Cattail tales

From California, Mexico, Australia, and Wisconsin

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from California, Mexico, Australia, and Wisconsin, based on studies by students who advanced knowledge and published their findings

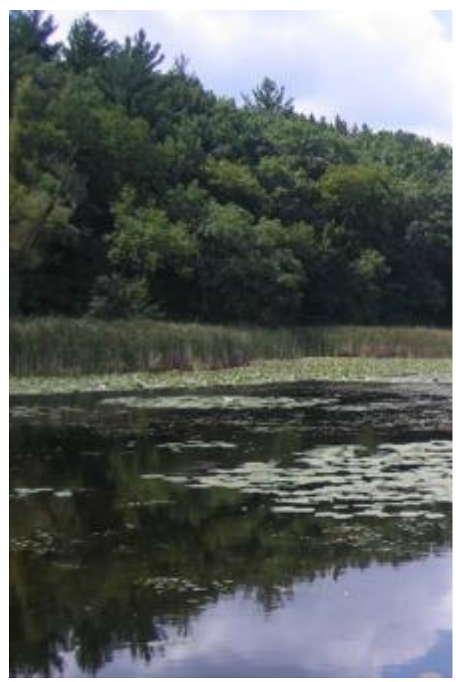
Cattails are common wetland plants that get their name from their brown, cylindrical fruiting stalk (female inflorescence), which reminds some of the tail of a cat.

Left: Mature cattails with seeds

Right: Seeds with fluff, ready for wind

When fruits are young, however, the male inflorescence is still attached to the stalk (above the female flowers), at which time the “tail” looks more like a sausage on a skewer. Fruits are edible when newly formed, but I haven’t tasted them (yet), despite a career-long pursuit of ways to combat this widespread plant where it outgrows diverse, native vegetation.

Cattails are members of the plant family Typhaceae, which has one genus, *Typha*, which has about 40 taxa (species + hybrids) around the globe. They’re all tall, clone-forming plants that tend to invade mudflats and to outgrow alternative wetland species.



Where cattails thrive

Cattails are so common that they often serve as icons or logos for freshwater wetlands. However, cattails don’t represent all wetlands, only those that are very wet--the ones we call **marshes**. The preferred cattail habitat is standing water throughout the growing season, as in this Wisconsin lakeshore marsh. Where the water table drops during summer and where the water is usually flowing, other native plants tend to have an advantage or at least the ability to co-exist with cattails.

Cattails are restricted to shallow water. Deeper water supports submersed and floating aquatics, like water lilies. When you're in a boat on a lake, you can look toward a lakeshore marsh and note where cattails encounter deeper water. Usually it's an abrupt boundary, because the lower edge of the cattail clone is the result of vegetative reproduction, not individual seedlings.

Cattails establish quickly on mudflats and in disturbed areas, after which they spread vegetatively and outgrow potential "rivals". Along lakeshores (as in this photo), they might continue to expand vegetatively as a mat that floats over quiet water on the edge of a shallow lake. Flotation is possible because cattail rhizomes and roots have abundant **aerenchyma*** (air tissue, which I call **Nature's Styrofoam,** because it is both light weight and sturdy). Later, waves might break up the edge of a clone that overhangs lake water and disperses as a "floating island". If the cattails float onto in a suitable shallow-water area with soft mud, or a rocky area where flotsam can accumulate sediment and form soil, a new marsh might establish. That's one way that cattails disperse.

Cattails spread much more widely as light-weight seeds attached to fluff that floats with the wind after the dry tail "explodes". On the right, you can see seedlings that established from seed on a bare mudflat that was excavated and planted with seeds of diverse natives. Cattails were not planted, but wild fluff blew in from marshes (nearby or miles away), and cattails took over via seedling establishment. That's the most common way that cattails disperse and the best prospect for establishing genetically diverse stands that can then fill in vegetatively.

How cattails dominate freshwater marshes

Cattails are able to dominate marshes by growing tall fast and producing abundant biomass. Long, straight cattail leaves are held upright by being stiff yet light weight (aerenchyma. Slice a leaf with a sharp blade and lock at the cross-section with a magnifying glass. You'll be impressed with the internal architecture. Cell walls are surrounded by air inside a thin, flattened leaf. If you slice the leaf lengthwise, you can see the large amount of air inside the thin leaf. In contrast, notice that the stem that holds the "tail" is--and has to be--much sturdier. Hold a cattail leaf horizontally and see if it can support a tail or anything weighty; no, it can't; it's too flimsy. So how do light-weight leaves remain upright? By growing in dense clones, where the dense vertical canopy can resist the wind and pelting rain.

Aboveground biomass dies at the end of the growing season and persists as a thatch for a year or more, as it slowly decays. Last year's litter adds structure to the marsh as well. Notice how the vertical leaves that emerged this year are "woven" through the thatch, propped up at the base to grow and remain tall from spring to fall. A leaf all by itself would bend and break and add to the thatch. For a personal experience, try walking through a cattail marsh. The rhizome network might keep you from sinking into the mud, but the dead-leaf thatch will trip your feet!

***Aerenchyma** is air-filled tissue. Unlike styrofoam (aka polystyrene), it's non-polluting. Flood-tolerant plants build roots, rhizomes, stems and leaves with aerenchyma, like people use styrofoam in foundations, walls and roofs. Light weight construction materials minimize raw materials and can be very strong. Especially important for wetland plants, aerenchyma **allows air to flow** from leaves to stems to roots, where live cells can absorb oxygen and metabolize (i.e., burn carbon-containing molecules to respire and release energy. The more oxygen that gets to its roots, the more flooding a plant can tolerate.

Cattails would not be very competitive without vertical leaves (shoots) that rapidly grow from deep shade at the soil surface to full sun at the top of a multi-meter canopy. How do they absorb enough light? Check the position of their flexible leaves as they move with the wind. Vertical leaves can absorb a lot of light when the sun is overhead and the leaves minimize shading one another. Note how vertical light penetrates to the stem bases. Even new shoots at the base of the leaves receive some light. Does a leaf that moves with a gentle wind receive more light than one that is perfectly still? Research shows that photosynthesis continues with both constant and flickering light. However, constant light might heat the leaves more and increase transpiration (moisture loss), and the surface of a still leaf might overheat and damage the chloroplasts. There is likely an optimal degree of leaf flexibility—stiff enough to remain upright while still allowing a leaf to sway with the wind. We need more research to reveal more details of cattail adaptability to changing climate—both gradual warming and extreme heat events.

