Genevieve B. Anderson 2001-2002

Lecture Dedication

I dedicate my lecture to William C. Jorgensen, for years of friendship and mentoring. Fondly called 'Jorgy', by his students and colleagues, he developed Santa Barbara City College's marine biology program from 1966 until he retired in 1982. Jorgy shared with me all of his course materials, successes and failures (and what he learned from them). Most importantly, he shared his philosophy about teaching. I can still hear him saying "students come first, get them excited right away with 'hands-on' activities". It has been this emphasis on 'hands-on' activity, which I have developed for almost every weekly lab exercise. My past students tell me this is what really made my teaching come alive for them. Jorgy not only gave me the materials for a great start back in 1982 but has continued his support with valuable advice to me for over 20 years. Thank you, Jorgy, from the bottom of my heart.

The Lecture began with touch tanks of live marine organisms set up outside the Garvin Theatre for a half hour. The tanks were filled with all the creatures covered in the lecture plus many more. Eighteen of Genny's past and present students (back to 1980) helped with the touch tanks and acted as ushers in the theatre. The auditorium filled minutes before the actual Lecture was scheduled to begin. The auditorium darkened and a five minute slide show (of 57 images) was presented. The show was composed of Genny's slides taken on marine biology trips all over the world (Galapagos, the Caribbean, Australia, the North Pacific and Antarctica) set to the music entitled Cat Walk by Jungle Moon. Then Lana Rose, Academic Senate President, introduced Genny.

Tales from Our Tidepools, Treasures Beneath the Sea

Genevieve B. Anderson
Professor of Biological Sciences

Acknowledgements Thank you, Lana Rose. Being nominated as Faculty Lecturer is, and will remain, I am sure, the highest point in my career. There are so many outstanding teachers here at SBCC--I am deeply touched to have received this honor. I could never have achieved my life goals without the help and support of many people, and this event gives me the opportunity to publicly honor the most important ones.

First, there are my parents, Janet and Bill Bockus. Thanks for providing me with the most wonderful childhood and family support that I can imagine. This is the man who "played algebra" with me before I even went to school, and instilled a love of math and science in me. Although he himself is an artist, he recognized my early interest in science and encouraged me my entire life, constantly giving me self-confidence to enter the world of science during the 1950s and '60s when women in science were scarce.

My mom is the woman who is my role model for support and efficiency. She was the mom who was always on time, always the volunteer for scout leader, carpool driver and anything else that would make my life more enriched. This woman did the same thing for all five of her kids. We were all born about a year apart, so you can imagine how organized she is. She was also the one who would gently prod us to get back on track if she sensed we were straying.

Second, there are my children, Marah and Michael Anderson. Raising both of you and sharing adventures to faraway places with you has been a personal highlight. You have provided me with endless hours of wonder as I have watched you both mature into fine young adults.

Now, there's the most important person in my life, my husband, Shane. You have been the most wonderful husband, father and fantastic best friend. We have shared 32 years of married life, and each day is interesting. We are so lucky to share the same passion for the ocean in our careers, as well as our hobbies. There is never a question about what type of vacation we will plan--it will always include the ocean.

Dr. Peter MacDougall, this will be your last Faculty Lecture in your capacity as Superintendent/President. I want to thank you for your 21-22 years of giving more than 100% to this college. I could hardly hold back the tears when you announced your retirement as of this summer. I wish you well and thank you for providing me with a most wonderful place to work … our ambience here at SBCC is unmatched.

Dr. James Nybakken, my major professor from Moss Landing Marine Laboratories has traveled all the way from Monterey for my lecture. I am honored to have you and your wife, Dr. Bette Nybakken, here. This gives me the opportunity to thank you for your expert scientific guidance thirty years ago with my Master's Degree.

There are so many others to thank -- the Board of Trustees, my past educators, my colleagues in the Biological Sciences Department, the college support staff (especially Rob, Beverly, Tom, Chris, Jason, Andrew and Sean who provided the Faculty Lecture logistics), and everyone else on campus with whom I interact. This is a *GREAT* place to work.

Finally I would like to acknowledge the hundreds of students, both past and present, whom I have had the pleasure of teaching--you have brought me joy, happiness and many challenges--whether you were the 'A' student or something lower, I have enjoyed each and every one of you.

Introduction

As evidenced by the thousands of memorable photographs from trips I've taken with my husband and children, love for marine biology has focused our family, hobbies and vacations around the ocean. We have been lucky to travel extensively--often with the help of marine biologist friends who work in exotic places and invite us to visit. These

international experiences and on-site photographs have greatly enhanced my ability to teach marine topics of worldwide importance.

The hardest thing I had to do as Faculty Lecturer was to select the topic for my lecture. Of course it would be something about marine biology because that is my expertise, hobby and passion. The oceans cover over 70% of the surface of our planet and are unbelievably diverse. There are so many fascinating topics in marine biology--many constantly covered on the Discovery and Learning TV channels. I lecture about so many of these in my courses--coral reefs, Galapagos, Antarctica, whales--and they are all exciting. These places and critters were potential topics of interest to a Faculty Lecture audience.

For help I turned to my marine biology students (all 150 of them) last spring, before I began preparing my lecture. At the end of the semester I asked them to think back on everything they had learned in my class and to give me their opinion about what part of it they would like to have presented in a one-hour public lecture. Over 80 percent of them wrote that it was the common creatures living on our beaches that meant the most to them. Many said they had been beachcombers and surfers their entire lives and had walked by these creatures without knowing why they were there. They said that, after my class, the beach was never the same … every time they would go to the beach they would have all these words and explanations for what was there and why. They said that they were always telling their families and friends about these things and that everyone thought they were experts. So I decided to focus on something right here in our backyard--something each and every one of you can experience--our Santa Barbara tidepools.

These tidepools remain my favorite ongoing marine biology experience. Every trip is a delight to me and every trip is different--even after over 20 years of taking students on tidepool adventures. I still love it! Each trip is special.

After deciding on my topic, I began preparing last summer. With only an hour's presentation, how could I even begin to enlighten you to the wonders that await us each day on our shorelines? I decided to create this lecture from the bottom up--by first going to the tidepools with the idea that I was a new and naïve visitor. What would I want to know and what would I see?

