Salt Marsh Secrets

Who uncovered them and how?

By Joy B. Zedler

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:

Salt marsh Weeds

Invasive (weedy) species differ from non-invasive species by behaving more aggressively. Invasive plants have a strong tendency to establish in disturbed areas, to become dominant, and to crowd out prior resident plants. Call them “bullies,” if you like.

Iceplant (*Carpobrotus edulis)* Photo: Marin Audubon Society

Iceplant is an evergreen, succulent, perennial weed. It expands vegetatively over coastal dunes and salt marsh edges. It rapidly covers the soil and excludes other species. When planted along freeways to control erosion, this weed gains access to nearby native wetlands. In the 1980s, I spent many Saturdays pulling its seedlings from sandy dunes in Los Peñasquitos Lagoon along Freeway 5. That entertained me while the kids took horse-riding lessons at a stable upstream.

Above, iceplant holds soil in place adjacent to Tijuana Estuary. What weed wouldn’t be tempted to hop the fence and invade the salt marsh? Lucky for salt marshes, most weedy plants don’t tolerate salt. So salt marshes aren’t usually invaded unless salinity drops following heavy rainfall or freshwater flooding. Within the cordgrass marsh and across the intertidal plain, exotic weeds (from another region or country) are rare.

On land, many of our most conspicuous weeds are annual plants—because the plants and seeds that grow around our homes are "domesticated," and because on land, an annual can grow much taller much faster and rival the resident native plants. Backyard weeds don't have to expend energy dealing with salt or waterlogged conditions. They can invest more energy producing seeds that disperse readily, which helps them be in the right place when the right disturbance comes along to allow germination. Do you recognize these weeds: mustard, rabbitsfoot grass, Australian saltbush, brass buttons or any of the iceplants? Just for fun, when you see a weed in fruit, count the branches with fruits; remove one branch; and then try counting all the seeds. (But don't spread the seeds where they can germinate!) How many seeds were there per plant?

What kinds of disturbances allow weeds to invade?

To understand salt marsh weeds, we wanted to know why they invade. A disturbance that opens the canopy would allow light to reach the soil. If that disturbance happens often enough and in enough patches, it could sustain weedy populations. Which disturbances do that? Digging animals, grazing animals with hoofs, voracious herbivores, and—you guessed it—humans…..who dig and mow and harvest and cultivate, and otherwise disrupt plant canopies. Where people grow crops, weeds evolve. And where people carry seeds deliberately or accidentally, the weeds grow and invade and spread widely.

So now we have weeds that follow people around and invade open canopies. Only a few can enter the salt marsh, however. The invaders have to be salt tolerant or able to invade quickly when the salt marsh soils are diluted with freshwater. Invasions happen after a major flood or downstream from a street gutter where a local resident keeps forgetting to turn off the lawn sprinklers. One year, I sampled several street drains that discharged irrigation water and rainfall runoff into the Tijuana Estuary salt marsh. Each inflow supported a "plume" of weeds with limited salt tolerance. Two common weeds were mustard and rabbitsfoot grass (below).

Low-salinity "germination windows" are opportunities for weeds to invade. Native plants could invade, too, but chances are that the seeds that will be floating about will be those of weedy annuals—the plants that invest heavily in seed production so they are available wherever and whenever there is an opening in the salt marsh canopy.

Tidal inundation discourages weeds. Recall from chapter one that salt and inundation are the two stresses that prevent most weedy-type plants from moving from uplands to salt marshes. And because "weeds" are species that follow people around the world, most of the species that co-exist with us and become weeds are upland plants associated with gardens and agriculture.

Are all weeds exotic (from somewhere else)? No.

At some distant time, when salt-tolerant species evolved, their seeds probably floated around the ocean and were swept into salt marshes with the inflowing tide. That's probably why we have a few dominant salt marsh plants that thrive in saline areas—they were widely dispersed, able to establish, prepped to become dominant, and able to crowd out other species. Species of *Spartina* in the grass grass (family Poaceae) and species of *Salicornia, Sarcocornia,* and *Athrocnemum* (members of the goosefoot family, Chenopodiaceae) occur worldwide. All these genera have weedy species. Those that live in a region for centuries (recorded history) are considered natives.

The idea that some native salt marsh plants are "weedy" is suggested by common names like pickleweed, salt wort ("wort" is a general term for an herb), and alkaliweed (*Cressa truxillensis*). Purer (1942) said the first two were among the most widespread plants. And in 1976, perennial pickleweed and salt wort had the greatest biomass in Ted Winfield's study.