Cattail **roots** take up ample nutrients and use inorganic nitrogen as both ammonium and nitrate (so there's little "down time"). Ammonium is abundant when the marsh mud is anoxic, and nitrate forms where **ventilation** occurs—oxygen to moves down stiff air-filled leaves. Comparisons of cattails with other wetland plants indicate **high amounts of aerenchyma** in roots*

Aerenchyma makes up most of the leaf volume, and the porous walls between cells allow oxygen to flow or diffuse, from high concentrations down the leaf to low concentrations in the roots. Oxygen is released by chloroplasts that trap light and convert carbon dioxide to organic carbon, and release oxygen (photosynthesis). So oxygen diffuses from leaves toward rhizomes and roots, which also have ample air tissue. Once in the roots, oxygen can leak into the soil and affect busy microbes. For example, methanogens are anaerobic microbes that release **methane** (a powerful greenhouse gas); however, methanogens can give way to aerobic methanotrophs that consume methane and release carbon dioxide. The balance between emitting and denaturing methane needs more study.

Now look to see how the leaves emerge and grow. They are packed tightly, making a very sturdy base, despite being composed of flimsy individuals. This is smart construction! It is also efficient, from the perspective of minimal energy needed to grow a leaf. Most of the weight of a leaf forms an outer tube, like a "straw," and most of the leaf is just air. The tubular growth form, and dense clones allow a cattail to grow several meters tall, and they can do so in short order. This is smart growth.

As you can tell, cattails are well adapted to their marshy habitats. While their air-filled leaves, stem bases, rhizomes and roots might seem insubstantial when taken apart, they are strong when grown as dense vertical canopies and rhizome mats. The aerenchyma allows cattails to perform important ecosystem functions efficiently, like converting carbon dioxide to biomass, storing carbon in organic soil, providing habitat for marsh birds, trapping sediment, stabilizing soil, and converting methane to carbon dioxide.

*__Measuring aerenchyma__. Doctoral student Suzanne Kercher grew seedlings of *Typha* and 16 other taxa) in summer 2000. She placed each seedling in a pot in its own bucket in a greenhouse and watered buckets, to create 4 hydroperiods, then compared each species belowground aerenchyma, using vacuum extraction. She carefully weighed roots (to get initial wt.), then immersed them in a vacuum flask filled with 250 ml of water. She stoppered the flask and applied an electric vacuum pump for 2 minutes. That drew water into the plant's aerenchyma, and root weight increased. She removed the water-filled roots and measured the increased weight as aerenchyma volume. **Result**: *Typha latifolia* roots averaged 62% airspace when grown at low water levels and 53% when flooded. That's a lot of air space—more volume of air than live-tissue! In contrast, graminoids averaged 50% aerenchyma and 10 forbs averaged 30%. See details in her published paper (Kercher and Zedler 2004).

The problem with cattails: They take over and displace other species

Cattails are found on all continents except Antarctica (Bansal et al. 2019, maps of several species). In North America, the most widespread is *T. latifolia,* the broadleaf cattail. It grows in temperate and warmer climates throughout the continent. An additional taxon is the hybrid *Typha* x *glauca,* which formed when a European species, *T. angustifolia,* invaded stands of *T. latifolia* and then spread from New England west to the Dakotas. Across the southern states, *T. domingensis* prefers warm climates, from Florida to California. It is not (yet) widespread in temperate regions. In the southern hemisphere, *T. orientalis* is native in eastern Australia. Malaysia, China, and beyond.

Several of my graduate students studied cattails of the above taxa, and they did so in **four locations**: *T. domingensis* in southern California and in central Mexico, *T. orientalis* in western Australia, and *T.* x *glauca* in Wisconsin, where the hybrid and its parents are often indistinguishable in the field. The following **four tales** demonstrate that cattails have strong tendencies to take over (over-dominate, displace) other wetland vegetation, but they do so under **different circumstances**:

- In southern California, ***Typha domingensis*** (native cattail) grew up to 9 feet (3+ m) tall in the San Diego River channel (32.7° North Lat.) where the upstream freshwater marsh extended downstream toward the intertidal salt marsh, which was dominated by native pickleweed (*Salicornia virginica,* now *Sarcornia pacifica)*. After years without river flooding, there were extreme rainfall events in January and February 1980. The freshwater flows led this native cattail to expand downstream. The increased flows from extreme rainfall were extended through April 1980 by the deliberate release of excess water from an upstream reservoir. The cattail invaded the dying salt marsh, which could not tolerate prolonged inundation, and a native cattail replaced the native pickleweed.

It's important to know that the continuously flowing river was not natural this region's Mediterranean-type climate. For decades, flows were augmented by water that was imported from outside the region (e.g., California's Central Valley). Also flows were constrained at the ocean mouth, where both salty tide water and freshwater inflows were confined to a flood control channel. In 1980, extreme winter flooding was followed by the release of excess water from a reservoir (to protect the dam). Thus, flooding continued downstream for months. This excess fresh water drowned the formerly-intertidal salt marsh (Zedler 1981). No wonder cattails took up residency--and persisted well after flooding ceased and tidal regimes once again supported salt marsh plants. Research was needed to identify causes of the cattail invasion. Normally, southern California coastal saltmarshes have hypersaline soil (40-45 parts per thousand, compared to sea water at 34 ppt). A substantial reduction in soil salinity seemed like it had been the main culprit.

Graduate student Pam Beare took up the challenge of explaining why cattails invaded and persisted where pickleweed had dominated. To do so, she tested the full range of salt tolerance of seeds, seedlings, and mature rhizomes. First, she showed that cattail seeds would not germinate in salinities above 20 ppt, although pickleweed seeds could. She also showed that cattail seedlings were sensitive to salt over a period of several weeks. However, adult-rhizome sprouts of cattails were more tolerant of hypersaline conditions, but they did not thrive or flower.

We concluded that *T. domingensis* could invade a salt marsh given 2-3 months of lowered soil salinity. The hypothesis that the flooding of 1980 allowed expansion into the salt marsh was supported (Beare and Zedler 1987). Furthermore, the population was able to persist for two more years despite low river inflows (1981-82), because another bout of heavy flooding caused it to rebound during a prolonged winter rainfall season through April 1983. Lowered salinity played an important role in catalyzing rapid and persistent growth of *T. domingensis.* Many years later, without major floods, the cattails persisted further upstream, but only in small patches that did not extend into the intertidal zone. Tidal action resupplied salty water to the former salt marsh, and the pickleweed reestablished and flourished in hypersaline soil.

