



Flipping the Script: Learning from Establishment Failure to Improve Water Hyacinth Biological Control

Mariani F.; Beets J.P. ; Borkent C.J.; Rector B.G.; Diaz R.

Water hyacinth: a highly invasive aquatic plant

DESCRIPTION

- **Free-floating** freshwater perennial plant.
- Reproduces primarily through **vegetative propagation via stolons**.
- Leaves are emergent, ovate.
- Flowers are purple with six petals.
- Petioles are spongy.
- Exhibits two growth forms: elongated or bulbous.



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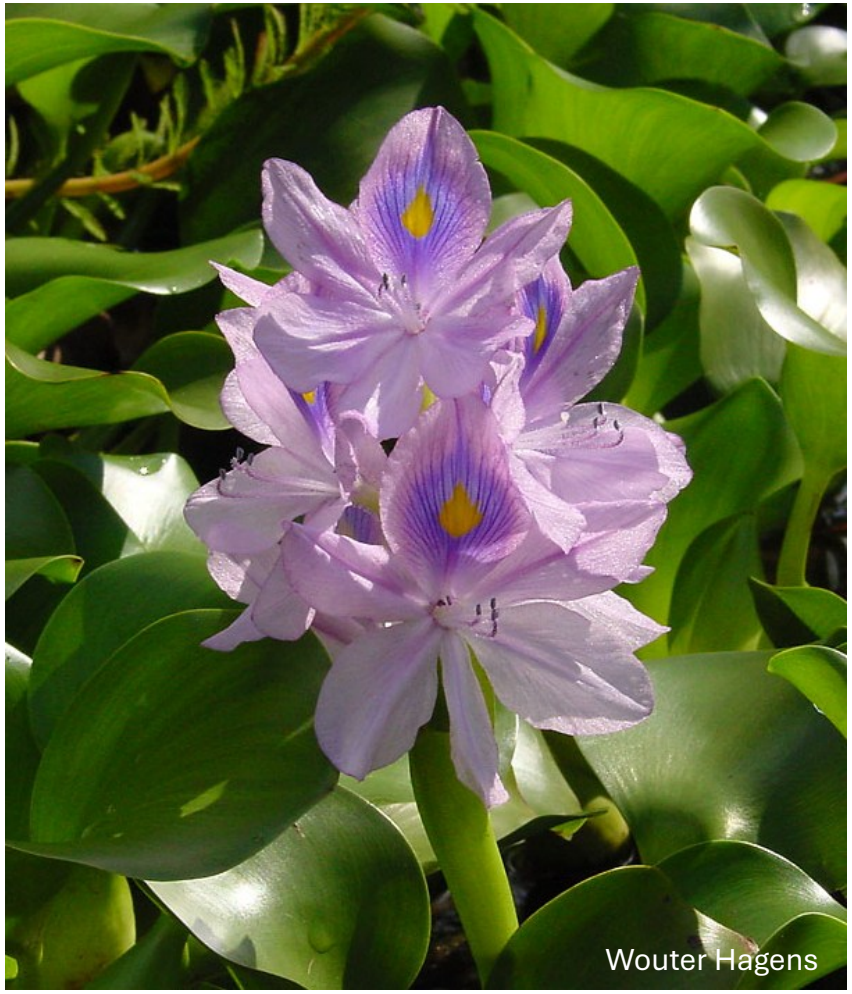

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Two distinct shoot types: elongated (left) and bulbous (right)

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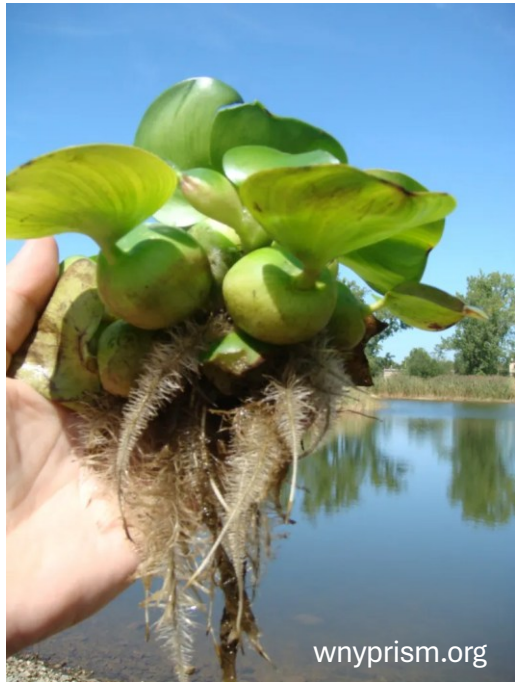



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SUMMARY OF INVASIVENESS

- *P. crassipes* is **native** to the **Amazon Basin** in South America (Julien, 2001)
- Introduced to the **U.S.** in the late **1800s** as an ornamental plant (Center, 1994)
- Rapidly spread across **aquatic systems worldwide**



LSU lakes, Baton Rouge, Louisiana

Four biological control agents released from South America against *P. crassipes* in the U.S.

