Biology and Ecology of Yellow Flag Iris: Research Updates to Support Integrated Weed Management

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The magnitude of global *Iris pseudacorus* invasions has increased dramatically in recent years.

Invasive plant populations are often observed to grow and spread more vigorously than conspecific populations in the native range.
President Thomas Jefferson widely recognized as a Francophile, embraced all things French including art, culture, wine, cuisine, and gardens). He imported and grew *Iris pseudacorus* at his Monticello plantation, Virginia before 1771 (Wells et al. 2020 *Castanea*). His well-documented gardens contained many exotic seeds and plants from his travels abroad.

*Iris pseudacorus* spread from Virgina, USA: Virginia by 1771. By the 1860s, it was a naturalized invasive alien species along the Delaware River, Hudson River Valley; in Lake Ontario-Great Lakes region by 1886, Chesapeake Bay by the early 1900s, and in Oregon, Pacific Northwest and California by 1948. (Consortium California Herbaria)

Yellow Flag Iris, *Iris pseudacorus* L. Emergent Wetland Macrophyte

Arctic, Temperate and Subtropical Climate Zones
Freshwater and tidal wetlands, shallow lakes, ponds, rivers, ditches,
How did it get to my wetland???

Highly Attractive Plants Imported for Water Gardens and Aquaria escape and naturalize as invasive weeds

1. *Iris pseudacorus*, a showy wetland plant with yellow flowers, has been transplanted into gardens and ponds all over the world and has widely escaped and displaced native vegetation.

2. It is used in water and sewage treatment for metals removal, but it escapes wastewater treatment areas.

3. Ballast water discharge of yellow flag iris seeds into estuaries documented 1880s.

As a noxious weed, sales and transport of *I. pseudacorus* have long been prohibited in many states, but enforcement is difficult, particularly with internet sales.

**Historic import of plants for private ponds and botanical gardens, and modern global trade in horticultural and aquarium plants** have been pathways of alien plant species introductions to wetland and riparian ecosystems.

**Intentional Introduction**  ->  **Unintentional Consequence**

Beaury et al. (2021): 61% of 1285 plant species identified as invasive in the US remain available through the plant trade, including 50% of state-regulated species and 20% of federal noxious weeds.

**Intentional Introduction**

**Unintentional Consequence**

- **Price:** US $13.00
  - 23% $11.95
  - $11.60 Expedited

**3 YELLOW FLAG WATER IRIS PSEUDACORUS bulbs/ rhizomes**

**Yellow Pond Iris**

**4.4 out of 5 stars**

- **We are unable to ship this product to AE, AK, BC, GU, HI, PR.**
- **Very Hardy. Laughs at cold weather.**

10/2023
Establishment and Spread: Sexual and Asexual Reproduction

**Obligate Outcrosser**

- Capsules obscurely 3-angled with obvious groove at each angle
- **High seed production**
  - (400-1500 per plant)
  - Smooth, reddish to dark brown seeds (depending on maturity) which are flat and D- to circular shaped, with hard seed coats

**Rhizomes** are drought tolerant, but during floods, both rhizomes and seeds may be transplanted downstream. Bank erosion can mobilize rhizome fragments.

**Flower early spring late Mar-Apr**

**Seeds** release from dihisced capsules often hanging directly over water

**Bouyant Seeds**

- **Clones expand** quickly via tuberous rhizomes, spreading radially to form dense stands.
- **Rhizomes exposed** with bank erosion
- **Dense root mats** compact soil, inhibit seed germination of other plants.

**Vivipary**

- **Rhizomes pink, freely branching**

**Bombus sp. Apis sp. long-tongued flies, Hummingbirds**

**Bamboo sp.**

- FLOWERS EARLY SPRING late Mar-Apr
- Seeds disperse summer
Almost all plants were not clonally related. An unusual case of seed dispersal in an invasive aquatic; yellow flag iris (*Iris pseudacorus*)

Gaskin et al. 2016, *Biological Invasions*

Molecular ecology enables better understanding of introduction events, matching invasive populations to source populations, and knowledge of how species are spreading.

99.1% of seeds collected in MT were viable. Even when collected at 2 m apart (40m transect), only one pair of plants was clonally related.

Population genetic study

Found 167 unique genotypes in n=171 plants

Seeds – Sexual Reproduction Drives Dispersal - Recruitment of yellow flag iris!

Genetic studies in Pacific Northwest states revealed *I. pseudacorus* disperses almost entirely by seed, not by rhizome fragmentation.

Big news for management!

TIMING OF TREATMENT: BEFORE SEED PRODUCTION
**Alien: Yellow Flag Iris**

*Leaves* deciduous, stiff *erect* with upper part arching; leaves flattened, arising in a *fan* from the soil; raised midrib; sword-like, fine-pointed; 3-5 feet in height

**IMPORTANT!**

**MANAGE BEFORE SEED FORMATION**

**EDRR!**

Plants do not bloom and set seed until 2 yrs old. **MANAGE EARLY!**

Learn to I.D. prior to flowering!