So I went tidepooling last summer by myself, again and again. I realized it had been over 30 years since I had been alone in the tidepools (with my children, teaching and such; I was always leading a group). This has been a highlight of my life--hours of watching the sunrise and sunset, smelling the salt air, feeling the sun, wind, drizzle, and, most of all, hours of photographing my favorite critters. I decided to challenge myself to take all new digital images of my treasures in the tidepools from the point of view of a new visitor and learn to use a digital camera. So, all the images shown in this lecture are new. I have managed to keep them a secret from my students and colleagues until now.

Now, let's get to it! Please come with me to the tidepools. There is an old saying: Time and tide wait for no man (nor woman for that matter). I would like to take you on a virtual trip to the Santa Barbara tidepools.

Tidal Cycles

The most important thing in planning a tidepool trip is to schedule it for as low a tide as possible. This can be done with tide books and calendars (available at most dive shops and sporting goods stores). Most areas on Earth, including Santa Barbara, have two tidal cycles each day created by forces in our universe, primarily from the moon and sun. A high/low cycle is followed by another high/low cycle--really on a 25-hour sequence so tides will change their time daily, getting about an hour later each day. Where we are, the two cycles are of unequal height. In a 25-hour period there will be a high high tide (over five feet above sea level). This high tide will be followed by the lowest low tide (the average of which we call zero, or sea level). Then there will be a second high tide, which averages five feet here in Santa Barbara. This is called the low high tide. Finally there will be another low tide, averaging two and a half feet above sea level and called the high low tide.

These names are tricky but it is easy to see this on our local shorelines. So the cycle repeats. These key heights create "zones" of horizontal stripes (bands) in the rocky intertidal that have very different environments as far as dryness goes.

Horizontal Bands--the Zones

Above five feet the surface is covered only by the highest high tide and thus dry three-quarters of the day. We call this the "Splash" Zone. Then, between five feet and two and a half feet, the surface is covered alternately by both high tides so it is dry between the high tides--about half a day. This band is called the "High Tide" Zone. Between sea level and two and a half feet the rocks are only left dry at the low low tide. This area is thus dry only a quarter of each average day and called the "Mid Tide" Zone. Then there is what we call the "Low Tide" Zone … the area below sea level that is exposed for only a few hours every few weeks at special "minus" tides (remember, zero sea level is the average of the low low tides). These special "minus" tides are the perfect time to go tidepooling and you can plan your trip, using a tide book, knowing that the tide will be very much the same for an hour before and an hour after each predicted tide. You usually have a good two hours to enjoy a nice low tide.

As the water goes down, most of the critters go out with it, but some can't move and are left on rocks. These critters must be adapted to withstand, not only the dryness of their area, but waves, storms, wind and rain. Each zone has what I call its "indicators"; species I know will always be there no matter what. There are three in the Splash Zone,

three in the High Tide Zone, one in the Mid Tide Zone, and thousands in the Low Tide Zone (I call these the "treasures" but three can be considered "indicators"). It is their ability to withstand dryness, and their interactions with each other (eating, being eaten, competing for space, and reproducing) that determine who dominates within the rocky intertidal areas.

I would like to tell you "tales" of the "indicators" of the upper three zones and then a little about my favorite "treasures" from the diverse Low Tide Zone. My lecture's photographic images transport us to local tidepools. My pictures were taken on our Santa Barbara coastline, between Goleta and Carpinteria. They begin with an overview of the two best tidepool areas near Santa Barbara--Coal Oil Point and Carpinteria State Park.

At Coal Oil Point (also called Devereux Point) in Goleta, just up the coast from Santa Barbara, the rocky shore is more like a boulder field with many small turnable rocks providing a variety of habitats. When the water level is at high tide the tidepool area is not even noticeable, but at low tide the various sized rocks attract tidepoolers.

Down the coast from Santa Barbara, at Carpinteria State Park, the more massive, vertical bedrock faces of the rocky shore (with few turnable rocks) provide a concise look at the four zones. A small area of Splash Zone with its three indicator species (a snail, a limpet and a tiny barnacle) can be found high on the largest rocks. The High Tide Zone with its three indicators (two other barnacles and a mussel) and the Mid Tide Zone (with its one indicator species, an anemone) are well represented in the middle and lower portions of these massive rock outcroppings. The Low Tide Zone (with three indicators, a plant, sea stars and another anemone, then all the thousands of treasures that can be found below the water) is only accessible at extreme minus tides.

Splash Zone

Now let's begin with the Splash Zone and work our way down. The very best place to see the Splash Zone is at the Santa Barbara Breakwater. The top of the seawall is 13 feet above sea level and gets splashed with waves at every high tide. Neither Coal Oil Point nor Carpinteria have rocks that are this tall and thus have limited Splash Zones.

The last pictures I took for my talk were of the Splash Zone species living the highest above the ocean and I nearly gave my right arm for these. You see, two months ago I was finishing my digital images at the Breakwater … having spent over an hour photographing the Splash Zone critters at low tide, balancing on a rocky ledge to photograph the seawall. As I finished, the ledge broke and I was down on the rocks below, camera and photos just fine (in my left hand), but my right arm was under me and badly broken. I am still learning to use my right arm again, and it was a good lesson to always be careful.

Periwinkle Snails

Now for the first critter. Like King of the Mountain, the little periwinkle snail prefers to crawl up above the highest water level to the area that gets just the smallest splash from the highest high tide waves. It has the record for the marine animal that can stay out of the ocean the longest. Some remain above the splash of the ocean for two to three months.

Periwinkles, also known as Littorina planaxis, rarely are over three-quarters of an inch. They come in an unbelievable assortment of shell colors and patterns. From uniform dull gray to shiny shells checkered or striped with white, these snails often cluster together in a crack or crevice. They secrete a special mucus around the opening to their shell. This hardens, cementing them to the rocky shore. They spend days like this without expending any energy--just "hanging out" on the rocky surface.

When they are hungry they emerge, first eating the hardened mucus and then they crawl about leaving slime trails, like land snails. They glide along; scraping the plant scum off the rocky surface with a special structure in their mouth called a radula.