MOTTLED WATER HYACINTH WEEVIL



© 2015 G. Montgomery

Neochetina eichhorniae

- Released in **1972**, **Florida**

Damage

Adults feed on leaves, creating characteristic scars that reduce plant vigor

CHEVRONED WATER HYACINTH WEEVIL



© 2009 J. Ott

Neochetina bruchi

- Released in **1974**, **Florida**

Damage

Similar feeding behavior to *N. eichhorniae, c*omplementary in impact (Heard and Winterton, 2000)

WATER HYACINTH MOTH



Niphograpta albiguttalis

- Released in **1977**, **Florida**

Damage

Larvae tunnel into petioles and stems, weakening the plant structure and buoyancy

WATER HYACINTH PLANTHOPPER



© 2025 T. Sparks

Megamelus scutellaris

- Released in **2013**, **Florida**

Damage

Nymphs and adults feed on sap, reducing plant growth and reproduction

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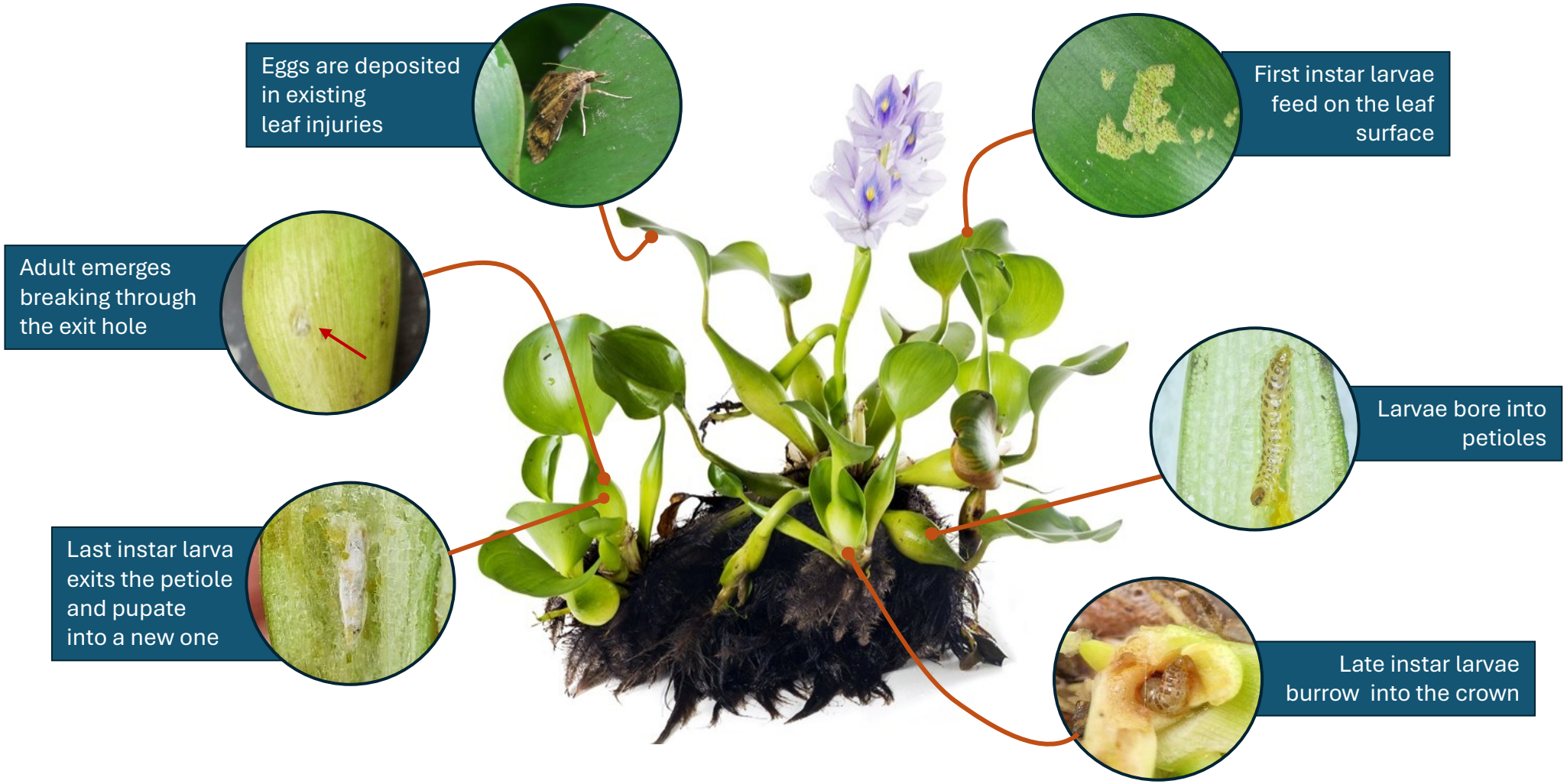
Tunneling larvae of *Niphograpta* damage vital tissues of water hyacinth