The **unique circumstances** that catalyzed cattail over-dominance in this Mediterranean-type climate were: (a) imported water that created marshy habitat and allowed cattails to occupy the lower San Diego River, (b) confinement of the lower river to a leveed channel (lower intertidal zone below), (c) extreme rainfall events that added above-normal freshwater flows (both depth and duration), and (d) the release of water from an upstream dam that extended flows well into the normal dry season, which lowered marsh soil salinities, despite the site's 3-m tidal range. No other stream/river mouth in southern California experienced a total loss of salt marsh with cattail over-dominance (Zedler 1981).

• In Central Mexico (Morelia, Michoacán, 19.7060° N), ***Typha domingensis*** is productive and tall (well over the head of local scientist Esteban Aureoles-Celso (photo by S, Hall) in freshwater wetlands. Local farmers harvest the leaves to use for their livestock's fodder and bedding, for fertilizing crops, and for crafts (Hall, Lindig and Zedler 2008). Farmers cut the leaves by hand (e.g., using machetes), and the leaves regrow so quickly that they can harvest 3-4 times per year at ~20º N. latitude. In a 10-ha site within Morelia's Mintzita spring-fed wetlands.

Steven Hall interviewed farmers and received permission to set up controlled-harvest plots to compare the effects of

1) harvesting all vegetation once at 20 cm above the soil;

2) two harvests: as in #1 plus one more harvest after *Typha* shoots regrew to 1.6 m;

3) four harvests: as in #1 plus 3 harvests after *Typha* shoots regrew to 1.6 m;

4) control (no harvest).

Now for the **exciting results**: All harvesting treatments (up to 4 per year) reduced *Typha* height, density, and rhizome starch reserves after five months, yet all harvested plots recovered within the year. Steven Hall had expected *T. domingensis* rhizome starch to be depleted with harvesting, because *Typha latifolia* was known to transport rhizome starch belowground when producing new above-ground biomass. He was correct, but the rapid recovery was surprising.

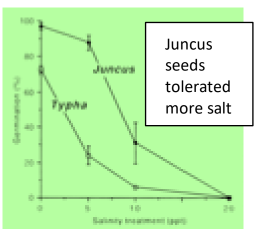
Our main question was whether harvesting would facilitate native plants by reducing the "overcompetitive" cattail. Indeed, uncommon species and new arrivals tended to recruit into harvested plots. Native vegetation was **more diverse** where harvested than where cattails were not harvested. Grasses and forbs, mostly perennials, recruited under a thinner canopy. In fact, a single harvest was enough to increase diversity. The initial harvest seemed to cross a threshold for vegetation change (both for species presence and abundance). On harvest had a strong effect; neither the plant community nor *Typha* responded strongly to later harvests (Hall et al. 2008).

An additional factor that affected species composition and richness was water depth (or some unknown factor correlated with depth). For long-term management to retain native plant diversity, it will be important to sustain both water supply (to allow more species to thrive) and harvesting (to limit cattail over-dominance! Given that our treatments mimicked a subset of actual harvesting practices, we conclude that harvesting cattails is a win-win strategy that provides the harvester with useful biomass while helping to conserve biodiversity. There is no reason to attempt to eradicate a native cattail where residents profit from sustainable harvesting, developed through Traditional Ecological Knowledge. The current management regime is supported by "western science."

The **unique circumstances** that explain cattail abundance in this warm climate were: (a) a year-round growing season that favored native cattail dominance, (b) a large, natural groundwater-fed spring with constant shallow-water, and (b) cultural practices (grazing, harvesting up to 4 times per year) that reduced but did not eradicate cattails, and (c) a diversity of other native wetland plants that filled in where cattails were kept in check.

• In Western Australia, ***Typha orientalis*** was introduced from eastern Australia, where it is considered native.

In the Canning River Estuary (32.0° South Lat., within south Perth; see aerial photo), it invaded the native *Juncus kraussii* salt marshes--especially along small drainage ditches that conveyed freshwater surface water from adjacent urban areas through stands of native salt marsh. Extrapolating from findings from Beare's study of *T. domingensis,* it seemed likely that soil salinity reduction could explain the *T. orientalis* invasion hotspots. Some research was needed. In 1986, I decided to undertake a research project to test the link between *Typha* invasion and artificially lowered soil salinity during a sabbatical at the University of Western Australia in Perth. Dr. Arthur McComb and his doctoral student, Eric Paling, facilitated my experiments with *Typha* seeds, seedlings, and rhizome-bearing adult plants. Tests were conducted for both the invader *T. orientalis* and the native *Juncus kraussii*, which we grew alone and in combination. Both the native and the invader were least salt-tolerant at seed and seedling stages. *Typha* seeds were half as salt tolerant as those of *Juncus* when germinated at 10-ppt salt, but neither species germinated at 20 ppt salt (Zedler, Paling and McComb 1990; see our seed germination data, graph on the left).



Species that are salt-tolerant as adults often establish when freshwater lowers salinity. Doctoral student Gregory Noe tested germination and salinity in several California salt marsh plants and found that many native species respond to seasonal rain events (e.g., 3-cm rainfall in spring) by germinating at the beginning of the growing season (Noe and Zedler 2000, 2001). This does not mean that invaders like cattails could persist after a rain event lowers soil salinity, because tidal inundation and evaporation soon restore saline soil. But salt marsh plants can be triggered to germinate in spring after heavy rains have wetted the upper marsh soil and lowered salinity enough for seeds to germinate. It is the prolonged periods of low soil salinity that promote upland/inland plants to move into salt marshes (Parsons and Zedler 1997, Kuhn and Zedler 1997, Callaway and Zedler 1998).

In our Perth experiment, young seedlings of *Typha* grew tall fast but were killed when soil salinity was elevated by adding 10-20 ppt salt. In contrast, *Juncus* seedlings were still healthy at 4 months. Adult *Typha* rhizomes were more salt tolerant but did not survive in soil with 40 ppt salt in this 39-week experiment, but comparisons of 0, 10, and 20-ppt treatments for the invader and native showed that both species and salinity mattered, with *Typha* less productive than *Juncus* as salt treatment increased. When grown together, *Typha* outgrew *Juncus* at 0- and 10-ppt salt, but not at 20 or 40 ppt. Research in Western Australia supported the hypothesis that cattails can invade salt marshes where persistent freshwater dilutes salty soil in saline and estuarine marshes.

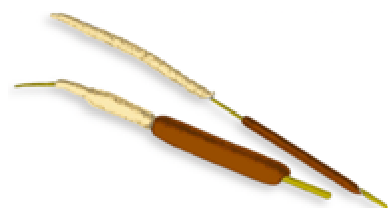
The **circumstances** that catalyzed cattail over-dominance in Perth's Mediterranean-type climate were: (a) moderate tidal flows, i.e., 0.5-m range, (b) urbanization without management of stormwater runoff, (c) ditching through native salt marsh vegetation to convey street and lawn runoff, and (d) arrival of an alien cattail species that took advantage of the lowered soil salinity and replaced the native salt marsh dominant.