In southern California, pickleweeds, both perennial and annual, dominate the intertidal marsh plain. The perennial thrives when tidal flushing is interrupted. It is very salt tolerant and has long-lived stems and branches. In contrast, the annual pickleweed spends most of its short life producing seeds. When the seeds are mature; it dies, leaving behind lots of potential offspring.

Having found that annual pickleweed can produce ~80 seeds per plant, it is easy to imagine how fast it might spread. One plant could produce 80 offspring if all its seeds fell on bare, waterlogged, saline soil. But it wouldn't persist as a monotype (single-species vegetation), because seeds of perennial pickleweed and other native halophytes would also arrive, establish, and thrive in bare, wet, saline soil.

Is pickleweed a weed? No and yes.

• No, because it is a native an essential component of the salt marsh plain, where it provides nesting habitat for the state-endangered Belding's Savannah sparrow. It is the most resilient halophyte of southern CA salt marshes; it dominated Tijuana Estuary in 1983, when the estuary was nontidal and when soils dried and were extremely hypersaline.

• Yes, because it thrives in disturbed saline areas and often forms a monotype (crowding out almost everything else). This can be annoying, but it serves as an indicator of disturbance. At the Tidal Linkage, we learned that perennial pickleweed was the best colonizer of bare plots, and it invaded plots planted with other species. Its seeds need a patch of light, some moisture, and soil that can hold water till the roots can grow deep. During 1984, when the Tijuana Estuary salt marsh was nontidal and drought-stricken, we dug a small pit and found this species' roots extending to soil depths near 1 meter (3 ft.).

Before the pickleweeds were divided into separate genera, all three were called *Salicornia.* All three were happy to occupy the Model Marsh (on the right) after tides adjusted the soil salinities. 1. Perennial pickleweed (formerly *S. virginica)* became dominant within 4 years; 2. Annual pickleweed (*S. bigelovii)* colonized shallow pools, and 3. Glasswort (*S. subterminalis,* now *Arthrocnemum subterminale)* established on the edge after being salvaged and transplanted.

What about alkaliweed? I noticed how weedy it can be after a farmer plowed the high marsh-upland transition at San Dieguito Lagoon. Next to the remnant high marsh, the plowed field had developed a broad band of solid alkaliweed. The seeds must have been dormant in the seed bank, ready to germinate with the first rainfall after plowing. Why did the farmer try to grow tomatoes in saline soil?

Why does California have so many exotic weeds?

California has lots of plant species, period. Why? I can think of at least four reasons:

- It's a large state with large range of latitude (geographic position: 32°32′N to 42°N)
- Its environmental conditions include coasts, grasslands, mountains and deserts.
- It has a Mediterranean-type climate that is not too challenging for many species.

California has ~3400 native species and another 1500 species that are exotic. The number of exotic species is huge, and the number of exotics that are weedy is also great. Why are so many of the exotic species weedy? Well, consider where civilization arose—in the Mediterranean region. So Mediterranean plants that became weedy around people found a comparable climate when their seeds travelled to California.

Many plants from other countries have grown and spread so well that they have become major pests. In many cases, it is because people have disturbed the land in ways that allow weeds to germinate and establish viable populations. Seeds of weeds traveled to new places on people's clothes or the fur and feathers of domestic animals.

The weeds that grew in oat and wheat fields produced seeds that were harvested along with the oat and wheat seeds. From there, they were transported to towns, where they were sold and transported to other new places. Seeds spilled along roadsides are a major path of weed dispersal. Every vehicle can pick up seeds in its tire treads and transport them further down the road. For that reason, ecologists like to limit roads in forests and natural areas—to minimize the transport of weed seeds.

California has over 38 million people and over 15 million acres of grazing land and over 25 million acres of agricultural land. In both pastures and farm fields, the soil is continually disturbed. California also has lots of gardens with plantings of species from somewhere else—and some of them will someday be considered pests.

Can we predict the next invasion?

One way to predict future pest plants is to learn whether they are weedy "at home." Some 774 species were identified in a recent search for potential invaders of California (Brusati et al. 2014).

Another way is to see which of those plants are already being sold in California for gardens and other ornamental use. Oh, oh!.....186 of the 774 species were considered potential invaders in California.

A recent study (Archbald and Boyer 2014) reports that "statice" = sea lavender (*Limonium ramosissimum* subsp. *provinciale*) has expanded to cover 15,144 m^2 of central and south San Francisco Bay (it was first documented in 2007). Its rapid spread is partly explained by its ability to produce as many as 17,400 seeds per plant. And where the invader was most abundant, the native halophytes were decreasing in abundance. So it goes with aggressive invaders!