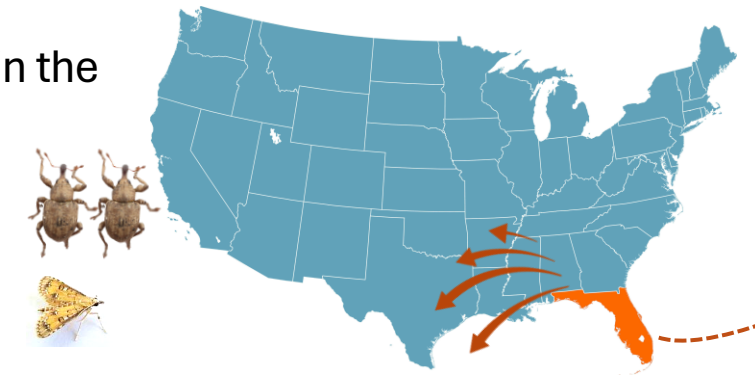
History of Water Hyacinth Biocontrol in the U.S.

GULF COAST (FLORIDA)

Biocontrol began in the **1960s** (USDA-ARS).

Agents released in the **1970s** :

- *N. eichhorniae*
- *N. bruchi*
- *N. albiguttalis*

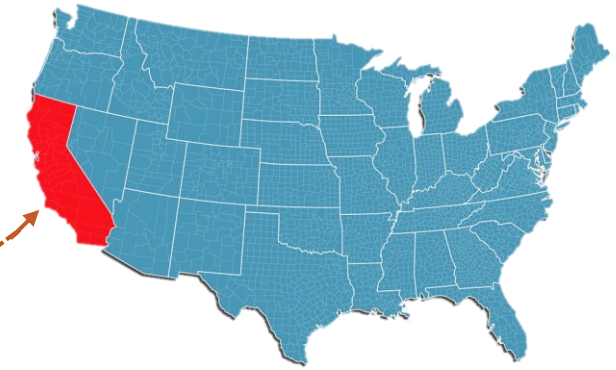


Outcomes:

- All successfully **established** (Tipping et al. 2014)
- Used to redistribute to other regions

CALIFORNIA (SACRAMENTO–SAN JOAQUIN DELTA)

Biocontrol began in **1982.**



Agents introduced:

- *Neochetina* spp. (from TX)
- *N. albiguttalis* – (from FL & LA, 1984)



Outcomes:

- *Neochetina* spp. established by **1985**
- *N. albiguttalis* **disappeared after 1989** (Akers et al., 2017)

Water hyacinth remains a major challenge in the Sacramento–San Joaquin Delta, California



A mechanical harvester starts from east end of Stockton Yacht Club mowing down the hyacinth. Photo: Roger Kelly

Botany

Water Hyacinth Thrives in Drought Stricken Delta

by Ted Andersen

December 22, 2014

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Sacramento-San Joaquin River Delta: Battle...

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Sacramento-San Joaquin River Delta: Battle continues against water weeds

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2. NCAA Tournament: Early look at Sweet 16 teams coming to San Francisco
3. Saint Mary's unable to upset No. 2 Alabama for Sweet 16 spot, 80-66
4. Update: Beach hazards statement issued for Bay Area Shorelines until Tuesday night
5. Photos: Spain SailGP wins Oracle San Francisco SailGP Final
6. Former Utah Rep. Mia Love, the first Black Republican woman elected to the US House, has died



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State begins effort to control Delta invasive plants

Staff Reports Mar 9, 2023 Updated Mar 9, 2023

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Understanding why some agents fail to establish is key to improving control efforts.

Main goal: Understand the conditions that support *Niphograpta albiguttalis* establishment in the southeastern U.S.

Specific objectives:

- Quantify *N. albiguttalis* **presence** and **density** across sites
- Identify **factors** linked to insect success