Summary. In both San Diego and Perth, two *Typha* species (native *T. domingensis,* alien *T. orientalis)* were tall, productive plants that could outgrow the salt marsh vegetation that they invaded. Lowered salinity removed the chief limiting factor (saline soil) In both locations, although other factors likely contributed. Nutrients were brought in with freshwater flows, and subsequent research showed that California salt marshes were limited by nitrogen (Boyer and Zedler 1998). Other belowground conditions and insects and other grazers might well have influenced the speed and persistence of cattail invasions. While latitude was similar (~32º), hemispheres differed, but with no obvious pattern.

Salinity was the primary factor holding back cattail invasion of tidal marshes in San Diego and Perth. However, it was not an issue in the freshwater-spring in Morelia, where the same *Typha* as in San Diego yielded to human harvesting, which reduced cattail dominance. But since there was no need to eradicate *Typha*, the cattails continually recovered without excluding native vegetation.

Now we shift to the Upper Midwest, where salinity is not a factor and different species of *Typha* are at play. What explains an overwhelming shift from the natural dominance of broadleaf cattail (*Typha latifolia*) to invasion by introduced *Typha* and subsequent hybrids? Where did they come from and how did they outgrow the native?

- In Wisconsin and the Upper Midwest. M**any circumstances** favor cattails besides the native ***Typha latifolia*.** The southern cattail (***Typha domingensis***) was **introduced** from warmer latitudes. While it is known to be invasive in Madison, WI (43.1° North Lat.), it is rare (Alice Thompson, personal communication). Ms. Thompson, a skilled botanist and restoration practitioner, personally eradicated a small population once she identified it in a stormwater retention pond. The greater height of *T. domingensis* was the first clue that it was not a familiar cattail. But few others would have noticed it. Not all marshes are visited by experts, and not all managers would notice a somewhat different patch or two of a somewhat taller cattail. This suggests the need for more well-trained botanists and more vegetation monitoring programs, if invasions are to be curtailed "in time." Experience around the globe tells us that eradication of invaders is most effective and most efficient if done early in the invasion process. The **circumstance** that allowed an alien to invade are stabilized water levels in urban stormwater ponds and a source of alien propagules, probably seeds—source unknown.



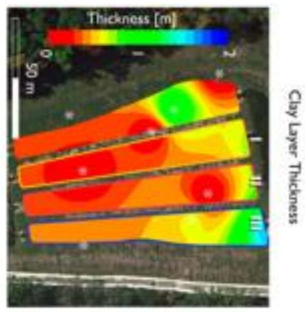
In Wisconsin and much of the eastern US, narrowleaf cattail, ***Typha angustifolia***, is widely invasive and considered **alien** (introduced from Europe). It differs from the native cattail in having narrow leaves, growing taller, and tolerating deeper water. In most places, it readily **hybridizes** with the native to form ***Typha* x *glauca*** (offspring of *T. latifolia* and *T. angustifolia* plus various back-crosses with either parent*).* The critical **circumstance** is hybridization. The hybrids are aggressive, widely invasive and have long narrow inflorescences with a gap on the flowering stalk between the male and female "tails." They have invaded native sedge meadows and altered wetlands, as well as newly created wetlands. What makes this cattail so amazingly invasive in the Upper Midwest? Considerable research was needed on various site-scale causes, such as eutrophication (nutrient increases) and the need for cures (hoped for cures, that is). Most of the remaining text discusses cattails as a group (*T.* x *glauca)* in part because the genetic make-up of field populations is difficult to trace or separate.

Environmental circumstances that facilitate cattail establishment and dominance in Wisconsin and the Upper Midwest include stormwater ponds, urban-runoff swales, dams that cause "internal' eutrophication, and wetlands that experience external eutrophication.

- Stormwater ponds: An 8-ha stormwater pond was excavated at the edge of the Arboretum to capture and treat urban runoff before it flowed into Southeast Marsh. In 2010, UW undergraduate Katherine Riha documented rapid cattail invasion and dominance in 94 of 96 plots that she placed along the shoreline. The cattails were *Typha angustifulia* and/or *T. x glauca*, apparently established from wind-blown seed. By October, native plantings had been overtopped by *Typha*, which had grown an average of

1.2 m, up to a maximum of 2.2 m tall. Over years, the cattails grew denser and taller, with fewer occurrences of native species, as censused by graduate students James Doherty and Eric Olson. Stormwater ponds are easy to spot in Madison; just look for a bermed pond with a narrow ring of cattails around open water. The berms are deliberately steep, to occupy minimum "real estate." Thus, the rings of cattail are usually quite narrow. Natural marshes tend to grade from tall to short cattails towards the landward edge.

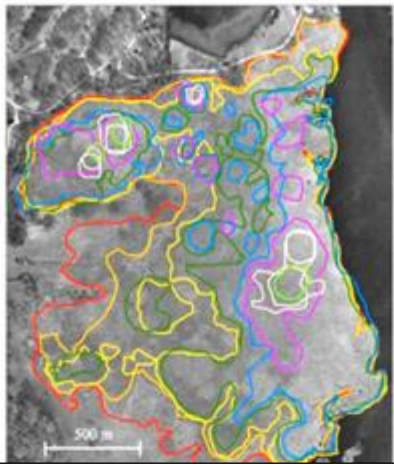
- **Urban-runoff swales:** In the Arboretum's parallel **treatment swales**, an interdisciplinary research team (Drs. Anita Thompson, Steve Loheide and me plus our graduate students, Jeffrey Miller, Stephanie Prellwitz, and James Doherty) compared the effects of urban runoff that had 3 hydroperiods, with maximum cattail growth



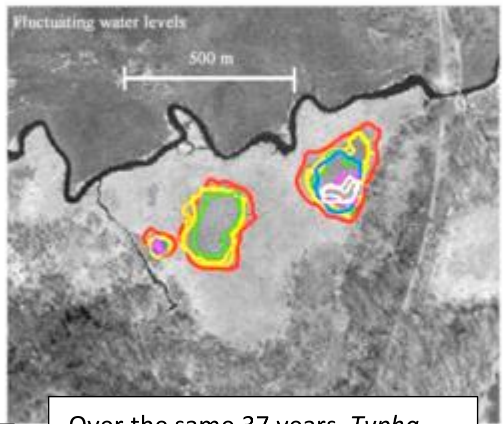
developed in Swale III where water ponded (versus infiltrated in swales I-II). The swales were designed to be replicates, but soil cores revealed a surprise below the ground: Subsurface clay differed in thickness and the thickest clay caused water to pond. Hydroperiod durations were: III>I>II, as was cattail abundance—more ponding, more cattails. All three swales supported cattails instead of the rich mixture of native species that were sown as seeds (another surprise). Cattails invaded most aggressively in Swale III. All three swales exported P (Swale III>I>II), and the wettest swale (III) also exported N and suspended solids (Doherty et al. 2014).