(photo from Upper Newport Bay by Robert De Ruff >corelectronics.com/DERUFF/Limonium ramosissimum.htm)

• Explore: See how many plant species you can find in a nearby lawn or growing in a crack in the sidewalk or along a fence. See if you can guess how their seeds got there—by wind? Water? Bird droppings? Vehicle tires?¨

• Calculate: Try a simple calculation: If every statice seed produced a new plant in a new place, how many years would it take to cover 15,144 m^2? (You can consult the full article online to find plant densities).

• Look for statice in the high marsh transition to upland at Tijuana Estuary near the Visitor Center and also at other regional wetlands. Where is it most abundant?

Two exotic weeds are problems in the high marsh

Although the lower marsh and marsh plain have few exotic weeds, the upper salt marsh has two very weedy exotic annual grasses. What problems are caused by rabbitsfoot grass (*Polypogon monspeliensis*) and sickle grass (*Parapholis incurva*)? Both tend to outgrow the native plants. The sickle grass was especially abundant among the endangered salt marsh bird's beak (see chapter three).

Rabbitsfoot grass

Pictures by G. Keighery; florabase.dpaw.wa.gov.au/weeds/

Sickle grass

Rabbitsfoot grass first intrigued me in 1980, when I saw it in a pot in a greenhouse in England, being treated with loving care. It is rare in UK. Yet it is overly abundant in salt marshes and riparian wetlands (along rivers) in southern California, where it is unloved by botanists.

Plants can be rare in one country and pests in another. Spike rush (*Juncus acutus*) is rare in southern California but a major weed in Western Australia! Can you guess why? Disturbed soils in Western Australia are often slightly saline. It seems to prefer brackish conditions here, too. When we germinated its seeds, it needed water that had less than 2% salt. Perhaps that's why it established well in the San Diego River Marsh after freshwater flooding.

Why is it called spike rush?

Ouch—I bumped into it again!

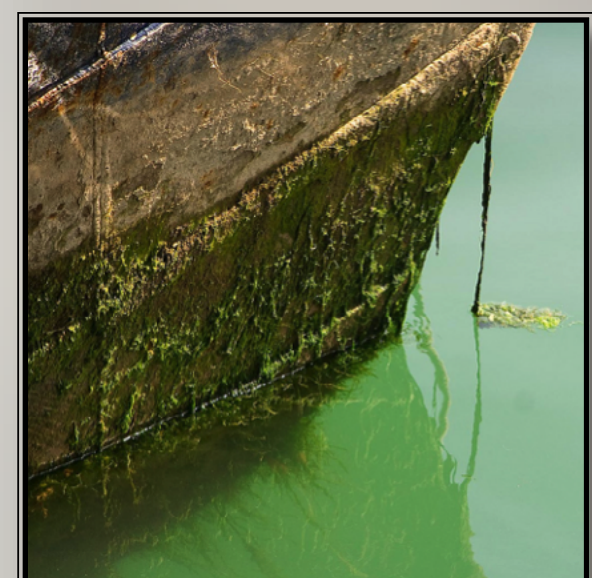
Why are salt marshes so similar in composition across continents, especially salt marshes with Mediterranean-type climates? Here are two reasons: (1) Ships move from port to port around the world. (2) People arrived by ship and settled where there was a freshwater source (at the river mouth). With ocean commerce and a water supply, cities grew around estuaries. What do ships carry with them unintentionally (not planned)? Answer: seeds from previous ports.

• Imagine that you pilot a ship that travels regularly from Santiago, Chile, to Humboldt Bay. Some seeds that are floating around in Chilean waters will get stuck to the hull of your ship and incorporated into the "biofilm" (called fouling organisms where they grown on surfaces like ship hulls that are supposed to remain clean. There, they create friction with the water and slow the ship; what pests!). Of course, seeds on the ship's hull can fall off in the ocean, mid-trip. So that might not be how a Chilean weed was introduced to Humboldt Bay.

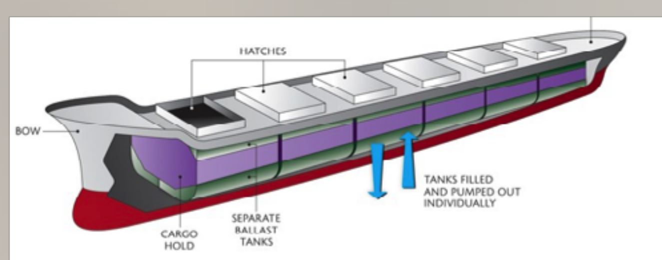
• Another place where seeds get stored is inside the boat in ballast water. After you unload your California redwood lumber in Santiago and you pick up a lighter load of cargo to carry back to Humboldt Bay, you'll need to adjust the boat's weight by loading some ballast water. Once balanced, you're set to travel across the ocean with a bit of cargo and some harbor water from Chile.

