Salt Marsh Secrets

Who uncovered them and how?

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An e-book about southern California coastal wetlands for readers who want to learn while exploring

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This e-book records favorite stories about salt marsh secrets that my collaborators and I uncovered while studying southern California coastal wetlands, from the 1970s to date. In 1986, we became the Pacific Estuarine Research Lab.

Please download the files as they appear online and enjoy learning what we learned…and more. You'll meet many "detectives," and you'll be able to appreciate how they learned so much--undeterred by mud and flood. Learn while exploring the salt marshes near you!

Each chapter (1-21) is being posted at the TRNERR as a separate file (PDF).
Chapter numbers precede page numbers (for chapter 1: 1.1...1.14).
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PDF name and brief description:

Preface: Learning while exploring
1DiscoveringSecrets: Introducing salt marshes
2SeasonalChange: How weather and tides change over the year
3RarePlant&Bird: An annual plant and a clapper rail
4WherePlantsGrow: The influence of salt and water and more
5Perennials&Annuals: How short- and long-lived plants get along
6SaltMarshWeeds: Which species invade and why
7Sedimentation: A little sedimentation is good; a lot is not
8Heterogeneity: Variable elevation and patchiness
9Transitions: From marsh plain to high marsh to upland
10TestingDiversity: What diversity affects and what affects diversity
11RunoffCattailsAlgae: Freshwater pulses trigger pesky invaders
12Dunes: Why our dunes are low and flat
13Damages: How we damage salt marshes
14GoFish: Fish and invertebrates respond to changing waters
15AnimalMobility: Mobile and immobile species
16FoodWeb: Who eats whom
17ConservationBattles: It wasn't easy saving salt marshes
18Restoration: Returning tidal influence
19TestingTheory: Contributions to the science of ecology
20References: References cited and other PERL research
21PERLalumni: Where the "detectives" are now

Where have all the sand dunes gone?

Unlike coasts with tall dunes that form with persistent strong winds, the coast along Tijuana Estuary has low dunes, and they have not been vegetated for many decades. An important native plant, sand verbena (*Abronia maritima*) has tough, deep roots that stabilize the sand and sprawling branches that could keep moderate winds from blowing the surface sand away. But the plant is very rare. Dunes are not low just because the winds are moderate. Humans have played a major role in flattening the dunes, and so have sea storms. As far back as World War II, the dunes and adjacent high marsh transition were used for military activities. Later, the sand was a favorite place for off-road vehicles, horseback riding, and foot traffic. All that disturbance abraded the vegetation and left the sand bare.

Dunes and beaches in southern California that were once dominated by the native sand verbena (a perennial plant) began converting to the invasive alien sea rocket (*Cakile maritima*, an annual plant). This happened sometime after its arrival in the San Diego area (between 1936 and 1963; Wood 1987). Beaches further south, in Mexico, still had dense cover of sand verbena in the 1980s.

After the 1983 storm subsided, substantial damages were obvious to the dune. Sand had been washed inland over the salt marsh and into the main north channel, called Oneonta Slough. So much sand had moved inland that it blocked tide water that was the "life blood" of the estuary. In fact, tidal flows were so reduced that the mouth of the estuary also filled with sand from long-shore sand transport, and tidal flushing ceased in April 1984.

Paul Jorgensen, estuary manager, had local sand bulldozed to rebuild the dune north of the estuary mouth. However, scientists at Scripps Institution of Oceanography predicted this would hasten landward migration of the dune.

Dredging Oneonta Slough and using the sand to rebuild the dune.

Brian Fink extended our salt marsh research onto the adjoining sand dune at Tijuana Estuary. The dune near the US-Mexico border was hard to avoid, because sand was being washed onto the salt marsh during storms. Because the native dune vegetation had been disturbed, exotic plants were able to advantage of the open sand.

Brian's MS research involved several outdoor and field experiments to figure out how to reestablish native dune plants at local dune systems: Los Peñasquitos Lagoon, Silver Strand State Beach, and Tijuana Estuary. He compared the ability of three native dune plants to withstand maritime stresses of seawater, salt spray, drought, low nutrients, and sand burial. Beach bur (*Ambrosia chamissonis*) withstood the most burial (30 cm of sand); sand verbena (*Abronia maritima*) was intermediate and beach primrose (*Camissonia cheiranthifolia*) was the most tolerant of sand addition (Fink and Zedler 1990).

How did Brian figure out how much sand burial each species could tolerate? He dug a very deep trench at our outdoor lab, filled it with 2 m (over 6 feet) of beach sand, planted 6-month-old seedlings of the three test species, which had grown from seed, and then subjected his plants to three levels of sand burial. The treatments were 0, 5 cm and 10 cm per month. After three months, he compared survival, as reported above.

Brian showed that seedlings of sand verbena could grow into plants that could stabilize dunes, especially where the drought-sensitive seedlings could be watered (irrigated). However, small patches of sand verbena were not enough to hold the dune in place during the 1986 overwash event. The wind and waves snapped the stems and exposed the roots. Even people could not withstand the fury of the sea during that catastrophic storm. Refer to the chapter on sedimentation to see one of Brian's planted plots during the 1986 sea storm. Even the fence did not remain upright!

Opportunity for experimentation

After the washover event, Lisa Wood persuaded Paul Jorgensen to leave some areas un-bulldozed, so she could document differences in vegetation. Indeed, areas that were bulldozed became monocultures of the alien sea rocket (*Cakile maritima*), which is an annual plant that grows upright stems. In contrast, the areas that were not bulldozed held, and continued to support sand verbena, primrose, and other species. The sand verbena persisted in the un-bulldozed areas.