This radula is common to many molluscs and is similar to a mini chainsaw--having rows and rows of sharp, hooked teeth for scraping. In fact, they are so efficient that they wear away the rock in some areas, deepening the high intertidal pools. You can imagine that the teeth get pretty dull quickly. This is no problem for a mollusc that continues to produce new rows of radular teeth its entire life--dropping off the old dull ones at the end of the scraper. Periwinkles can replace up to seven rows of teeth a day.

These critters are real couch potatoes--many only eat every two to three weeks, spending the bulk of their life cemented to the rocks, with a rare splash of seawater. Hot sun, rain and wind do not bother them. They have a "door", called an operculum, which keeps them protected. It is on their tail and closes their body inside their shell while they are resting--keeping in moisture on the driest days.

Once a year they expend extra energy in reproduction. These snails are separate sexed--the male needing to find a female for mating. In this species, the males appear unable to distinguish the opposite sex until actually trying to mate. In spring and summer males become very active--trying all neighbors for a possible mate and even fighting. Sometimes two males will be fighting over a third snail only to discover that the third snail is also a male. Eventually they are successful and, after mating, the female lays her fertilized eggs in a mucus bundle in high pools. These hatch as planktonic larvae and are taken away by the extreme high high tide waves.

Rarely do periwinkles encounter predators because they are so high, but if they fall down off their high and dry perch, they may be eaten by sea stars, crabs, or sea anemones.

Fingernail Limpets

Now let's move down a bit, just over the five-foot level. Only the size of a fingernail, the fingernail limpet (also called the rough or ribbed limpet, Collisella scabra and Collisella digitalis) is also a grazer, just like the periwinkle snail. Limpets are closely related to snails, but lack the coiled shell and operculum. There are several species of fingernail limpets, some with rough edges, and some with smooth edges. Lacking an operculum, like periwinkles, these fingernail limpets have a neat trick to avoid desiccation. They make the edge of their cap-shaped shell the exact configuration of the rock where they live and just pull down for a tight fit, keeping water inside. This special spot on the rock is known as their home scar.

When covered with a high high tide, these critters come out cruising. Having only about six hours each day under the water, they travel along the rocky surface near their home scar, scraping the algae off the rocks just like the periwinkles. After eating, these limpets usually return to their home scar before the tide recedes, so they can pull down and seal in moisture. It is unknown exactly how they find their home scar, but their tentacles appear to be more important than their eyes.

Although they are separate sexed (like periwinkles) they have no interest in mating. They have a unique reproductive mechanism, called broadcast spawning, to ensure fertilization. This is commonly found in many marine species and is accomplished by simply releasing eggs and sperm into the ocean. The swirling ocean water is where fertilization occurs. In order to assure fertilization, broadcast spawners release thousands to millions of eggs and sperm with each spawning to ensure just one offspring. Limpets have a planktonic larval form, like periwinkle snails, that results from the fertilized egg.

These limpets share the lower reaches of the Splash Zone with millions of tiny barnacles.

Buckshot Barnacles

No bigger than buckshot, the buckshot barnacle, Chthamalus spp., can live the highest of all the barnacles along our shoreline often covering the rocks with over 8,000 per square foot.

Each tiny barnacle is enclosed in grayish-colored shells that can completely close. Once they begin life on the rock, they cannot relocate as these shells are attached permanently to their substrate. When dead, the outside shell remains as an empty volcano until it degrades. You might wonder how so many can be found together in such a severe environment. One reason is that few predators venture up here to eat them. They can also close their shells to avoid desiccation.

They have an incredible reproductive style. They are what we call hermaphroditic in biology … that is they are both male and female in the same body. Each animal makes both eggs and sperm, but usually cannot get its sperm to its own eggs. Barnacles have an inflatable penis that is used in mating with a neighbor. This penis can inflate and

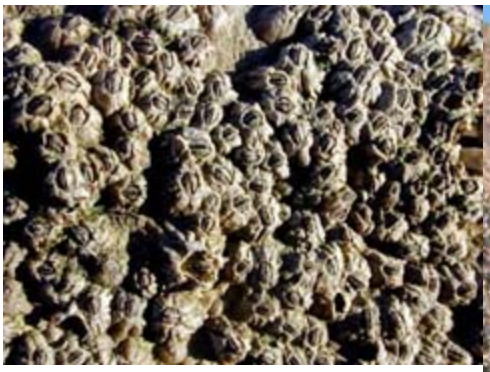
extend up to 2 inches from the tiny barnacle. For many of these buckshot barnacles this is 20 times the size of their full body! They mate during all seasons, except winter, and each may produce up to 16 broods a year. After mating, the barnacles' fertilized eggs (usually several hundred to several thousand in each brood) develop to a planktonic larval form that is shed into the water. Most of these never survive as they get eaten by filter feeders in their planktonic stage, or never find a place to settle and become an adult barnacle.

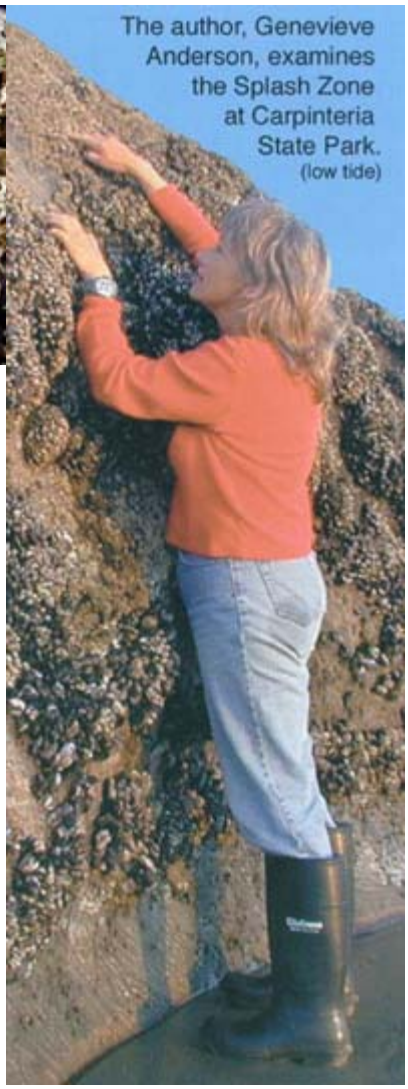
Now what about the 'lone' buckshot … without a neighbor to mate with? It seems that, in nature, if a buckshot barnacle is greater than two inches from any other buckshot then it can fertilize its own eggs (in breeding).