Once reproductively mature, best **timing for effective management** is in the pre-reproductive stage, or at least prior to seed production.

When not in bloom, it can be difficult to distinguish from cattails, bur-reed, and native irises.

**Proper Identification: First Step for Management**

**Erect Emergent Wetland Plant Species**

**Douglas Iris** *I. douglasiana*

Native to the California coast from Santa Barbara to Oregon

*Moist soil, seasonal wetlands, wet meadows*

**Native Iris Capsules** obscurely 3-angled with obvious groove at each angle

**Yellow Flag Iris Leaves** flattened, in fans, with raised midrib, leaf tips pointed

**Bur-Reed fruits** *(Sparganium erectum, S. eurycarpum)*

**Bur-Reed, narrow alternate** leaves, triangular x-section, flat only at tip

**Iris Capsules** obscurely 3-angled with obvious groove at each angle

**Bur-Reed, narrow alternate** leaves, triangular x-section, flat only at tip

**Iris, vertical veins, Cattail honey-combed veins**

**Cattail**

Leaf differences

Iris, flat diamond shaped at midrib; Cattail crescent-shaped, not flat
With global climate change, plant species in tidal marshes are being exposed to increasing salinity and longer inundation periods related to concomitant sea level rise (SLR) and alteration of local watershed runoff, and precipitation amounts and patterns. SLR exposes plants to increased physiological stresses and influences their survival, distribution and productivity along intertidal gradients, depending on their elevation relative to tides.

**Alternative Plant Responses to Environmental Change**

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<th>Extinction</th>
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Weed invasions and their impacts are the outcome of both changing environmental conditions and plant traits promoting fitness, as well as constraints on trait plasticity to adjust to change. 

Global change factors are expected to alter physiological and ecological traits of alien aquatic plants, and accelerate their spread and invasion risk into new areas. Rapid evolution is measurable and well documented.

Yellow Flag Iris, long established and a presumed glycophyte, is rapidly expanding into low to high brackish tidal wetlands where it alters habitats and reduces plant species diversity.
Decadal records of established alien *Iris pseudacorus* populations in the San Francisco-Bay Delta Estuary region wetlands

Recent rapid range expansion: spread and establishment of *Iris pseudacorus* along Suisun Marsh tidal sloughs

Managed Water Flow Directly Influences spread of buoyant seeds dispersing into water in summer.
Germination niche breadth of invasive *Iris pseudacorus* (L.) suggests continued recruitment from seeds with climate warming Gillard, Castillo, Mesgaran, Futrell, & Grewell. 2022 American Journal of Botany

Climate warming is altering cues that drive germination, yet studies on the invasion of wetland macrophytes often ignore germination ecology despite its importance to establishment.

We explored germination of seeds from *I. pseudacorus* populations in California.

Seeds did not require cold or warm stratification to germinate.

*I. pseudacorus* has a broad germination niche supporting its establishment in a relatively wide range of environments, including at high temperatures more frequent with climate change.

Embryo viability still high at high temperatures.

Using experimental results in a thermal time model, we derived germination temperature thresholds.

Germination occurred in the dark, germinability was 2 to 3 times greater under light, and highest with alternating temperatures.
High aqueous salinity does not preclude germination of invasive *Iris pseudacorus* from estuarine populations

Morgane Gillard, Jesús M. Castillo, Caryn J. Futrell, Brenda J Grewell

*Ecosphere* 2021

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**Dispersal**

Highly buoyant seeds allow for dispersal by water

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Brackish salinity >12.5 dS/m inhibited germination of seeds, but 56% germinated.

After 55 d floating in seawater, buoyant seeds of *I. pseudacorus* retain their ability to germinate, and germinate quickly with freshwater exposure. (FGP 96%)

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We tested germination under fresh to seawater salinity levels (0, 12.5, 25, and 45 dS/m) and under moist and flooded hydrological conditions

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*Increased salinity with Sea Level Rise won’t solve our problem*

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High aqueous salinity exposure does not preclude germination of yellow flag iris

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Results inform risk assessments, suggesting invasive populations of *I. pseudacorus* can colonize new sites following potentially long-distance dispersal with tidal currents, and highlight the need for management with sea level rise.