• Oh, oh; there are also a lot of hitchhikers--seeds and other tiny organisms from Chile—or from any other country whose ships have docked in Santiago. Yikes! When you reach Humboldt Bay and dump the excess water, some of the seeds will find a place to germinate and establish a new population.

• This is no fantasy. The Chilean cordgrass, *Spartina densiflora,* apparently stowed away in the ballast water of ships travelling from Santiago to in Humboldt Bay, where it became the overwhelming dominant.



Without constant removal, ships accumulate biofouling organisms and debris. Is this boat hull swapping species with the pea-soupy water where it is docked? How many millions or billions of algal cells and seeds might there be in this biofilm? How about in the ballast water of the ship below?



< physicscentral.com (left); 5/shipping-terminology-for-learners-what.html (right)

The essence of weeds

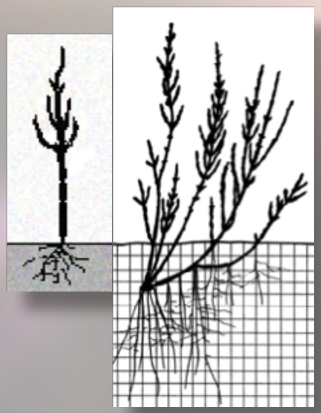
"Weed" is what people call a "plant out of place." That means it's something about us and our values. A weed is a plant that annoys people, usually by being too abundant and growing where something else is supposed to grow. So gardens have weeds, lawns have weeds, corn fields have weeds, the cracks in the sidewalk have weeds, and even our rain gutters have weeds (at least for awhile after rainfall). One early-arriving European plant earned the name white-man's foot, because it followed settlers' every step. To read more, see if you can find it at http://plants.usda.gov (type in the name and choose "common name", not scientific name).

Well-known attributes of weeds are that they are readily spread about (dispersed) and they produce a lot of offspring. So a plant that has seeds that can stick to your shoes or vehicle tires is a good candidate for broad dispersal and a good explanation for why roads and walking paths have lots of weeds alongside. And a plant that germinates readily and produces a lot of offspring in places that are disturbed by people is a good candidate for annoying people. Historically, maybe it was the mastodons that ripped up the earth; today it is people. In both cases, the earth was disturbed. When roots are uprooted, the tight associations between fungi and roots are disrupted. Also, a lot of space and resources become available for something new to establish. Who better than a weed whose seeds are floating with the wind or washing along the soil surface after rainfall?

A weed that has "mastered its profession" does the following: it quickly germinates, sends down roots to soak up water and nutrients, and reproduces. Some of the most aggressive weeds reproduce by flowering and setting seed, as well as sending out stems below- or aboveground to establish new "ramets." (Ramets are small plant units that can live independently.) The latter plants are almost always perennials. Annuals invest more of their energy in seeds and shallow, fine roots-- without rhizomes (underground stems).

Where wouldn't you expect to find weeds? How about where few people travel? Don't count on it! There are even weeds in Antarctica—not high on most tourists "must visit" list. I read that 33,000 tourists and 7,000 scientists visit Antarctica each year, so of course their clothing and gear (especially that wonderful invention "velcro") carry seeds, and some of the seeds grow. Lesson: Clean your shoes and velcro bindings of seeds before entering a nature reserve.

ARE THESE WEEDS "WEEDS"? Annual pickleweed is rare; perennial pickleweed is not. The species differ in root depths, rhizomes, woody tissue, height and ability to dominate.



(Annual drawn by D. McIntire © Zedler; perennial image from Purer (1942; 2-cm grid))

An easy way to characterize a plant as "out of place" is to check its origin. Did it occur naturally in southern California salt marshes, or did it show up as a hitch-hiker when Europeans settled the region around 1820? A few people have excavated deep cores in the soil and looked for seeds or pollen from times past. A small weed called sheep sorrel (*Rumex acetosella,* native to Eurasia*),* is a "marker" for contact with Europeans. Sedimentation occurred more rapidly above soil where such indicators were present, indicating the disruptive activities of logging, cattle ranching, and cultivation of soil between 1820 and 1880 (Duncan 1992).