As you move closer to the five-foot tide level, you begin to encounter a larger barnacle, called the balanus barnacle, which cannot tolerate the dryness of the Splash Zone. Now we move to the High Tide Zone.

The Splash Zone

(5 feet above sea level and higher; dry 3/4s of the day)





Three species commonly present in the Splash Zone:

- **Periwinkle Snails, herbivores (plant eaters) - clustered in a very high rock crack (top image)**
- **Fingernail Limpets, herbivores - single individual on buckshot barnacles (middle image)**
- **Buckshot Barnacles, filter feeders (plankton eaters) - covering high tide rock (bottom image)**

Few other species can withstand the dryness of the Splash Zone

High Tide Zone

Balanus Barnacles

Several species of balanus barnacles, Balanus spp., begin to crowd out and take over space covered by the higher living buckshot barnacles--starting about five feet above sea level in Santa Barbara. These larger balanus barnacles are much bigger than the tiny buckshots (within a few months of their lives) so are rarely mistaken for the smaller buckshots that remain about 1/8 of an inch in diameter. Like most barnacles, once settled, the balanus cannot relocate. Reproduction is similar to the buckshots (hermaphroditic, mating, planktonic larvae) but they usually only produce 2-6 broods per year and generally during winter.

All barnacles are filter feeders--extending feathery legs into the water at high tide to comb plankton from the water. These 'furry' legs then kick the plankton down into the volcano shaped shell to the mouth area of the barnacle. Comb-like structures near the mouth remove the plankton from the legs before they stick out again for more. Barnacles may inadvertently feed on their own babies when they are still planktonic larvae.

At the five-foot level you encounter another type of barnacle, the gooseneck barnacle (also called the leaf barnacle).

Gooseneck Barnacles

These gooseneck barnacles, Pollicipes polymerus, have the characteristics of the more common volcano-type barnacles (like the buckshot and balanus), in that they are also filter feeders, capable of living rather high in the intertidal, being hermaphroditic, cross fertilizers, and having numerous planktonic larvae. They differ in that their bodies are on top of a permanently attached stalk covered with a thick skin. This stalk is a wonderful seafood (no guts inside) and tastes much like clam when steamed.

They tend to reproduce in summer with 3-7 broods per year. A unique thing about the planktonic larva of this species is that when it settles out of the plankton it generally crawls around, hunting for adults of its species before adhering to a solid substrate. This explains why single goosenecks are rarely seen--even when there is empty space on the rock there are always hundreds of goosenecks crowded together in rounded hummocks.

They can live 20 years, or more. As they grow they make new calcareous plates protecting their bodies. When first secreted, these plates are shiny and pearlescent. After repeated high tides and battering waves (with sand and rocks), the pearly shells become pitted and dull. It is interesting to look through these masses of gooseneck barnacles in our tidepools and see newly secreted shells. This means that the barnacle is happy, healthy and growing.

Mixed in with the gooseneck and the balanus barnacles is the most common member of the High Tide Zone--the mussel.

Mussels

Starting at about five feet above sea level, it is the California mussel, Mytilus californianus, that dominates Santa Barbara rocky shorelines exposed to waves. The mussel does not do well above this height, unless in a protected crack, as it is too dry.

The mussel is a space dominator--attaching itself with an array of exceptionally strong byssal threads. Each of these is laid down individually by the animal's soft and flexible foot, which protrudes from between the two shells at high tide until it touches a solid surface. A special liquid is secreted inside that runs down a groove in this foot and out the end. This liquid is like super glue and hardens as a small pad at the bottom attached to the surface. As the mussel withdraws its foot, the liquid continues to harden, producing a strong thread attached to the inside of the animal's body. Numerous byssal threads are laid down by each mussel to keep it attached. When they are young they can loosen their threads and move about a bit, but when they are older most of them stay put. They do not hesitate to grow on top of each other and other species--resulting in interesting mussel clumps that are themselves a habitat harboring over 100 species of marine organisms.

Mussels open their shells just a crack at high tide to feed, which allows them to circulate 2-3 quarts of seawater through their shells each hour--mucus on their gills traps plankton for their food. When there is lots of plankton mussels can grow up to three inches each year and will overgrow most other species. But … although they dominate the area between 2.5-5 feet above sea level, in Santa Barbara, they rarely get a chance to live lower in the intertidal because their main predator, the sea star, consumes them. Studies done by scientists who remove the sea stars from rocky intertidal areas show that mussels will prevail all the way to 20 feet below sea level as giant clumps if left unchecked by their natural predator. Other factors also affect them, like big waves tearing off clumps that get too large, or parasites, but it is the sea star that has the most influence.

Large rocks in the intertidal that span two and a half feet above sea level show a distinct line of zonation where the mussel-dominated High Tide Zone and the Mid Tide Zone meet. At two and a half feet above sea level (about as high as sea stars will go to feed), Santa Barbara's rocky shores show a marked change as mussels disappear and the aggregating anemone becomes the dominant species. We now enter the Mid Tide Zone--dry only a quarter of an average day when it is low low tide.

The High Tide Zone

(Between 2.5 and 5 feet above sea level;
dry 1/2 of the day, every 6 hours)

Tidepool rock at Coal Oil Point, above, shows the Splash Zone at the top of the rock, and the High Tide Zone as a horizontal band of gooseneck barnacle clumps with mussels.

Images, clockwise from upper right:

- **Balanus Barnacles (one is feeding)**
- **Gooseneck Barnacle**
- **Mussel clump**
- **Mussel with byssal threads**

These three common species of the High Tide Zone are larger than the Splash Zone species and can easily outcompete them for space, but they cannot dry out 3/4s of the day. They are all filter feeders and considered 'shellfish', a favorite food of the sea star. Sea stars are sensitive to drying out, so they rarely feed in this zone. But, below the High Tide Zone, the sea stars consume most of the shellfish.