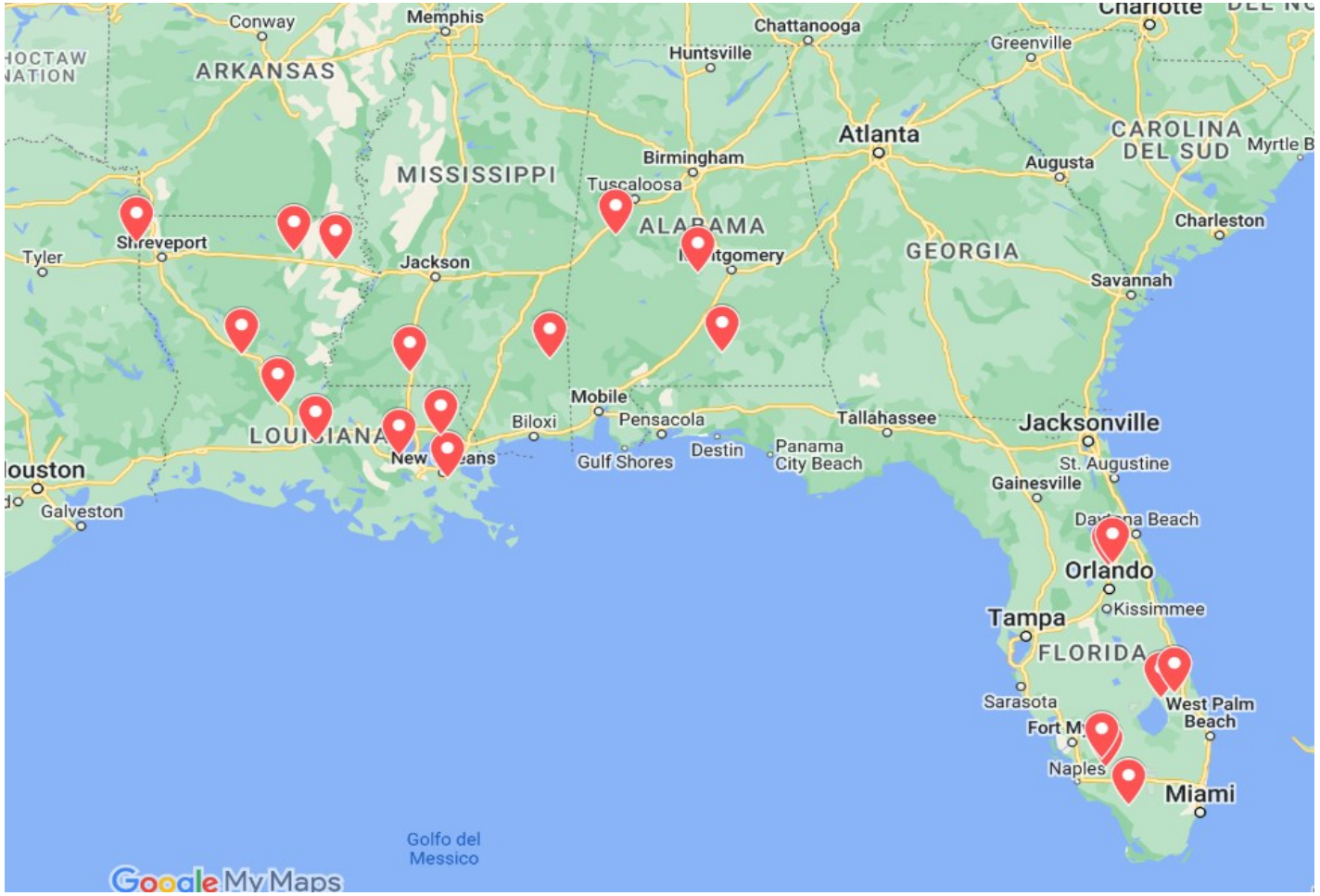
Hypotheses:

Insect establishment is influenced by:

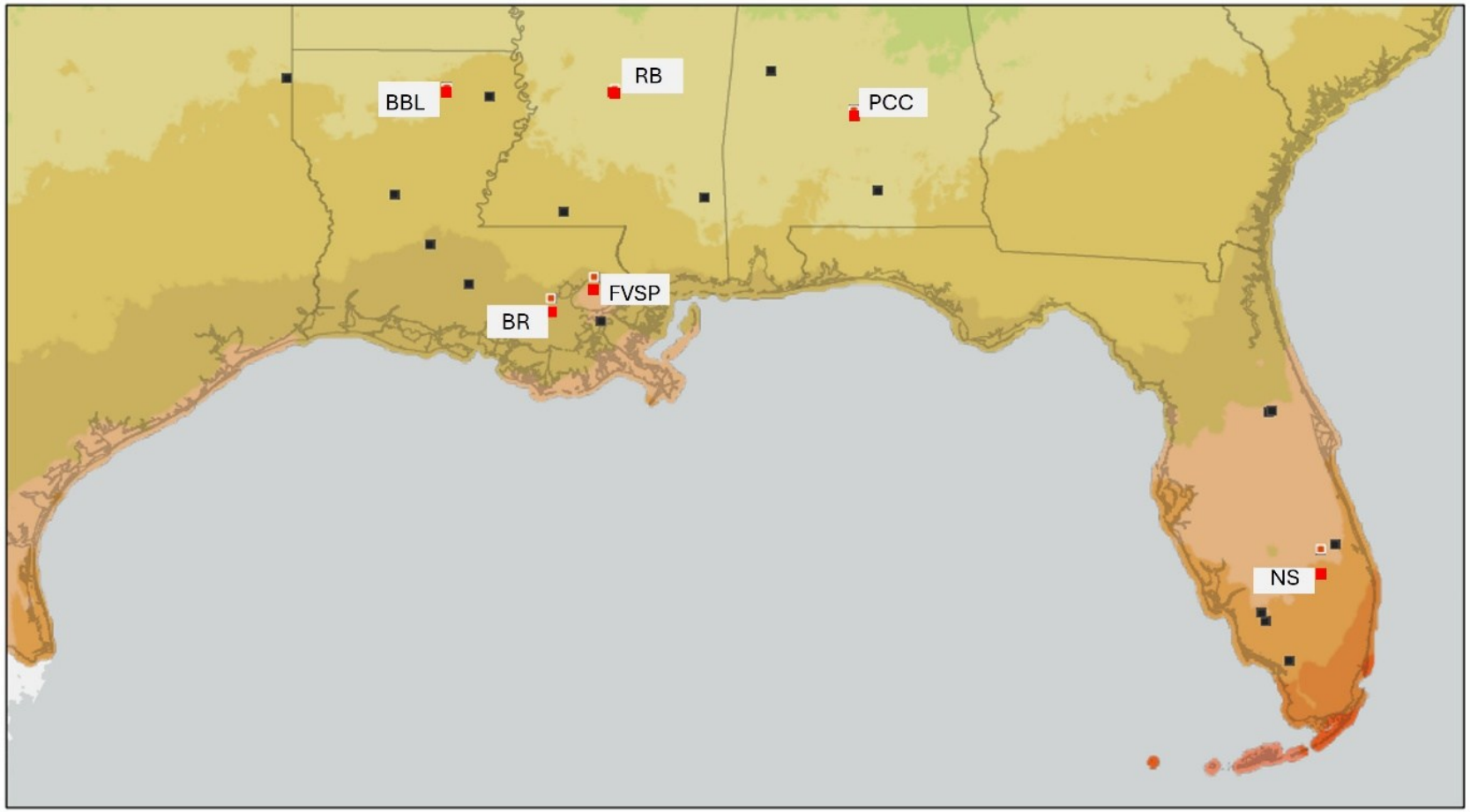
- **Latitude**
- Water **chemistry** and **nutrients**
- Host **plant characteristics** (e.g. softness, C/N, growth form)
- Herbivore **competition**



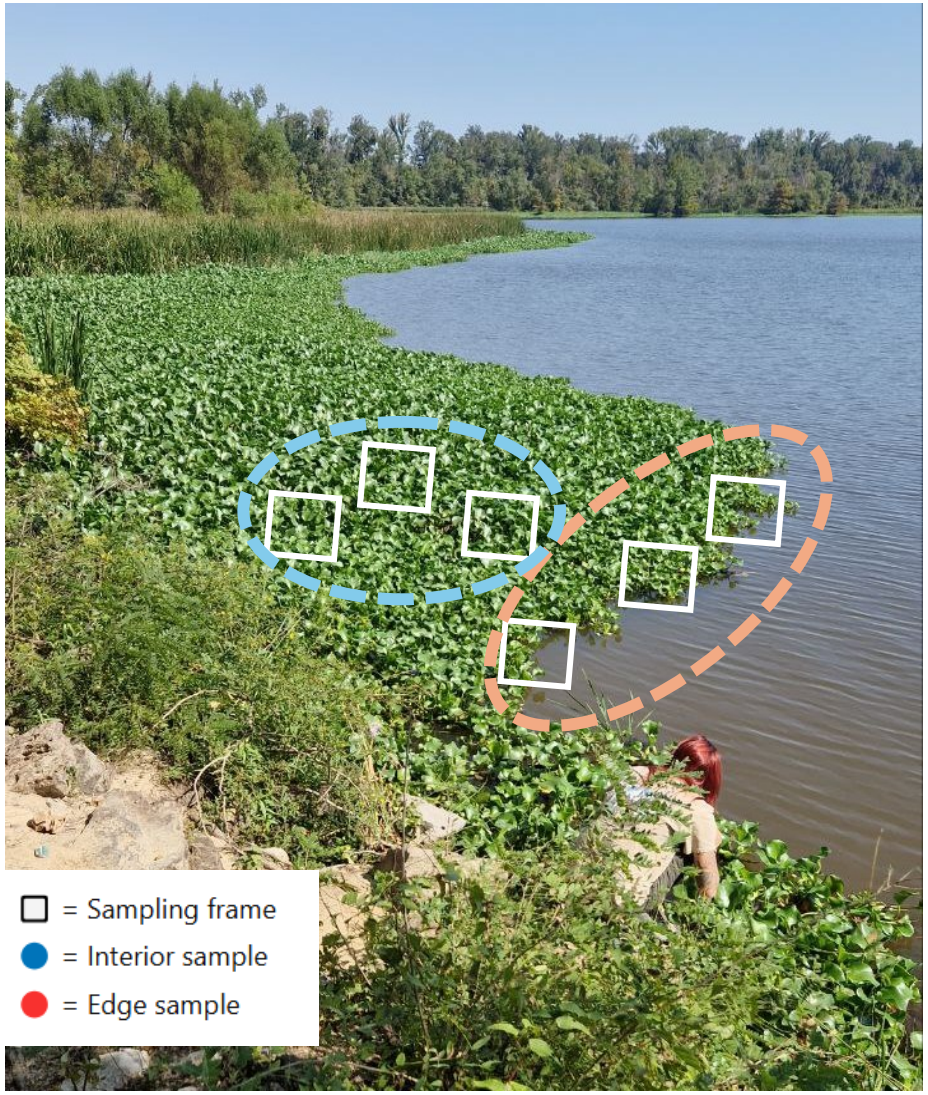
Field study across 22 sites spanning 8° of latitude (25–32°N)