- **Dams and "internal" eutrophication**. Standing water and nutrient addition are two circumstances that tend to coincide. First, placing a dam on a flowing stream stabilizes the water levels. For example, sedge meadows would normally have a summer drawdown that favors tussock sedge (*Carex stricta*). However, behind dams, water levels are stabilized and favor cattail marshes. Stabilized water levels further favor dominance by hybrid cattails, which prefer conditions where nutrients are more available (Boers et al. 2006a, Boers and Zedler 2008). This has a direct effect on cattails by creating their preferred habitat (standing water) and an indirect effect of mobilizing phosphorus (P) in the shallow-water mud; this is called "internal" eutrophication. With low water, iron in wetland soil (ferric iron or Fe^{3+}) bonds with P to form an insoluble complex, trapping the P so cattails cannot access it. With flooding, however, the soil becomes anaerobic; Fe^{3+} gets reduced to ferrous iron (Fe^{2+}); and the iron complex releases its phosphorus. Voila! P becomes available to plants. Wetland soils release phosphorus when the flooding period is prolonged. Shallow water with plentiful nutrients is ideal for cattails.

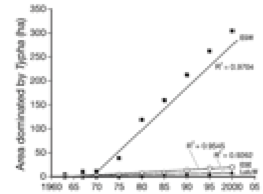
Doctoral student Aaron Boers compared cattail clonal expansion using aerial imagery from a marsh at Eagle Spring Lake, where water levels were stabilized behind a century-old dam (left aerial photo) versus wetlands with natural hydrology (variable water levels, on the right). Cattails took over the dammed marsh but were not invasive where water levels fluctuated.



Typha expanded at Eagle Spring Lake



Over the same 37 years, *Typha* was not invasive at Lulu Lake



Typha expanded only behind a dam

Boer's findings were supported by experiments, which showed that *T.* x *glauca* could take up more P where water level was stabilized vs. fluctuating; also cattails produced more biomass with P addition (Boers et al. 2006, 2008; Boers and Zedler 2008).

- Wetlands with "external" eutrophication: Nutrients arrive in wetlands from the air (e.g., in rain and as dust), from surface water runoff and in inflowing waters of streams and lakes. Nutrients can be dissolved or attached to sediments that get churned up and mobilized during storms and other disturbances. Eutrophication is "external," when the source of nutrients is outside the wetland. It is the most common and widely known source of eutrophication. It happens when excess nutrients are applied to crops, washed off or leached from disturbed soils.

Doctoral student Christin Frieswyk surveyed coastal wetlands along Wisconsin's Green Bay and described monotypes of invasive *Typha* where the marsh receives copious nutrients and sediments from the Fox River; this was in contrast to Long Tail Point Marsh which supported good quality emergent marsh co-dominated by cattails and bulrushes.

Summary. The above circumstances (stormwater management, dams, surface-water runoff) allow cattail take-overs by augmenting nutrients. Indeed, human-caused eutrophication is the most common cause of cattail over-dominance, whether nutrients are added intentionally to nearby fields as crop fertilizer; whether nutrients are liberated with a change in hydroperiod, as behind dams; or whether nutrients arrive in flows from unintended upstream sources. As shown by sequential field research, cattails can respond to both internal and external eutrophication. In Gardner Marsh, the Wingra dam stabilized water levels, mobilized nutrients in the increasingly anoxic soil, and allowed cattails to replace a sedge meadow (Hall and Zedler 2007). Later, in a field experiment, the same cattails grew even more robustly when Isa Woo added N and P fertilizer (Woo and Zedler 2010). In Wisconsin, invasive cattails thrive in shallow water along the edges of thousands of lakes with and without dams, where people visit, swim, paddle canoes, launch boats, and create wave--activities that continually churn up sediments and mobilize nutrients. People and cattails are constant companions.

Are there latitudinal patterns?

Studies of cattails in four widespread locations did not suggest large-scale geographical patterns. Latitude did not correlate with aggressiveness. *T. domingensis* did not appear to be more aggressive further south than north, or vice versa--although it might grow taller with year-round growing seasons at 20 and 32° N than in Wisconsin.

Comparing salt marsh invasions across hemispheres, *T. orientalis* seemed just as opportunistic as *T. domingensis* where soil salinity was lowered by freshwater urban runoff.

If latitude doesn't help explain differences among cattails, which biological traits are similar among these four tales? Consider the following:

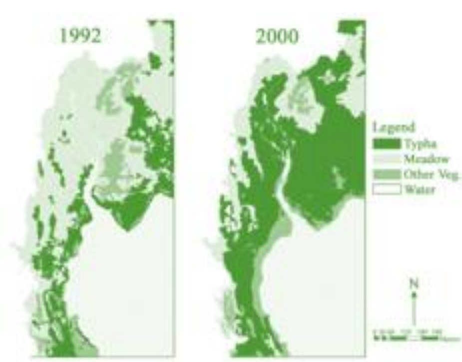
Latitude	Study Area	Focus on *Typha…*	Origin
43 º N	Wisconsin	T. x *glauca*	Hybrid
		T. angustifolia	Alien
		T. domingensis	*Alien*
32 º N	San Diego	*T. domingensis*	Native
20 º N	Morelia	*T. domingensis*	Native
32 º S	Perth	*T. orientalis*	Alien

Biological traits influence behavior

While it's not scientific to make subjective judgments about good and bad behavior, scientists are nonetheless encouraged to speak to broad audiences using understandable language. Here, "good" and "bad" refer to benefits to Nature and damages to biodiversity.

- Good traits assist Nature conservation. Tall, dense vegetation provides **habitat**, (notably for explained why cattails invaded and persisted amphibians, blackbirds, ducks, cranes), and food (including litter) and cover for fish and aquatic invertebrates, birds and familiar mammals. Muskrats eat cattails and cut leaves to build huts that are surrounded by water, which protects their young from predators that would otherwise attack from overhead, on the land, or in the water.

And it's good that dense, interwoven cattail roots and rhizomes create thick mats that **hold sediment** in place. Cattails' ability to stabilize sediment helps keep the water clear. Likewise, highly productive cattails trap and store carbon belowground. Unfortunately, where they occur, they usually form a monoculture. Their tall form and dense underground growth allows them to dominate the vegetation, which is another way of saying that they crowd out other species.