Mid Tide Zone

Aggregating Anemones

The aggregating anemone, Anthopleura elegantissima, dominates Santa Barbara's rocky shoreline from sea level to 2.5 feet above sea level, not because it is a good competitor for space, but because the sea star has removed all mussels and most everything else with a shell (barnacles, snails, limpets). The sea star does not prefer to eat (or even touch) the anemones, so the anemones exist here without a predator and without any space competition with the shelled species.

Each anemone is round, with a mouth in the middle. The mouth is surrounded by feeding tentacles that have stinging cells capable of capturing small crustaceans, fish and anything that happens to touch them that cannot get away. The tentacles feel sticky to humans, but we are only feeling their 'sticky' cells. The real stinging cells of the aggregating anemone cannot penetrate our hands so it is safe to touch them. But there are stinging cells that might irritate sensitive flesh so I always warn my students that 'kissing' anemones is not allowed.

Food that is gathered by the tentacles is pulled to the mouth where it is ingested and digested. They are very simple animals, without a complete digestive tract, and thus there is no anus. So, ingested material that is not digested (like shells and bones) must be regurgitated back out the mouth. Sounds rather unpleasant, but this explains why sometimes the tidepool anemones look like they are turning inside out. Wayward periwinkle snails, if they have toppled from their high perch, may be swallowed by these anemones, but the snail will usually keep its trap door operculum closed until the anemone tires of its presence. Then, when the anemone spits it out, the periwinkle snail starts its long trip back up the rock to its preferred (and safe) Splash Zone.

At low tide these anemones pull in their tentacles and become a lump on the rock. The sides of their bodies are covered with adhesive structures that attach bits of shell, rock and seaweed. When closed up at low tide the attached material causes the anemone to look like a bed of crushed shell, but when you touch it, the anemone (whose body can be up to 80 percent water) releases water and feels gushy. The bits of debris probably reflect light to keep the anemone cooler and reduce water loss at low tide since these critters do not have a protective shell. The debris could also be dispersing wave action as the tide ebbs and flows each day.

This species is one of the most exciting to me in the tidepools, not because of what it does while we are watching at low tide, but because of what it does at high tide. At high tide, this species can split down the middle, pull apart and reform, resulting in two identical (but smaller) individuals. Each of these divides repeatedly until there are hundreds of aggregating anemones, all crowded together (thus the name aggregating). Each animal in the group is genetically identical, a clone.

The most exciting thing happens when two clones meet. Members of the same clone extend their tentacles at high tide and do not mind touching members of their own clone … but, should a member of another clone be touched, they fight until one moves or

dies. There are special fighting tentacles (that are deflated and not visible until a clone war starts) tucked just under the regular tentacles and the outside of the body. These special fighting tentacles are called acrorhagi and during a clone war they are inflated. They look different than the regular tentacles, being shorter, rounder, and very white.

The clone war is a slow motion confrontation with the clonal adversaries stretching toward their enemy to touch the acrorhagi. The acrorhagi have nasty stinging cells that damage the tissue of whatever they touch. Back and forth for hours these anemone enemies fight until one moves or dies. This behavior leaves wonderfully obvious anemone-free areas in the Mid Tide Zone wherever two clones meet. We don't have to do DNA analysis to know there are two (or more) clones present on the intertidal rocks. Other critters may use these anemone-free areas to travel through the Mid Tide Zone.

The aggregating anemone not only asexually reproduces to form clones, but once a year it releases eggs or sperm into the water as a broadcast spawner. Its planktonic larva is the source of the original anemone on the rocky shore that forms each clone. These anemones are separate-sexed so each clone is either all male or all female.

As you view the Mid Tide Zone and get close to sea level, you are likely to encounter the "star" of the tidepool tales--literally. That would be the sea star, roaming the rocks in search of anything with a shell to eat.

Sea Stars

Not an indicator of the Mid Tide Zone, nor even commonly found there (at low tide), the sea star has a profound effect on the Mid Tide Zone due to its presence there at high tide. The most common sea star species in the Santa Barbara tidepools is one of the knobby sea stars, Pisaster ochraceus, also called the ochre sea star. Each one can eat up to 80 adult mussels each year and thousands of barnacles. This is the "keystone species" in our rocky intertidal. Without its presence the mussels would dominate and species, like the aggregating anemone, would be crowded out. Furthermore, there would not be the great diversity of species that is encountered in the Low Tide Zone (below sea level) that I like to refer to as 'treasures'. Everything would be overgrown by mussels.

The sea star's preference for shellfish is because they are uniquely adapted to hold onto solid shell with hundreds of sucker-tipped tube feet that are found under each leg. These are run by water pressure that enters the sea star through a special sieve plate on the upper surface of its body. This sieve plate (also called a madrepore) can usually be seen if you look closely at the back of a sea star just off-center. These tube feet can pull two pieces of shell apart for hours (or days, if needed) until their prey tires. They never tire because they have hundreds of tube feet--always resting a few. Once there is the tiniest crack (a tenth of a millimeter is all that is needed) the stomach of the sea star can emerge, ooze into the crack and digest the prey. In general, it takes more than six hours to consume a mussel. The upper limit of where sea stars prey on their favorite food, the mussel, is 2.5 feet above sea level because the rocky shore dries out every six

hours when you get higher than this (the High Tide Zone) and sea stars do not tolerate that much dryness.

The sea star is one of the top predators in the ocean--few things prey on sea stars. It is the desperate shark and a few sea otters that are the main sea star predators. Even then, if the predator just bites off an arm or two, the sea star has amazing regenerative abilities, and can often regrow missing arms. They can sometimes even regrow an entirely new animal from just one leg. They have sexual reproduction mostly during spring and summer. This occurs when the separate-sexed adults release their eggs and sperm from five openings on their top surface. Often when one sea star spawns this causes those nearby to also spawn, creating a concentrated mass of eggs and sperm in nearby waters--increasing the chance for fertilization. This broadcast spawning is well known by aquariums that quickly remove any spawning animals so as not to cloud the water for their visitors.