Field study across 22 sites spanning 5 zones of USDA cold hardiness map



Field collection protocol for water hyacinth plants



Sampling method

- At each site: 6 replicate samples using a 28 × 28 cm PVC frame
  - **3 external samples**
  - **3 interior samples**
- All plants with roots within the frame were collected
- Samples stored in labeled bags (site, replicate, ext/int)
- Transported to the lab for analysis
- Water quality on site with probe
- Water sample for lab analyses

Measured parameters across sampling sites

🐛 Natural enemies

Niphograpta albiguttalis

- Number of larvae
- Number of adults
- Damage presence

***Neochetina* spp.**

- N. of larvae
- N. of *N. bruchii* adults
- N. of *N. eichhorniae* adults
- Damage level (n. of feeding scars)

Mites

- Presence recorded (0/1)

🌿 Plant parameters

- Number of plants (per quadrat)
- Growth form (B/E)
- Height, width (cm)
- Tissue hardness (N)
- Biomass (g)
- Carbon (C), Nitrogen (N)



💧 Water parameters

Water quality – Physical

- Temp (°C), Pressure (mmHg)
- SPC, Conductivity, TDS, Salinity

Water quality – Chemical

- pH, ORP (mV), DO (% and mg/L)
- Alkalinity
- Ca, Mg, Fe, Mn, K, Na, S, Cl
- Hardness, Total salts

Field sampling during the day…







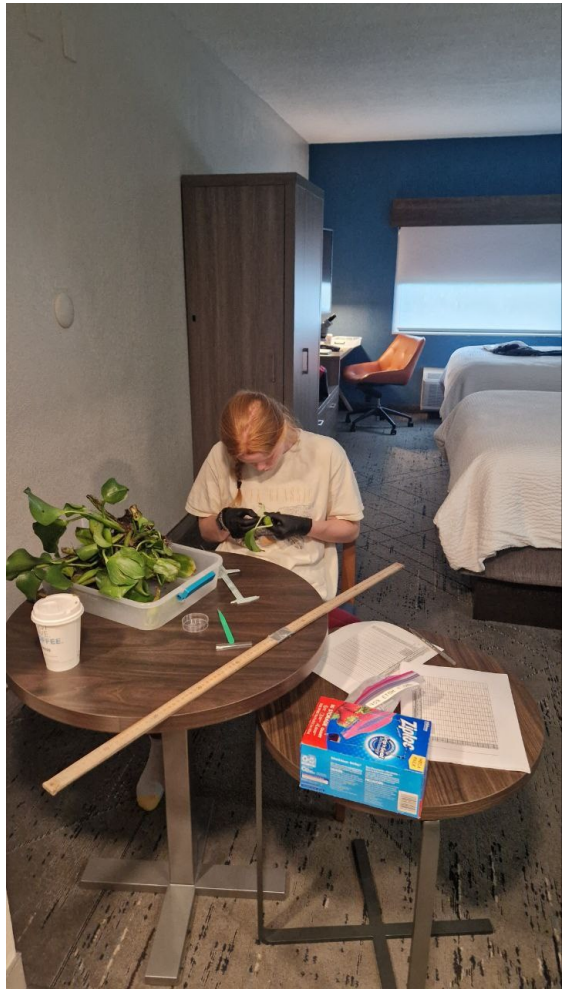


…lab processing later in the night









Simple visual cues and plant dissection help detect herbivore presence in the field