Fifty years ago, Peta Mudie, a researcher with the Geological Survey of Canada, excavated a deep soil core at Tijuana Estuary. She used the pollen from sheep sorrel to help her conclude that sedimentation rates were around 50 cm per century in southern California, compared to pre-European rates of around 10 cm per century (Mudie and Byrne 1980). Of course, one core is a small sample and is not likely to represent either riverine or marine deposition. The general finding, however, is consistent with the pattern that human settlement and activities increased erosion upstream and, hence, deposition downstream.

Calculate: Convert 50 cm per century to mm per year. Hint: first convert 50 cm to mm (multiply by the number of mm/cm); then convert centuries to years; then divide mm by years. How does the result compare to recent rates of sea level rise? (See chapter on SLR).

Do low-intertidal areas resist invasion?

Mangroves example from Florida
(nps.gov/foma/naturescience/images/red-mangrove).

Not entirely. Mission Bay's remnant cordgrass marsh was invaded by the white mangrove (*Avicennia marina,* a.k.a. gray mangrove). Unlike many weed invasions, this one resulted from a deliberate planting in 1964 by a physiologist from nearby Scripps Institution of Oceanography. Apparently the scientist thought it would be handy to have his own population of this Australasian mangrove to study its salt tolerance.

What followed was a mangrove infestation that kept expanding until the US Fish and Wildlife Service became alarmed. Agency biologists predicted that the tall canopy would attract raptors to perch and prey on clapper rail chicks. In the 1980s, this weedy tree grew taller than cordgrass, giving avian predators a perch and vantage point for finding nests and chicks of the endangered clapper rail.

Volunteers began pulling up the white mangroves in the 1980s. Several years of pulling seedlings seemed to accomplish the goal, but then it re-appeared in 2006. Where did the second infestation come from? Either seeds were still present and dormant, or seedlings were present but too short to see until 2006. Important lesson: Once "controlled," a weed still might not be eradicated (fully removed).

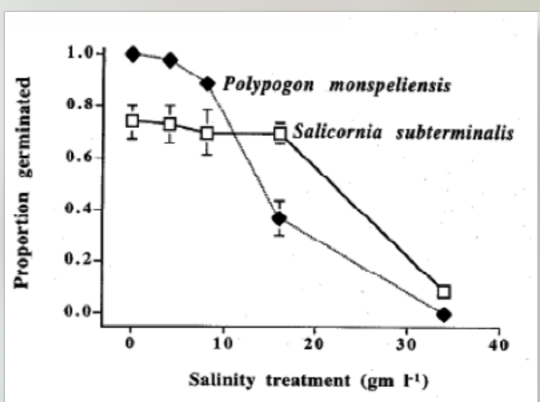
Are salt marsh canopies easily invaded?

Most weeds that invade southern California salt marshes find a weak link in the defense system of native vegetation in locations where saline tidewater inundates the soil only briefly (upper salt marsh and transition to upland), and only after enough rain falls to saturate the soil and leach out much of the salt. Then, weeds that can stand a little salt have a chance to establish, spread, and "annoy people."

As discussed in chapter one, sea salt (rich in sodium chloride, NaCl) is a problem for all plants that live next to the sea. The salt draws water out of cells, and the sodium is toxic to enzyme systems. It takes specialized adaptations for a plant to tolerate salt, as described earlier. Also there aren't many species that can tolerate both the stress of salt and the stress of waterlogging (smothering from lack of oxygen).

Several invasion patterns were revealed by Nathan Kuhn's study. He explained how southern California's native, perennial, high marsh dominant, glasswort (*Salicornia subterminalis*, now *Arthrocnemum subterminale*) could be invaded by the invasive, exotic annual rabbitsfoot grass (*Polypogon monspeliensis*). Usually perennial plants have a competitive advantage over annuals, and especially when the perennial is evergreen, as is glasswort.

So how does an impertinent (bold) annual gain a toe- (or root-) hold under a permanent canopy of glasswort?



From Nathan's results, it is clear that rabbitsfoot grass seeds germinate better at low than high salinities. How could you, as a researcher, learn more about salt tolerance ≥ 20 $g\ L^{-1}$?

Hint: Would you spend time repeating low-salinity treatments or would you add treatments above 10 $g\ L^{-1}$?