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Dr. Morgane Gillard,
Post-Doc, UCD, USDA
now Sitelécom, Dijon, France
Salinity and inundation effects on *Iris pseudacorus* (yellow flag iris): implications for tidal wetland invasion with sea-level rise

Grewell, Gallego-Tévar, Gillard, Futrell, Reicholf, & Castillo 2021 *Plant and Soil*

### Early life stage

*Iris pseudacorus* is best adapted to freshwater condition: functional traits are optimal, with significant production of biomass

### In freshwater conditions, tolerance of permanent inundation

At the pre-reproductive, colonizing life stage, the high sensitivity of *I. pseudacorus* to salinity limits its capacity to acclimate to increasing inundation

### Allocation to below ground reserves in benign (freshwater) conditions may support survival through suboptimal high salinity/inundation periods

### Management Implications:

Efforts to control the invasion of *I. pseudacorus* in estuaries should focus on rapid management of newly colonizing populations in freshwater tidal locations prior to reaching seed production stage at age 2 yrs. Successful establishment and growth of juvenile *I. pseudacorus* is best supported in these benign environments.

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**Establishment Life Stage**

Greenhouse experiment
3 salinity X 2 inundation levels X 3 populations X 4 replicates from an estuarine gradient San Francisco Bay-Delta Estuary.
Comparative Biogeographic Research
Yellow Flag Iris
Native vs. Introduced Range

STUDY SITES

Populations C1-C5:
San Francisco Bay-Delta Estuary,
California, USA

Populations A1-A5:
Guadalquivir Estuary, Andalusia,
Spain

Dr. Jesús M. Castillo
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Contrasted impacts of yellow flag iris (*Iris pseudacorus*) on plant diversity in tidal wetlands within its native and invaded distribution ranges

Gallego-Tévar, Grewell, Whitcraft, Futrell, Bárcenas-Moreno, Castillo 2022, *Diversity*

In a recent study, we assessed the impact of *I. pseudacorus* populations along estuarine gradients on resident plant communities in its native and invaded ranges.

In the native range (Andalusia), *I. pseudacorus* was associated with high plant species richness, evenness, and diversity.

Shannon–Wiener $\alpha$-diversity, species richness and evenness were evaluated in patches with and without *Iris pseudacorus* in its native (Guadalquivir Estuary) and invaded (San Francisco Bay-Delta Estuary) distribution ranges, to investigate the effects on the plant community.

*Iris pseudacorus* greatly reduced plant species richness and diversity in the naturalized California range at local and watershed scales. Effects were independent of variation in soil salinity.
Decomposition of biomass can degrade water quality, eutrophication fuels more growth. Populations of yellow flag iris can create a positive feedback loop increasing its spread and negative environmental impacts. Iris pseudacorus out-competes native plants for pollinators. Roots trap sediment, sediment raises local elevations, clogs irrigation canals, narrows waterways, decreases flood capacity. Sediment increase enables new seedling growth, + shrubs and trees altering to drier ecosystem. Consumptive use of water supports biomass production and reduces water supply for beneficial uses. Reduces species richness and diversity of native plant communities. Reduces food supply, nesting habitat of many wetland dependent fish & wildlife, changes ecological functions.

Yellow iris was found growing to the complete exclusion of Typha and other native marsh plants along the Merced River in California (Raven and Thomas 1970). I. pseudacorus in Mission Valley, Montana has been reported to reduce a stream’s width by up to 10 inches a year (Tyron 2006 in: Washington Noxious Weed Control Program 2009). (Dieringer 1982, Sarver et al. 2008, WA Noxious Weed Control Program 2009, Lui et al. 2010, Jacobs et al. 2011, ODA 2012, Gallego-Tévar et al. 2022).
Phenotypic trait differences between *Iris pseudacorus* in native and introduced ranges support greater capacity of invasive populations to withstand sea level rise. Grewell et al. 2023 *Diversity and Distributions*

**METHODS**
We compared 15 growth, morphological, biochemical, and reproductive plant traits from populations in the native and invaded range, and explored their relationships to measured and modeled environmental factors.

**RESULTS:**
- Alien invasive *I. pseudacorus* plants in California were more robust than those from the native range, in response to differences in environmental conditions and genetic processes.
- Alien *I. pseudacorus* plants in California were less affected by increasing salinity and were exposed to deeper inundation water along the estuarine gradient than those native in Andalusia.

**RESULTS:**
The vigor of the invasive plants was reflected by higher specific leaf area, less leaf turnover, more rhizome carbon storage reserves, higher fruit and seed production, and greater seed mass than expression of these traits by native plants.

**Conclusions**
Functional trait differences suggest established populations of alien *I. pseudacorus* in the San Francisco Bay-Delta Estuary have adapted greater physiological capacity to adjust to environmental stresses induced by rising sea level than those in the native range (Guadalquivir Estuary, Spain).

Knowledge of these trait responses can be applied to improve weed risk assessments and protect estuarine ecosystems thru science-based IWM plans.
THANKS TO Cal-IPC and all COOPERATORS/PRACTITIONERS striving to improve weed management, environmental quality, and conservation of native California flora.

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Thanks for your interest!  
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