The Mid Tide Zone

(Sea level to 2.5 feet above sea level; dry 1/4 of the day)

Tidepool rock at Coal Oil Point, above right, shows the mussel-dominated High Tide Zone (top of the rock), the Mid Tide Zone from the middle of the rock down to the water (covered with aggregating anemones), and the Low Tide Zone with floating surfgrass (at the water level and below). The tide is at zero (sea level).

Images, clockwise from middle right:

- **Aggregating Anemone clone, closed above water line, and open below water line (feeding)**
- **Ochre Sea Star, keystone species of the rocky intertidal, a carnivore, clears all 'shellfish' from the Mid Tide Zone leaving space for anemones**
- **Ochre Sea Star showing numerous calcium knobs on the top with madrepore just off center**
- **Close-up view of Aggregating Anemone, (closed at low tid); an omnivore (eats anything)**
- **Anemone-free area, seen diagonally, between two clones of Aggregating Anemones**

Low Tide Zone

Sea stars prefer the lower reaches of the rocky shore and are most common below sea level in the Low Tide Zone. The ochre sea stars, found in rich shades of orange, brown and rose, venture through the Mid Tide Zone, clearing shellfish and thus leaving room for the aggregating anemone clones. A closely related species, the giant sea star, Pisaster giganteus, can also be found in the lower pools and comes in shades of blue and purple. It is also a mussel predator, but cannot withstand the desiccation of the Mid Tide Zone as well as the ochre sea star. Several other sea star species are commonly found in the Low Tide Zone like the bat star, leather star and sunflower star.

Surfgrass

One of the few flowering plants in the ocean is surfgrass, Phyllospadix torreyi. It is on almost every Santa Barbara shoreline that has rocks and waves at sea level. Not able to withstand much desiccation, this plant grows much like garden grass, sending out lateral runners along the surface and establishing new plants, creating masses of vibrant green at sea level. During minus tides the surfgrass is left dry for a short time, but is a wonderful visual cue to where sea level is located. As a photosynthetic plant it creates oxygen as a waste product of photosynthesis. Normally this is washed away by the ocean currents, but at a minus tide, surfgrass in still tidepools on sunny days is covered with bubbles of pure oxygen. It is fun to look through the strands of surfgrass for the 'treasures' hiding in the low tide pools.

Starburst (Sunburst) Anemones

Before we get to the 'treasures', I would like to introduce you to the starburst (or sunburst) anemone, Anthopleura sola. Closely related to the aggregating anemone, this species was given its own name only two years ago. Up until then it was known as a form of aggregating anemone that lived below sea level and did not clone, remaining solitary.

The starburst anemone also has fighting tentacles, called acrorhagi, just like the aggregating anemone. It fights with its neighbors, using these acrorhagi, to remain a little more than tentacle distance apart. If two starburst anemones touch their feeding tentacles they inflate their acrorhagi and fight until one of them moves. Thus they maintain even spacing in the Low Tide Zone. When tidepooling it is the starburst anemone that may often be caught in the middle of a fight, with its white, blunt acrorhagi inflated.

The starburst anemone is rarely found above sea level. At low tide you often must walk on top of the starburst anemones while exploring the tidepools of the Low Tide Zone. Remember that each day all of these species are battered by the waves so your gentle foot is not much when compared to crashing waves. These are hardy species.

It is interesting to look at the different color patterns on the tentacles and oral disks of these starburst anemones. The various shades of green come from a combination of the natural color of the anemone and from green-colored symbiotic algae that grow in their tissues. Anemones found under rocks or in the shade have little symbiotic algae so are generally very pale. The various striping on their tentacles is genetic and serves to show how each is unique (unlike the clones of aggregating anemones where each clone member is identical).

The Low Tide Zone

(Sea level and below; dry only at minus tides)

Above, right, the author hunts for treasures among the surfgrass of the Low Tide Zone. Surfgrass, one of few flowering plants in the ocean, begins growing at sea level and is an easy indicator of tide height and the Low Tide Zone. If surfgrass is exposed, it is a minus tide, below sea level.

Sea stars (of all kinds) lurk here, as well as the starburst anemone, top row left. The regular tentacles of anemones are used to catch food. Starburst anemones maintain even spacing by fighting with special tentacles called acrorhagi. Two fighting starburst anemones, with inflated acroraghi, are shown, second row left (close-up of inflated acrorhagi, second row right). (Aggregating anemones also use acrorhagi to fight between clones, but not between members of the same clone, thus leaving the anemone-free areas between clones.) Besides the surfgrass, sea stars and starburst anemones, many other species can be found (called 'treasures' by the author).

'Treasures'

Now for the 'treasures', the things that are different each time you can get to a minus tide area. There are thousands of species that might be encountered, but I picked a few of my favorites to share with you. You never know what treasures will be found on a tidepool trip. In general, several of my favorite treasures are always found, but never all. Each has its own story and mystery, making it truly a 'treasure beneath the sea'.

As you move to the lower depths of the tidepools at a minus tide you may encounter various species of algae. Especially noticeable in Santa Barbara is the feather boa kelp

(Egregia), with its unique growth area looking like an hourglass, and its own species of limpet that feeds on the center strap-like stipe.

Crabs abound as the garbage collectors in the tidepools. From the high intertidal, and very common (but hard to catch) lined shore crab, Pachygrapsus crassipes, to the large male decorator crab, Loxorhynchus crispatus, most crabs will consume anything and thus act to clean up the tidepools. A few, like the kelp crab, Pugettia producta, prefer plant material.

Extremely shy by nature, octopods are a delightful tidepool find. They generally hide so it is only the most watchful and observant tidepooler that usually discovers this interesting animal. Once found they can be placed in a pool and observed to change color, shape and skin texture. Our common species, called the two-spotted octopus, changes from matching its environment to standing out in contrast to it. The name (two-spotted octopus) comes from the two fake eyespots, below its real inconspicuous eyes, that can be turned on or off. A close look at the pattern of the fake eyespot is needed to distinguish the two species of the two-spotted octopus (Octopus bimaculoides and Octopus bimaculatus). Octopus bimaculoides' eyespot has a blue chain instead of a starburst.