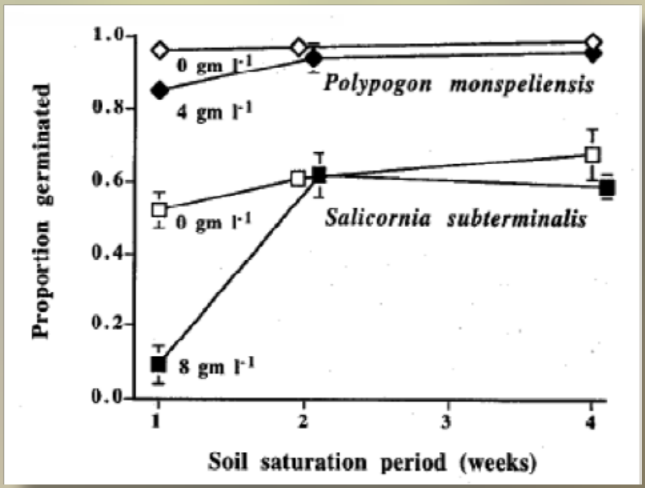
Would you also want to repeat at least one of the low-salinity treatments to see if your experiment could duplicate the earlier results? What might cause different outcomes?

Hint: Which factors besides salinity affect germination?

Because John Callaway also germinated *Polypogon* seeds, compare Nathan's results with John's (below).

Note: $g\ L^{-1}$ means grams/Liter or "grams per liter." Seawater = 34 $g\ L^{-1}$ = 3.4%

First Nathan needed to know how soil salinity and saturation with water would affect the two species. Indeed, glasswort seeds and young plants were more salt tolerant than those of the invader, and the native was better adapted to saline conditions. That is, glasswort grew best at salinities near seawater (23 g L^{-1} and 34 g L^{-1}) in the greenhouse, while germination and growth of the invader were reduced by high salinities. Furthermore, the invader germinated and grew well at all soil moisture conditions tested, while the native glasswort did not fare well with prolonged soil saturation.



Here are Nathan's results for 1, 2 and 4 weeks of saturated soil, with salinities of 0 and 4 g L^{-1} salt (0.4%) for the invasive grass and 0 and 8 g L^{-1} salt (0.8%) for the native glasswort. Both species germinated better with at least 2 weeks of saturated soil and with no salt.

Lesson: Some wetland plants need wetter conditions for part of their life cycle but not necessarily during their entire lifetime. Glasswort seedlings need wetter soil to establish than later, when their roots are deep.

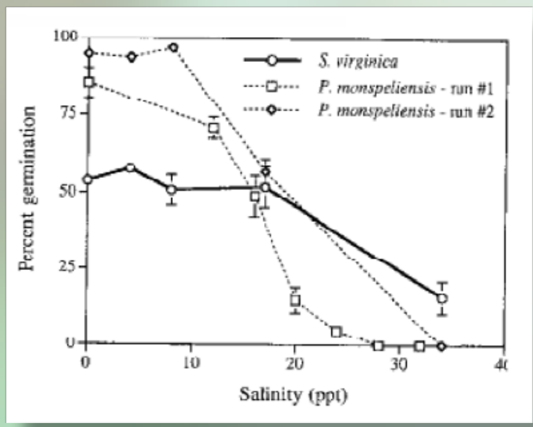
Some plants that depend on plentiful water (a.k.a. hydrophytes) actually have limited tolerance to prolonged hydroperiods (flood duration or period of inundation) or deep water or both. Water tolerance is not an all-or-nothing phenomenon (pattern). This fact helps explain why some hydrophytes can live in deep-water marshes, while others are restricted to the edges of wetlands or, in the case of annuals, to the moist times of the year. The hydrophytes that are not so tolerant of flooding can avoid deep water by growing where the water is shallower or by growing when the water is shallower.

Secret revealed: Weed-seed germination can be prevented by just adding a little salt. Nathan decided to test whether the addition of salt would favor the native over the invader, and his field experiment showed that applying 850 g per square meter per month for 3 months could control the exotic without noticeably harming the native glasswort. That's the kind of research result than can help managers control a weed. Nathan's approach was natural, non-toxic, fairly easy and safe to apply, and relatively cheap. All are better for controlling an invader and than using toxic chemicals (if they can be avoided).

John Callaway's study of rabbitsfoot grass is notable in two ways—he tested multiple hypotheses and he used a variety of experimental approaches to answer what seemed to be a simple question at the time: Why does rabbitsfoot grass invade salt marshes in wet years? As in many ecological studies, more can be learned from a comparison than a single species or situation; hence, he compared rabbitsfoot grass to perennial pickleweed, the native salt marsh dominant.