	N. albiguttalis		*Neochetina* spp.		Mite
PRESENCE OF INSECT					
DAMAGE BY INSECT					

Extensive field dataset for biotic and abiotic conditions across 22 sites

4/0 Cols	Date	Latitude	Site	Int/...	IntExt...	Rep	Num pla...	B/E	height	Niphlo ...	Num...	Neoch...	Neo...	Num...	Mite da...	Hardne...	water temp...	pressure ...	dissolved ...	sp. Co...	pH pr...	alkalinity	hardness	man...	nitrate in ...	sodium	carbon...	nitrat...	total...	C:N	Total ...	Density ...	Pred...
2312	10/08...	31,40...	SL	INT	0	2	30	E	29,9	0	0	45	1	0	0	-4,36	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2313	10/08...	31,40...	SL	INT	0	2	31	E	29,9	0	0	11	1	0	0	-4,36	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2314	10/08...	31,40...	SL	INT	0	2	32	E	29,9	0	0	50	1	0	0	-4,36	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2315	10/08...	31,40...	SL	EXT	1	1	1	B	8,98	0	0	21	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2316	10/08...	31,40...	SL	EXT	1	1	2	B	8,98	0	0	4	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2317	10/08...	31,40...	SL	EXT	1	1	3	B	8,98	0	0	2	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2318	10/08...	31,40...	SL	EXT	1	1	4	B	8,98	0	0	36	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2319	10/08...	31,40...	SL	EXT	1	1	5	B	8,98	0	0	49	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2320	10/08...	31,40...	SL	EXT	1	1	6	B	8,98	0	0	10	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2321	10/08...	31,40...	SL	EXT	1	1	7	B	8,98	0	0	24	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2322	10/08...	31,40...	SL	EXT	1	1	8	B	8,98	0	0	2	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2323	10/08...	31,40...	SL	EXT	1	1	9	B	8,98	0	0	31	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2324	10/08...	31,40...	SL	EXT	1	1	10	B	8,98	0	0	19	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2325	10/08...	31,40...	SL	EXT	1	1	11	B	8,98	0	0	23	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2326	10/08...	31,40...	SL	EXT	1	1	12	B	8,98	0	0	0	1	1	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...
2327	10/08...	31,40...	SL	EXT	1	1	13	B	8,98	0	0	10	1	0	0	-2,18	26,7	751,8	109,4	84,3	7,54	39,04	30,66	0	1,77	2,88	39,...	0,...	0	57,6...	2	0	0,...

- Dataset includes ~ **3,000 water hyacinth petioles** sampled across 22 sites
- Each row corresponds to an individual petiole
- A total of **48 variables** were recorded

What explains *Niphograpta albiguttalis* establishment?

Two complementary analyses:

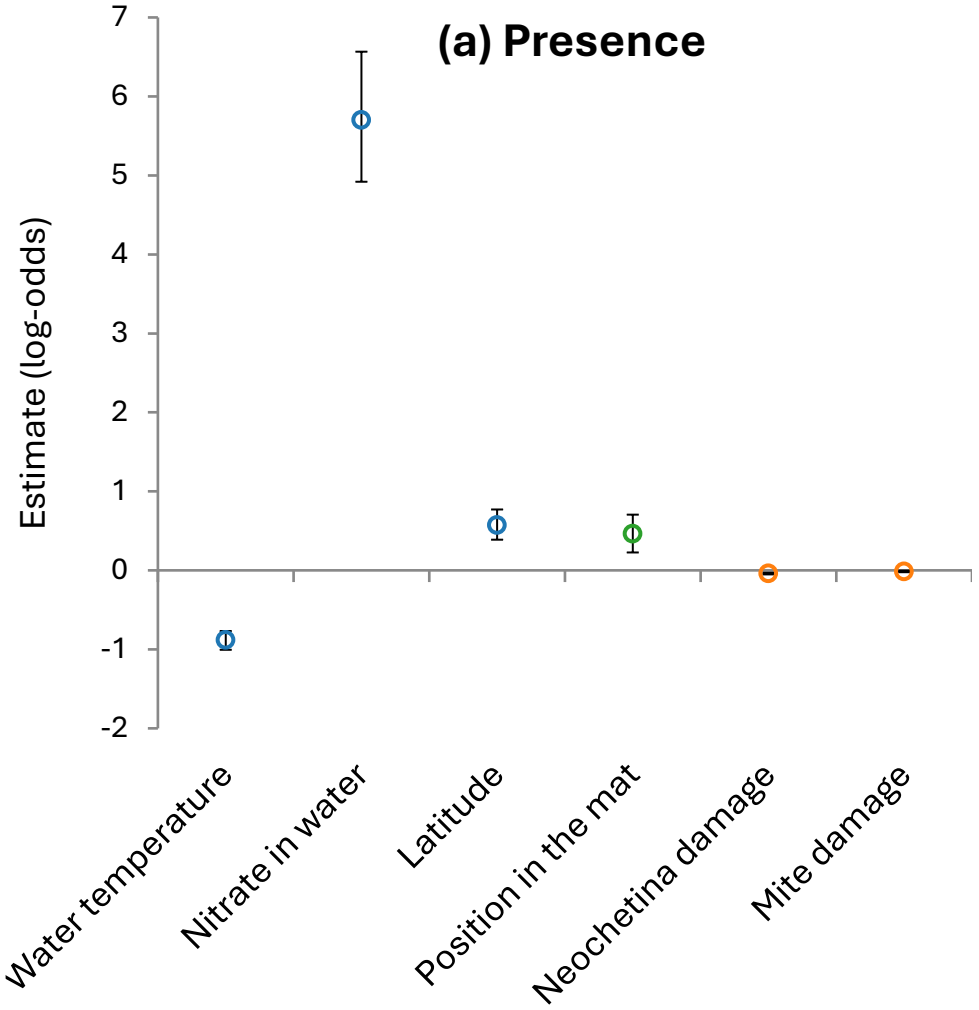
- **Presence** analysis: *What determines **where** the insect is found?*
  Model: **GLM** (Binomial Distribution)