Midwestern land managers can, and do. take advantage of cattail **habitats**. Wisconsin's largest cattail wetland is the **45-km^2 Horicon Marsh.** This once-natural wetland has undergone drainage, drying, cultivation, fires, levee construction, and rewetting. The resulting cattail monotypes are managed by **varying water levels** to favor waterbirds, i.e., providing vegetation for cover, mudflats for macroinvertebrates, which are food for shorebirds, and ponds managed for geese, ducks, and shorebirds through coordinated cattail-control and open-water/mudflat restoration. Varied habitats are possible because subareas are diked and water levels can be controlled for multiple waterfowl-management impoundments. Patches of vegetation, open water, and mud offer food and cover for a diversity of nesting and migratory waterbirds, such as tens of thousands of redhead ducks (https://dnr.wisconsin.gov/topic/Lands/WildlifeAreas/horicon).

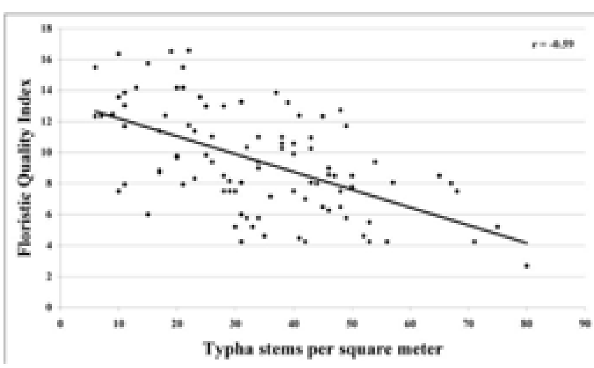
- Bad traits allow cattails to over-dominate. The scale at which hybrid cattails take over is so large that it can be documented using aerial imagery. Along Green Bay, for example, historical aerial photographs from 1967 to 2000 of three coastal wetlands allowed doctoral student Kristin Frieswyk to quantify how agricultural lands were urbanized. and native *Typha latifolia* was replaced by *Typha* x *glauca*. Peter's Marsh (map by L. Ladwig and C. Frieswyk from Boers et al. 2006a) was invaded rapidly after 1992.

At a regional scale, along the Lake Michigan shoreline, native cattail (*T. latifolia)* marshes expanded downslope as lake levels fell and then were "squeezed out" later, when lake levels rose. Because *T.* x *glauca* is **more-inundation tolerant** than native cattails, the elevation range were natives could thrive was compressed. Lake level was a key factor (Frieswyk and Zedler 2007). `

- **"Hybrid vigor**" is growth that exceeds that of either parent. It is well-known, especially for *T. x glauca.* Here's what Dr. Nancy Tuchman and co-authors (2009) said about a cattail invasion in lower Lake Huron, Michigan. "*Relative to uninvaded areas, Typha–invaded areas differed in plant–community composition and had lower species richness, higher litter mass, and higher soil organic matter and nutrient concentrations (all P <0.001). Overall, Typha invasion appeared to displace native species and enrich wetland soils. These changes could benefit Typha at the expense of native species, potentially generating plant–soil feedbacks that pose special challenges for wetland management and restoration."* It is hard to find a cattail marsh that lacks hybrid clones. On aerial photos, their taller stature makes circular patches visible and easy to track. Measuring clone diameters on successive imagery allows estimates of lateral spread (Boers et al. 2006, Boers and Zedler 2008).

Disturbance favors cattails

- **Disturbed sites attract cattails**. The native plants seem unable to compete with cattails wherever there is hydrological, physical, chemical and/or biological disturbance. Such disturbances are common factors in Midwestern wetlands. I have seen only a few marshes where cattails and diverse native plants co-exist; one small remnant in the Arboretum is in a never-plowed wetland. And it is not just the diversity of native plants that diminishes, but also the vegetation "quality." Ecologists often use a **Floristic Quality** Index (FQI) to characterize the composition of a wetland. The FQI summarizes the mixture of high-quality species (those restricted to natural remnants with minimal disturbance and low-quality species (those that occur primarily in very disturbed sites).



Cattails are rated low on a scale of 1 to 10. And their presence lowers overall marsh community quality. Here's an example.

In northeastern Illinois, just south of Wisconsin, doctoral student Aaron Boers documented lower quality of species where cattails were denser (see graph); there were also fewer species (Boers et al. 2006b). In the same 4-ha complex of research wetlands, Boers attempted to shift dominant cattails toward diverse native plants. He removed *T.* × *glauca* from experimental plots in July 2002, but it soon reinvaded vegetatively. In 2003, plots averaged 9.2 *T.* × *glauca* stems (ramets or clumps) m^{-2}....and double that in 2004. So, the native plants didn't recover, even after cattails were removed and natives were replanted (Boers et al. 2006a).

- **Disturbed watersheds provide conditions that favor cattails.** In the Upper Midwest, early immigrant people drained and plowed former wetlands and reduced the areas where diverse native species to remnants that are like islands in what is now a sea of corn and soybean fields. These actions substantially reduced the area of diverse natural wetlands (46% loss of wetland area in Wisconsin from the 1780s to 1980s; Dahl 1990). We have altered entire watersheds by cultivating crops and compacting soils, urbanizing and hardscaping landscapes, altering historical hydroperiods (adding water, diverting water), disrupting the natural biota (adding species, removing species), modifying topography, and deliberately adding nutrients to watersheds and surface waters. Many modified watersheds have increased runoff (due to added hardscapes and compacted soils) and excess runoff discharges excess nutrients and pollutants to downstream wetlands. When a cultivated field or lawn is fertilized, the rains wash nitrogen and phosphorus off the land surface and into ditches and streams, most of which eventually lead to marshes. Cattails are quick to take note and take advantage. Nutrients alone can shift a sedge meadow to cattails (Woo and Zedler 2002). Competition occurs where we create **conditions/opportunities** for aliens and hybrids to find a niche, and if the occupant is a native plant, the invader will likely take over.

Can wetland managers control invasive cattails?

As our human population grows, we enlarge the area that is suitable for ourselves—we create farms and cities, and we modify lakes, rivers, and other waterways. The circumstances we create lead to habitats suitable for cattails—stormwater ponds, dams, and stabilized water levels. **Cattails and humans** are like "**companions**"—not always congenial but perhaps **inseparable**.