John's five hypotheses were:

- Perennial pickleweed seeds will germinate at higher salinities than those of rabbitsfoot grass (because the pickleweed is native to more saline habitats).
- Adding freshwater will increase rabbitsfoot grass abundance, especially without tidal influence (because we had observed this during wet years).
- Rabbitsfoot grass will produce more biomass under brackish conditions (4-8 g per liter salt) and perennial pickleweed will produce more under saline conditions (34 g per liter salt = sea water).
- Perennial pickleweed will outproduce rabbitsfoot grass under wetter conditions (because perennial pickleweed is often inundated by tidal water, while rabbitsfoot grass tends to grow at the edges of wetlands).
- Perennial pickleweed will produce more belowground biomass than rabbitsfoot grass (as is usual for perennials vs. annuals).



John carried out the experimental tests in a growth chamber (for H 1), in a greenhouse (for H 3,4&5), and in outdoor tidal mesocosms (for H 2)!

In the growth chamber, high salinities reduced germination of rabbitsfoot grass more than perennial pickleweed (graph on right).

In the greenhouse, rabbitsfoot grass outproduced perennial pickleweed at all salinity and water levels tested.

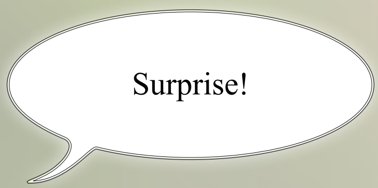
In the outdoor mesocosms, adding freshwater increased rabbitsfoot grass cover and perennial pickleweed cover was reduced.

After dozens of comparisons and statistical analysis, John found support for hypotheses 1, 2, 3, and 5, but not 4. All the patterns were attributable to salinity, not tidal hydrology. The effect of seawater was more about salt than inundation. However, we learned an important lesson in the outdoor mesocosms, namely that the result, which seemed counterintuitive, was probably an effect of the nature of the tidal mescosms. They were at a relatively high intertidal elevation, so the vegetation was not often inundated. Had they been excavated deeper, more high tides would have covered the soil, and perennial pickleweed might have had an advantage.

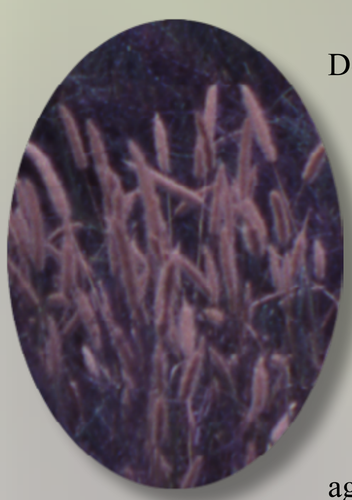
Lesson: Experiments can only reveal what our specific treatments tell us. We can speculate about the effect of other tidal effects, but other tidal conditions would need to be tested in further research. And because it takes a full growing season to accomplish most field experiments, we are usually out of money before every promising lead can be followed.

Lesson: Put lots of thought and effort into selecting experimental conditions to test hypotheses. The work of collecting data will then be more likely to improve understanding and be publishable.

The high productivity of rabbitsfoot grass was a bit of a surprise. Even when grown with seawater, rabbitsfoot grass outproduced perennial pickleweed. When grown in the same pot, rabbitsfoot grass produced 4x as much biomass as perennial pickleweed. No wonder rabbitsfoot grass invades such a variety of habitats; all it needs is a short-term wet period with reduced salinity.



This research project was a lot of work, and I think John enjoyed every minute of it. Some of his findings inspired Greg Noe to take on further studies of salt marsh annuals (see previous chapter).



Do you think the fruiting head of rabbitsfoot grass looks like a rabbit foot? Does it make a memorable common name? Why do you suppose it is called “annual beard grass” in Australia? Did this grass invade Australia before rabbits did?

Besides using salt to reduce invasive upland grasses at the high marsh-upland edge, what tools does a manager have to control weeds?

Gardeners and farmers often turn to herbicides—chemicals that kill plants. Most herbicides are general – they kill all plants. At best, they might kill just forbs (broad leaved flowering plants). Chemists have produced many herbicides to kill forbs and not grasses, because so many of our key agricultural crops are grasses.

Is herbiciding a panacea?

Panacea means a "cure-all" or something that makes everything ok. An herbicide that could eradicate invasive annual grasses with no unintended negative impacts (things we don't want to happen) would be a panacea—especially if the herbicide were cheap and easy to apply! Unfortunately, it's not quite like that. Here are some likely unintended negative impacts

- Non-specific targets, meaning that all plants are harmed. Glyphosate is a broad spectrum herbicide.
- Herbicide label says it has a specific target, but it turns out to be ineffective against the one you wish to kill. In Wisconsin, Mike Healy tested sethoxydim, which was labeled as grass-specific. However, it only stunted our target, and only briefly. The next year, the grass was back to its usual tricks (Healy & Zedler 2010).
- Serious harm to animals. Glyphosate harms amphibians (frogs and salamanders, which live in water as eggs and larvae and on land as adults). Amphibians are very sensitive to harmful chemicals because they have permeable (porous) skin. When they are young and living in water, the harmful chemicals easily move into the skin, then to the blood and internal organs where they interfere with development, growth and survival. Herbicides cause lesions (skin sores), abnormal feet and limbs, and death. Even minor injuries make a frog more vulnerable to disease and predation.