Octopods are masters at blending into their environment by changing color and skin texture in seconds. The octopus can bite with a beak, found in the middle of its eight legs. A drop of poison is generally delivered with this bite. The poison is enough to paralyze small fish or crabs, but usually does not hurt humans (unless you happen to be allergic to it). It is best to avoid any octopus bites as one never knows if you could have a reaction (similar to a bee sting) that may be harmful. When stressed, the animal may shoot out a cloud of ink as a smokescreen and jet away.

Two species of common sea urchins, Strongylocentrotus spp., are annoying to careless tidepoolers and scuba divers who may get their spines lodged under their skin. The spines are not poisonous but should be removed. They can cause serious problems if they lodge near a joint. The smaller and more lavender-colored species are S. purpuratus, also called 'purps', and the larger and usually darker-colored species is S. franciscanus, also called 'frans'. It is mostly the frans that are collected by our local sea urchin divers, who harvest them for the five reproductive organs inside. When ripe, these organs are a delicacy in Asia and used in sushi bars … they are called uni.

These urchins are pretty strict herbivores and eat mainly kelp, chewing voraciously with five sharp teeth that are on the bottom. These five sharp teeth, called Aristotle's Lantern, are constantly repaired and can be completely replaced in 75 days. The urchin is prey for several fish and some sea otters. In fact, some sea otters feed so exclusively on sea urchins that the purple pigment of the urchin is incorporated into their bones and, when dead, they have lavender-colored skeletons.

Related to sea urchins, several other species of Echinoderms may inhabit the lower tidepools. These include bat stars, Asterina miniata, found in a profusion of colors.

Remember how I was telling you how the knobby sea stars would evert their stomachs out of their mouths? Well, this species does it on a regular basis and is easily caught with its gooey stomach everted. Also found in the lower pools are leather sea stars, Dermasterias imbricata. Brittle stars, Ophiothrix spiculatamay be found under rocks and in rock cracks. Brittle stars are very different than the sea stars we have been talking about. They are filter feeders, often found in great numbers on our ocean bottom, under the sand and in tight spaces.

Abalones (Haliotis spp.) have been revered by man for thousands of years for their yummy flesh and their beautiful shells. In recent years, in Southern California, their numbers have so decreased that they are no longer taken by either sport or commercial means. Their decline is due to a multitude of factors, some natural and some brought on by man. There is a lot of controversy about this decline, but scientists have detailed the life cycle enough to allow mariculture farms to control the broadcast spawning of males and females, fertilize the eggs, raise the planktonic veliger larvae, and get them to settle, becoming baby abalone. The herbivores are grown (fed by kelp) by the thousands in the mariculture farms and sold to gourmet restaurants. Each spring semester I purchase several to show my students what a live abalone is like, including its internal structures, and then I prepare it in lab, giving each one a taste of this expensive delicacy that was once as cheap as hamburger.

Looking a little like a rabbit, sea hares are a common treasure in Santa Barbara's Coal Oil Point tidepools. They can get up to 16 pounds but are usually more like three to four pounds in the lower pools. Although these slugs appear to be just a big blob, they have a hidden trick … beautiful purple ink that can be released if you reach inside the skin flaps on the top and tickle them. In nature this acts as a smoke screen (similar to the octopus's ink).

The finest treasures for me are the sea slugs, called nudibranchs. For some reason I just love these critters. There are over 100 species in California and each has its own unique and interesting story. Many are brightly colored, but some blend into their surroundings or match their prey (upon which they may live). The most common and most flashy of the nudibranchs is the Spanish dancer, Flabellina iodinea. It is easy to see why it is called the Spanish dancer, as its colors remind one of flamenco dancer costumes. This species also 'dances' occasionally by letting go of the substrate and wildly thrashing its body back and forth, creating the same look as a flashy flamenco dancer's skirt. These are such beautiful creatures--it is hard to imagine that some animals find them toxic.

Many of the slugs (including the Spanish dancer species) feed on stinging animals, like jellyfish and sea anemones. They are capable of keeping the stinging cells alive in their bodies at the tips of all those 'furry' processes, known as cerata. Then, when a predator (like a fish) comes by for a bite of this slug the stinging cells fire and the fish is repelled. The predator is rarely wounded, but it is believed that the predator remembers the flashy colors and never again bothers what it thought was a tasty morsel. So, the flashy color is thus a type of 'warning coloration'.

Marine slugs also have interesting reproductive habits. They are hermaphroditic, but must mate with another individual. Their reproductive pore is on the right side of their body so they must position themselves just right. Eventually they get together, cross-fertilize and then separate to lay their fertilized eggs. The eggs hatch as planktonic larvae.

I just can't help but show you other beautiful nudibranchs and a few related slugs, like Janolus barbarensis, Hermissenda crassicornis, Triopha catalinae, Anisodoris nobilis, Acanthodoris rhodoceras, Diaulula sandiegensis, and Berthellina engeli. And finally the two species I did my Master's Degree research on, Corambe pacifica and Doridella steinbergae, that live on the encrusting bryozoa (white patches) on kelp and are so camouflaged that they are nearly impossible to see. They not only look like the bryozoa, they eat it and lay their eggs on it.

As the water recedes during low tides there are some fish that get trapped in the tidepools. These are mostly small sculpins, blennies and kelpfish, but occasionally a large fish is there, like the cabezon. They just wait out the low tide that may only be an hour or two at the lower levels, and then go about their business.

Looking up from the water a tidepooler will almost always see numerous shorebirds, like the snowy egret and godwits. Occasionally there will be a seal or sea lion hauled out on the tidepool rocks, basking in the sun. It is especially common to see harbor seals at the downcoast end of Carpinteria State Park, where there is a harbor seal rookery. Each March there are numerous babies born here--you can observe them from the cliffs just downcoast from the oil pier.

A unique treasure for me is the presence of my students in the tidepools, discovering new things and understanding the complex dynamics that create our complicated shorelines with the four distinct zones.