Do wetland restoration efforts curtail cattail dominance? While land managers around the world have restored wetlands and expanded wetland remnants, the gains do not make up for historical losses in either quantity or quality. There is virtually always a "**recovery debt**". Moreno-Mateos and collaborators (2017) coined the term recovery debt when they found shortcomings of global restored ecosystems as follows: "annual deficits of 46–51% for organism abundance, 27–33% for species diversity, 32–42% for carbon cycling and 31–41% for nitrogen cycling….consistent across biomes but not across degrading factors. Our results suggest that recovering and restored ecosystems have less abundance, diversity and cycling of carbon and nitrogen than 'undisturbed' ecosystems, and that even if complete recovery is reached, an interim recovery debt will accumulate" (Moreno-Mateos et al. 2017).

Cattails respond to wetland restoration efforts whether they are invited or not. Bare mud and a few floating seeds are all that's needed. Four swales at the Arboretum were taken over by cattails despite sowing seeds of diverse native plants. The first seedlings that emerged were those of cattails, presumably dispersed by air-borne seeds. Note that cattails were lined up in the forebay of this swale system before the swales were graded and planted. Those cattails had not yet fruited, so seeds were arriving from elsewhere, probably via the wind or surface-water runoff.

Some approaches reduce cattail growth, but because cattails are widely dispersed, wind-borne seeds counter "control" efforts, such as lowering water levels and burning biomass. Short-term removal is not self-sustaining. Constant monitoring and adaptive management are needed to achieve lasting results. Regrettably, there is no species-specific or benign herbicide (glyphosate is not advised for aquatic habitats), and even if all current plants could be killed, cattails would readily re-invade. For example, Aaron Boers cut cattails and planted native vegetation to test the ability to convert cattails to diverse vegetation in experimental wetlands in northeastern Illinois, his intensive efforts had little effect after the first season. Likewise, when Steven Hall harvested cattails 3 times per (~6-mo.) growing season in the Arboretum, he could not keep cattails from dominating the marsh.

Continual **cutting or mowing** could reduce cattail dominance, as in Morelia, where four harvests per (12-mo.) growing season increased plant diversity while supplying leaves for crafts and forage and sustaining the cattail population. But what are Midwesterners willing to do with harvested cattail? Can we **use cattail biomass?**

Cattails were--and are--used by Native Americans and a growing number of nature foragers and artisans. Around the world, cattail leaves and stalks are woven into mats and baskets. In Morelia, Michoacán, local artisans are re-learning how to turn cattail leaves into souvenirs for tourists (personal communication, Dr. Roberto Lindig-Cisneros; see photo by S. Hall). In addition, cattail "down" (fluff attached to seeds) has been used to line moccasins and stuff pillows and diapers.

In Morelia, the revival of cattail harvesting has dual purposes, (1) to manage freshwater springs that provide Morelia's drinking water and (2) to create incomes for artisans (Dr. R. Lindig-Cisneros, UNAM-Morelia, personal communication). Harvesting cattails for biofuel or animal forage could become a sustainable and beneficial use.

Can we eat cattails?

Yes. Cattail fruits and seeds can be eaten, as can rhizomes (underground stems that produce lateral shoots) and attached buds, plus tender/young shoots, and pollen. You can cook rhizomes until they are tender, then eat like an artichoke. Roots and pollen have medicinal value. Harvesting cattails is not easy because the marshes are wet and squishy. Mucking about in the mud can be fun, but it can take a lot of muscle energy to harvest rhizomes for their flour, preparing them by washing, settling the solids, then drying, grinding, and baking something (which I learned through trial and error).

• Pollen yellows when mature. Collect male fruits and shake into a sturdy bag. Use as flour or dust over dark dough for breads or whatever suits your imagination.

• Female cattail fruits are tender and best to eat when young and green (in spring). Once mature, their texture/fluff becomes an issue.

• Newly sprouted green leaves (shoots) can be harvested and chopped for use in stir-fry or cut to cook like asparagus.

• Starch-filled rhizomes need to be scrubbed and roots removed. Strip out the fibers so they won't irritate your stomach. To collect the starch, mash the tissue, leach the "juice", and let the starch settle overnight. Pour off water and let the mush dry until it can be ground into flour. The native broadleaf cattail rhizomes are fleshy, while hybrid cattail rhizomes can be wiry and stringy.

Conclusions

Cattails are remarkable plants with many highly adaptive attributes--some that are considered beneficial to Nature and people (wildlife habitat, high rates of carbon storage) and others that are judged detrimental (over-dominance, displacement of natives). Thanks to research by my many students who chose to study cattails, I witnessed and helped document **four contrasting tales**, namely:

(1) An especially tall **native** cattail (*T. domingensis)* invaded and displaced a native pickleweed salt marsh in San Diego.

(2) *T. domingensis* was aggressive in Mexico's Mintzita Springs (Morelia, Michoacán), it was held in check by frequent harvests that benefited both farmers and biodiversity.
(3) An **alien** cattail (*T. orientalis*) invaded a native salt marsh in Perth, Western Australia.
(4) A **hybrid** cattail (*T.* x *glauca,* native x alien*)* invaded and displaced native, disturbed, and created wetlands in Wisconsin.

Humans played critical roles in all these dynamics—by augmenting flows of the San Diego River with imported water and confining flows near the river mouth to a flood control channel, by harvesting cattails in Morelia, by creating small ditches to convey urban runoff in Perth, and by altering hydroperiods and habitats in Wisconsin. Each of these four tales is unique, yet all are alike in revealing how humans and nature interact. Cattails prevail wherever there is opportunity, and humans create those opportunities. Just add **fresh** water! People and cattails are **constant companions**, because both *Homo sapiens* and *Typha* species depend on fresh water.

We have options for the future. Humans are now altering fresh water supplies at global scales, by melting ice in glaciers and at the poles, as well as by increasing rainfall. As the Midwestern climate warms and gets wetter, cattails will likely thrive and expand. If we don't like the outcomes, we have a few **options**:

The **first** option is to change our habits so climate change is slowed and stabilized, and so that precious fresh water is truly conserved---not allowed to become useless runoff.

A **second** option is to learn to live with cattails, as in Morelia.

A **third** is to combat cattails locally and strategically, i.e., managers and citizens would aim to minimize nuisances. In temperate regions, citizens could watch for new populations of the southern cattail, *T. domingensis,* and any hybrids it might form with resident cattails. Managers could monitor marshes using drones and remotely sensed imagery, watching for circular clones that over-top even the tallest canopies of *T.* x *glauca.*

Fourth, policy-makers would need to set realistic goals (probably not eradication) and focus on tackling the newest invasions.

As a **fifth** and complementary option, I suggest exploring opportunities to harvest and make use of the superabundant, over-dominant hybrid and alien cattails.

An **overall win-win aim** is to restore native plants that could co-exist with a harvested overstory.