Be very careful using herbicides. Read labels carefully and apply minimally, when and where advised. Some chemicals are not supposed to be used over water. Some are denatured by full sunlight and shouldn't be used mid-day.

Are all grasses bad?

The exotic grasses that invade native vegetation are bad for native plants. But many other grasses are good. Human civilization arose with edible grass seeds! Which ones do you eat? If you eat sugar from sugar cane, then you are eating grass! I confess that I eat cane sugar; I also eat wheat, rice, rye, corn, oatmeal, barley and wild rice; also some millet, teff and triticale (a wheat x rye hybrid). Of these, teff (*Eragrostis tef)* is the most difficult to find at the grocery store. Teff is a very tiny grass seed, native to Africa, that is ground to make injera, the marvelous Ethiopian "pancakes." Injera dough is fermented, baked, and devoured. Yum! Grass seeds make up most of the breakfast cereal and breads that are on the grocery shelves, and grass seeds make up a lot of most people's diets. Some say, "you are what you eat." If that's so, then we are grass!

The same traits that make grasses invasive also make them excellent crops: They are capable of very high productivity, especially high seed productivity. And, given that crop geneticists have been able to breed better crops, grasses have considerable genetic diversity and plasticity.

Catastrophic invasions are not secrets!

(en.wikipedia.org/wiki/Caulerpa_taxifolia)

A few years ago, biologists sampling Batiquitos Lagoon noticed an unusual alga that was later identified as *Caulerpa taxifolia.* This macroscopic "seaweed" was known to be widespread and productive in the Mediterranean Sea. It threatened to form an algal "bloom", which is a population "explosion" that produces floating biomass, shades the water column, and allows lagoon waters to become anaerobic (no oxygen), thus killing fish and invertebrates.

Fortunately, that species was noticed and recognized as a major threat so that it was eradicated (wiped out) just in time, i.e., before it spread "out of control."

Another exotic invader in San Francisco Bay has resisted control. The tall, aggressive, clonal cordgrass from the Atlantic Coast (*Spartina alterniflora)* spread over ~800 acres of tidal marshes, displacing large areas of native cordgrass. It also hybridized with the native, making it difficult to know which remaining plants are hybrids and which are pure natives.

Millions of dollars have been spent trying to eradicate it, but the outcome is uncertain.

(en.wikipedia.org/wiki/Spartina_alterniflora

Alien animals can alter estuarine food webs

Floating and swimming aquatic animals are often harder to see than salt marsh plants, so we don't notice them unless we sample the water with seines and plankton nets--and the sediments with sieves. Snails and mussels and clams tend to move less than planktonic animals, so they are easier to study. Jeff Crooks studied an invasive Asian mussel (*Musculista senhausia*) in Mission Bay and San Diego Bay. Sometimes, we found it in our benthic (channel bottom) monitoring samples from time to time. This small (up to 3.2 cm) animal lives up to 2 yrs.

Photo: Istrice; www.naturamediter-raneo.com

Jeff's research indicated that most animals only live a year, like the "annual plants" discussed earlier. With a short life span, an animal or plant can experience wide variations in abundance, growing very rapidly in good times and experiencing population crashes during bad times.

Photo by Peter J. Bryant

Invasive carnivores are particularly threatening to salt marsh food webs. The yellowfin goby (*Acanthogobius flavimanus*) is a good example. It came to southern California from Japan, probably as a stow-away in the ballast water of a ship. While feeding on native fish, it depletes the populations of both its prey and other predators, such as tidewater goby, which has less food when a voracious competitor is sharing its waters.

A really important lesson

If we want to sustain native species, we need to keep the habitat in its natural condition (not with added freshwater) so we can keep the weedy plants and animals under control. And since that still might not keep invaders in check, we need to keep watch and track the advance of weeds near coastal salt marshes. If your local estuary visitor center has "clean-up" days, you can volunteer to join a weed-pulling crew!

Help clean up Zedler Marsh at Los Cerritos Wetlands!

(www.tidalinfluence.com, Long Beach)