Lisa's thesis research focused on the effect of human disturbance on invasive plants. Well, it wasn't just humans but also disturbance from horses. Lisa—an avid equestrian—often watched the customers of the nearby Sandy's Stable riding rental horses toward the beach. Few riders were experienced, and none had guides. Sometimes she saw horses with empty saddles dashing back to Sandy's; sometimes she found a fallen rider in her field site—one more type of disturbance.

Lisa asked where and how the conversion from native perennial to exotic annual was happening. She compared plant cover on dunes at the Tijuana Estuary and on dunes south of Ensenada and at San Quintin Bay, both in Baja California Norte. Both dune systems in Mexico were relatively undisturbed. The dune at Tijuana Estuary had the highest disturbance level, then Ensenada, then San Quintin Bay. Based on sampling along transects, dune plant cover and species richness followed the reverse ranking, being highest where disturbance was least. Other factors that might have influenced the results could not be ruled out, however.

Lisa continued her exploration. Next, she asked whether the growth of sand verbena was reduced by sea rocket, and she set up an experiment to grow the two species together and see if sand verbena grew less than when grown alone. We had most of what she needed at our fenced field site just inland from Tijuana Estuary—space, soil, nearby sand, water, and plenty of sunshine. The hypothesis was that sand verbena would produce less biomass when grown with sea rocket than when grown alone.

• To test for intraspecific competition (reduction of growth when a species' own density increases), she grew sand verbena at 2, 4, and 6 plants per microcosm and sea rocket at 2, 4, and 6 plants per microcosm. To test for interspecific competition (reduction of growth when a species is grown with another species), she grew the two species together at densities of 2, 4 and 6 plants per microcosms, setting the ratio of sand verbena:cakile at 1:1; 1:3; and 1:5.

• She used 7.5-cm-dia PVC pipes cut to 1.5-m length for each microcosm (small container used for growing plants or animals under controlled conditions). And to simulate an actual dune, she trenched disturbed soil (to a depth of 0.75 m). She installed her 45 microcosms along three rows and then backfilled with excavated dirt and covered the dirt with a layer of dune sand. Voila—an artificial dune!

Relative to building an artificial dune, planting was easy—Lisa grew both species in our small greenhouse. Then she corralled me and others to "roll our own" paper tubes out of butcher-paper—2-cm-dia x 17-cm long, until she had ~500 tubes to fill with sand. Each had one seed added to produce one plant per tube. After about a month, she had enough seedlings to set up her competition experiment. She filled the microcosms with dune sand, then removed each paper tube and transplanted the seedlings as specified in her experimental design. Every three days, she watered the plantings. After 61 days, she dug up the microcosms, harvested the plants' roots and shoots (washing them over screens to retain plant material and discard sand), then dried and weighed the biomass.

The dune experiment indicated that sea rocket reduced sand verbena growth, but the effect was small. It is always difficult to interpret such results—Is a small reduction important and is the reduction always small? Scientist never run out of ideas or work! What are some of the remaining questions?

- Can sea rocket outcompete sand verbena or not?
- Did the microcosms have plenty of water and nutrients and light so that both species could coexist; after all, there's no competition if nothing becomes limiting.
- Does it take longer than 61 days for competition to exclude sand verbena?
- Was plant weight the best measure of competition, or might one species reduce another's seed production?

Now let's try a simulation model

MS students don't have lots of years to wait for plants to outcompete one another, but they can employ computer models to predict longer-term outcomes. With help from Dr. Ross Virginia, Lisa used a program called Stella to predict how her plants would perform over more years, with varied disturbance levels. The model, using her equations, verified that sand verbena could coexist with sea rocket at low levels of disturbance in a tall dune system with a native dune plant that helps to stabilize the sand—representing the dunes in Mexico. But at high levels of disturbance on low dunes, as at Tijuana Estuary, the model predicted that annual sea rocket could take over. Without sand verbena, the dune would erode. The annual cakile has little sand-stabilizing ability.

Lisa found the highest species richness at the lowest levels of human disturbance. Perhaps, if there had been an undisturbed area, it would have had even more native species; we can never know. Her work suggests that the effects of disturbance on species richness and diversity vary with the type of ecosystem and the type of disturbance.

Be cautious; field work can be dangerous

The beach just north of Mexico is not exactly the "wild west," but it is still remote. The beach is also south of the river mouth, so it's not easy to walk from the northern beach where the condos and apartments and most of the City of Imperial Beach are. I commend both Brian and Lisa for working on an isolated beach and venturing beyond the comfort zone (before cell phones). And I especially commend Lisa for her bravado!

Assault at the beach:

> "It was fairly early in my research that the assault happened.…I was able to fight the man off, and then call 911 to report the crime. The man was arrested within an hour of my report. A few days later I was asked by the police to participate in a line up to identify the man who was my attacker, and also testify at his trial. He was convicted of assault. The police informed me that it was my option to attend the sentencing. I chose to attend, and sat next to the prosecutor. The perpetrator's defense attorney asked the judge to reduce the sentence, because, especially given that his client was 6'2" and 180 pounds, and I was 5'8" and 130 pounds, he reasoned that clearly the man was not assaulting me. Had he wanted to rape me, the defense maintained, the defendant 'could have done it any day of the week.' It was 'just a cultural misunderstanding.' The prosecutor sitting to my right said some unkind things about the not-physically-fit defense attorney under her breath, suggesting that I could trounce him and his client on right there in the court room. Then, in a louder voice, she advised me to stand and tell the judge what happened. The judge found me credible and did not reduce the sentence - instead he added a little time. " Recollection of Lisa Wood, 2014.

After that experience, we found an expert to instruct the entire lab in self defense, and we employed field assistants for students working in remote areas.