Further reading

Learn from cattail managers at federal (USFWS, USGS) and state (WDNR) agencies: https://dnr.wisconsin.gov/topic/lands/WildlifeAreas/horicon/humhist.html; https://pubs.usgs.gov/sir/2012/5143/sir2012-5143.pdf [2012 summary of use of fire]; https://dnr.wi.gov/news/Weekly/article/?id=3069 [planning in 2014].

Learn from other Midwestern cattail researchers, professors and their many collaborators: Drs. Douglas Wilcox: Sue Galatowitsch, Arnold van der Walk, Dan Larkin, Nancy Tuchman.

Consult the original papers that are cited above for details:

Bansai, S., S. C. Lishawa, S. Newman, B. A. Tangen,, D. Wilcox, D. Albert, M. J. Anteau, M. J. Chimney, R. L. Cressey, E. DeKeyser, K. J. Elgersma, S. A. Finkelstein, J. Freeland, R. Grosshans, P. E. Klug, D. J. Larkin, B. A. Lawrence ,G. Linz, J. Marburger, G. Noe, C. Otto, N. J. Richards, C. Richardson, L. Rodgers, A. J. Schrank, D. Svedarsky, S. Travis, N. Tuchman, L. Windham-Myers. 2019. *Typha* (Cattail) invasion in North American wetlands: Biology, regional problems, impacts, ecosystem services, and management. Wetlands (2019) 39:645–684.

Beare, P. A., and J. B. Zedler. 1987 Cattail invasion and persistence in a coastal salt marsh: the role of salinity. Estuaries 10:165-170.

Boers, A. M., and J. B. Zedler. 2008. Stabilized water levels and *Typha* invasiveness. Wetlands 28: 676-685.

Boers, A., R. Veltman, and J. B. Zedler. 2006a. *Typha x glauca* dominance and extended hydroperiod constrain restoration of wetland diversity. Ecological Engineering 29:232-244.

Boers, A., C. Frieswyk, J. Verhoeven and J. Zedler. 2006b. Chapter 10: Contrasting approaches to the restoration of diverse vegetation in herbaceous wetlands. Pp. 225-246 in R. Bobbink, B. Beltman, J J.T.A. Verhoeven, and D.F. Whigham, eds. Wetlands as a natural resource, Vol. 2. Wetlands: Functioning, Biodiversity Conservation and Restoration. Springer Verlag.

Boyer, K. E., and J. B. Zedler. 1998. Effects of nitrogen additions on the vertical structure of a constructed cordgrass marsh. Ecological Applications 8:692-705.

Dahl, T. 1990. Wetland losses in the United States 1780s to 1980s. USDI Fish and Wildlife Service, Washington, D.C.

Doherty, J. M., J. F. Miller, S. Prellwitz, A. M. Thompson, S. Loheide, and J. B. Zedler. 2014. Bundles and tradeoffs among six wetland services were associated with hydrologic regime. Ecosystems 17(6):1026-1039.

Callaway, J. C., and J. B. Zedler. 1998. Interactions between a salt marsh native perennial (*Salicornia virginica*) and an exotic annual (*Polypogon monspeliensis*) under varied salinity and hydroperiod. Wetlands Ecology and Management 5:179-194.

Kercher, S. M., and J. B. Zedler. 2004. Flood tolerance in wetland angiosperms: A comparison of invasive and noninvasive species. Aquatic Botany 80:89-102.

Galatowitsch, S. M., N. O. Anderson and P. D. Ascher. 1999. Invasiveness in wetland plants in temperate North America. Wetlands 19:733-755.

Hall, S. J., and J. B. Zedler. 2010. Constraints on sedge meadow self-restoration in urban wetlands. Restoration Ecology 5:671-680.

Hall, S. J., R. A. Lindig-Cisneros and J. B. Zedler. 2008. Does harvesting sustain plant diversity in Central Mexican wetlands? Wetlands 28:776-792.

Hirsch, Chris. 2015. Practicum Report. Botany M.S. Degree Program, Ecological Restoration Track. Botany Department, University of Wisconsin-Madison.

Larkin, D. J., S. C. Lishawa, and N/ C. Tuchman. 2012. Appropriation of nitrogen by the invasive cattail *Typha* × *glauca*. Aquatic Botany 100:62–66. DOI:10.1016/j.aquabot.2012.03.001

Larkin, Daniel J.; Freyman, Monika J.; Lishawa, Shane C.; Geddes, Pamela; and Tuchman, Nancy C. 2012. Mechanisms of dominance by the invasive hybrid cattail *Typha* × *glauca*. Biological Invasions 14:65-77.

Moreno-Mateos, D, E. B.. Barbier, P. C. Jones, H. P. Jones, J. Aronson, J. A. López-López, M. L. McCrackin, P. Meli, D. Montoya, and J. M. Rey Benayas. 2017. Anthropogenic ecosystem disturbance and the recovery debt. Nature Communications. Jan 20;8:14163. doi: 10.1038/ncomms14163.

Noe, G. B., and J. B. Zedler. 2000. Differential effects of four abiotic factors on the germination of salt marsh annuals. American Journal of Botany 87:1679-1692.

Noe, G. B., and J. B. Zedler. 2001. Variable precipitation limits the germination of upper intertidal marsh plants in southern California. Estuaries 24:30-40.

Parsons, L., and J. B. Zedler. 1997. Factors affecting reestablishment of an endangered annual plant at a California salt marsh. Ecological Applications 7:253-267.

Tuchman, N. C., D. J. Larkin, P. Geddes, R. Wildova, K. Jankowski, and D. E. Goldberg. 2009. Patterns of environmental change associated with *Typha* x *glauca* invasion in a Great Lakes coastal wetland. Wetlands 29(3):964-9.

Woo, I., and J. B. Zedler. 2002. Can nutrients alone shift a sedge meadow towards the invasive *Typha x glauca*? Wetlands 22:509-521. (Selected by D. Wilcox as a top paper accepted to the journal in his 20-year position as editor).

Zedler, J. B. 1981. The San Diego River marsh before/after the 1980 flood. San Diego Natural History Museum, Environment Southwest Autumn 1981, number 495:20-22.

Zedler, J. B., E. Paling, and A. McComb. 1987. Salinity-controlled invasions of *Typha* in Mediter-ranean-type wetlands of Australia and California. Proc., Wetland and Riparian Ecosystems of the American West. Eighth Annual Meeting of the Society Wetland Scientists p. 299-303.

Zedler, J., E. Paling, and A. McComb. 1990. Differential salinity responses help explain the replacement of native *Juncus kraussii* by *Typha orientalis* in Western Australian salt marshes. Australian Journal of Ecology 15:57-72.

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