell walls for structural strength and are major contributors to coral reefs around the world. Some species of red algae are even parasitic, forgoing photosynthesis completely and adopting a strategy of living off another type of algae or surf grass.

INTERTIDAL FOOD CHAIN



INTERTIDAL ZONATION
on a semiprotected rocky shore

Tidal Range (m)	Zone	Conditions	Representative Organisms: Plants (Algae)	Representative Organisms: Animals
	Splash or Supratidal	- Above highest tides - Often wet from wave spray - Lower part submerged by waves at high tide - May extend more than 10 m above high tide mark where waves are large	cyanobacteria Prasiola (a green algae) Black lichen	periwinkle snail rock louse limpet (Acmaea)
2.5 **EXTREME HIGHER HIGH WATER**				
	Upper Intertidal	- Usually submerged for several hours each average high tide - May not get submerged during a 24 hour period of a neap (low-range) tide - Extensive wave action	red algae rock weed sea lettuce sea felt algal films	acorn barnacles anemones buck shot barnacles owl limpet
1 **MEAN SEA LEVEL**				
	Middle Intertidal	- Submerged and exposed twice per day - Most oranisms have adapted to a cycle of submergence and exposure - Predation becomes more important - habitiats vary (upper tide pools, damp crevices, etc. are common)	brown algae	blue mussel gooseneck barnacle thatched barnacle hermit crab turban snail dog whelk (snail) shore crab
0 **MEAN LOWER LOW WATER**				
	Lower Intertidal	- Exposed at minus tides only, extends down to lowest tides - Greatest diveristy and abundance - Organisms have adapted to slight exposure only - Deep tidepools may contain strictly subtidal species	coralline algae feather boa kelp broad-leaf brown algae surf grass benthic diatom films	ochre sea star purple sea urchin sea hare abalone chitons smooth turban snail
-0.7 **EXTREME LOWER LOW WATER**				
	Subtidal	- Always submerged - gradational to deep tide pools of the intertidal zone	elk kelp giant kelp	red urchin octopus spiny lobsters scallops sea otters