As one gets ready to leave the tidepools there is always a chance of catching the blow of a migrating whale. Especially from the months of January to April, the California gray whale is migrating to and from its breeding grounds in Baja and passing Santa Barbara. The whale feeds on zooplanktonic crustaceans in the Bering Sea, off Alaska, each summer. In the fall it leaves to travel along the coastline to Baja for its winter mating and birthing. Then it returns north each spring. Occasionally my students and I have been surprised as we look up in the tidepools and see a gray whale breaching nearby.

With all the thousands of possible treasures in the tidepools, these are but a few of the visible ones. Now, there is a special microscopic treasure that is unbelievably important in the marine ecosystem. This is the plankton … the gray whale reminds me of its importance since this large leviathan relies entirely on animal plankton (zooplankton) for its nutrition. Let's take a small sample to provide a quick look at the world of plankton.

Treasures

Of the Low Tide Zone

Each tidepool trip generally includes the common species, shown on these four pages, as well as several 'treasures'. These 'treasures' may include crabs, sea stars, various types of slugs (like nudibranchs and hares) and octopods.






Special Ending

Microscopic plankton is best appreciated back at the lab. As I prepare a slide for viewing I never know just what to expect … plants (phytoplankton), animals (zooplankton), or both; larval forms of the tidepool critters or other unique species that live only in the plankton. Each tow is different. For this lecture demonstration, I used plankton caught by my students in the Santa Barbara Harbor. I videotaped this in my laboratory last month with our unique classroom videomicroscopy unit.

The sample is dominated by phytoplankton--it is diatoms, like the big round Coscinodiscus, that are the base of so many marine food chains. It is these diatoms that are fed upon by small planktonic animals (like the small zooplanktonic crustaceans that are the food for filter-feeding whales, such as the gray whale). Another diatom, Pseudo-nitzschia, is one that the California State Department of Health is particularly interested in. This diatom produces a toxin, called domoic acid, which could affect humans if concentrated in the flesh of filter feeding shellfish consumed by man. Recent blooms of this species have caused the Department of Health to closely monitor it and even to close some bays to the consumption of their shellfish by humans. My students at SBCC are involved each semester in taking plankton tows from Santa Barbara Harbor for the Department of Health.

Toxic substances from plankton are more commonly attributed to dinoflagellates. There are many species of dinoflagellates in our waters--most have little influence on humans but a few species are responsible for shellfish poisoning (and the mussel quarantine each year from May through October) and red tide. In addition, a few other species are bioluminescent and produce light if disturbed. When bioluminescent dinoflagellates bloom in our ocean the waves light up at night and produce an exciting spectacle. A few hours after dark, bioluminescent dinoflagellates make two chemicals (luciferin and luciferase) that glow for a few seconds when mixed. Each single celled dinoflagellate mixes these only when disturbed. If a predator tries to eat this dinoflagellate, it gets a flash of light and is usually scared away. When waves break the dinoflagellates are also disturbed and glow.

These bioluminescent dinoflagellates are often cultured by biologists for research on this phenomenon. A warm water species, Pyrocystis fusiformis, is packaged and sold for educational purposes by Sunnyside Sea Farms in Goleta. Small vials of this bioluminescent dinoflagellate live for months and provide glowing light each night when gently shaken. [Vials of Pyrocystis fusiformis were distributed to the audience, the house lights turned off and everyone in the theater participated in a one-minute activity shaking their vials for a spectacular show of bioluminescence.]

The plankton is the last of the treasures that can be introduced in this short lecture. There are thousands of other species that might be found in the lower tidepools here in Santa Barbara--most are visible but remember that there is a whole world right below your level of vision, the plankton.

Conclusion

As you leave any tidepool trip take only memories; leave the critters and leave the shells (they are shelter and home to some species even though the original owners may be dead). If you have moved a rock, always return it to its original position so the thousands of critters that call this special place home will have their correct habitat. Know that there are California State laws governing what you can take, and you must have a license to do this. Read and obey the laws if you choose to take from the ocean. It is a unique and wonderful place if we all respect it.

Last year Dr. MacDougall sent me an article from the Chronicle of Higher Education (April 13, 2001 issue), entitled "Saving the Earth's Oceans" by Colin Woodard. It had both positive and negative aspects, but what I liked about it was the reminder that we humans have always considered the oceans "as simply too big to damage," but we have learned differently in the last few decades with the understanding of how much the oceans influence Earth (not just locally, but the entire planet's climate and atmosphere). The conclusion was that our ultimate goal should be "the creation and maintenance of thriving marine ecosystems that can produce the resources our increasingly crowded planet will need in this century." You can do your part by understanding more about your local shoreline and being an advocate for its protection each time you are there.

My life would not be the same without the ocean and all those who kept telling me I could do anything I wanted my entire life. So many women hit glass ceilings or are steered away from male-dominated areas because of their gender, but my life has been a series of doors constantly opening because I was a woman (even though I went to school in the '50s and early '60s when math and science were not 'girl' subjects). Throughout my life, I have been supported by my parents, teachers and colleagues. As a college student and graduate student I was again encouraged at every turn (even when I attempted some things that were beyond my physical abilities, I was supported by my friends and colleagues who would work out ways so we could all be successful). So, I have tried to be a female role model for women in science and marine biology. My dreams of living a happy and fulfilling life have come to reality. Now I hope to mentor the next generation in the same way that I was mentored. In the words of Helen Reddy … "I Am Woman, Hear Me Roar … I can do ANYTHING." This is how I feel.

FAVORITE REFERENCES

Behrens, David W. *Pacific Coast Nudibranchs,* Sea Challengers, 1991

Morris, Robert H., Donald P. Abbott, and Eugene C Haderlie, *Intertidal Invertebrates of California*, Stanford University Press, 1980

Ricketts, Edward F., Jack Calvin and Joel W. Hedgpeth, *Between Pacific Tides*, Stanford University Press, 1985

MacGinitie, G. E., and Nettie MacGinitie, *Natural History of Marine Animals*, McGraw-Hill Book Company, 1968

The complete set of lecture images (137) and this text available at Genny Anderson's class website: www.biosbcc.net/ocean