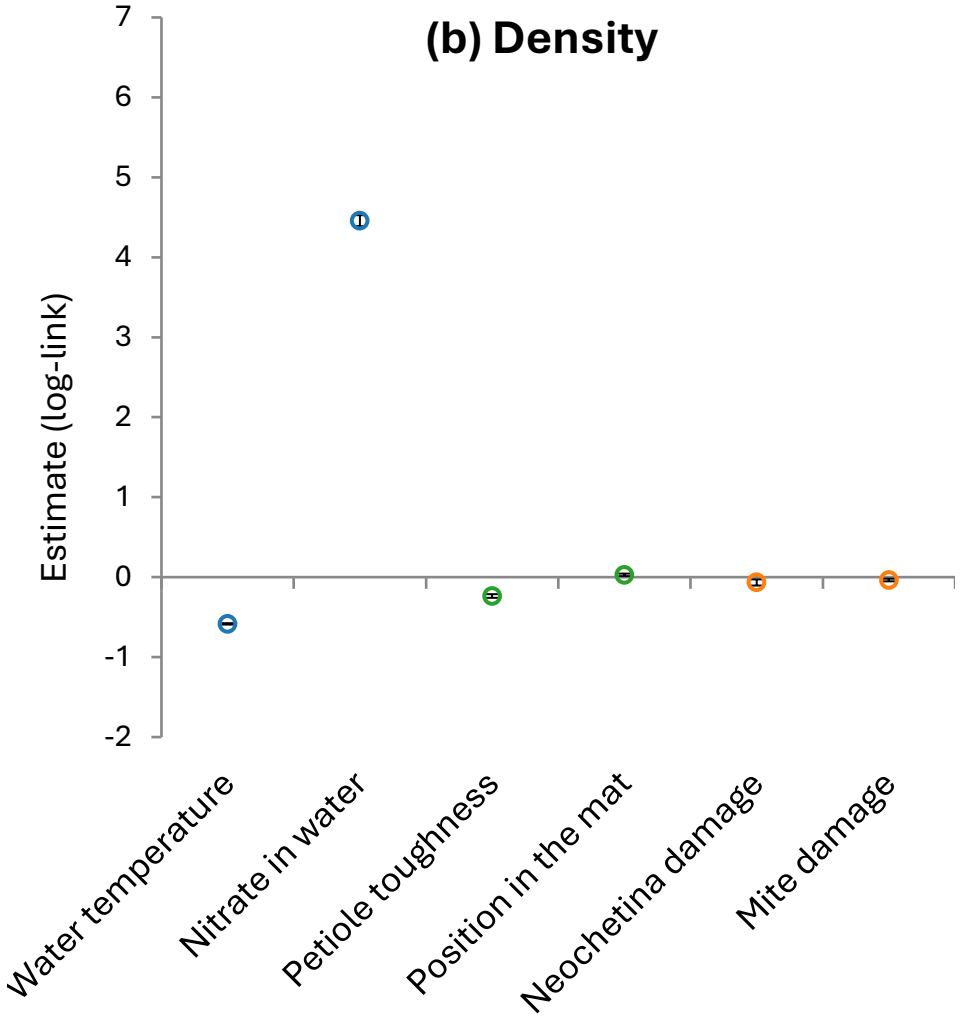
- **Density** analysis: *What determines **how abundant** the insect is?*
  Model: **Generalized Regression** (Gamma distribution)

Predictor variables

- **Latitude**
- **Plant traits**: growth form, size, hardness, C/N, etc.
- **Water parameters**: temperature, pH, nutrients, hardness
- **Natural enemies**: *Neochetina*, mites

Generalized models for **presence** and **density** identified the same drivers





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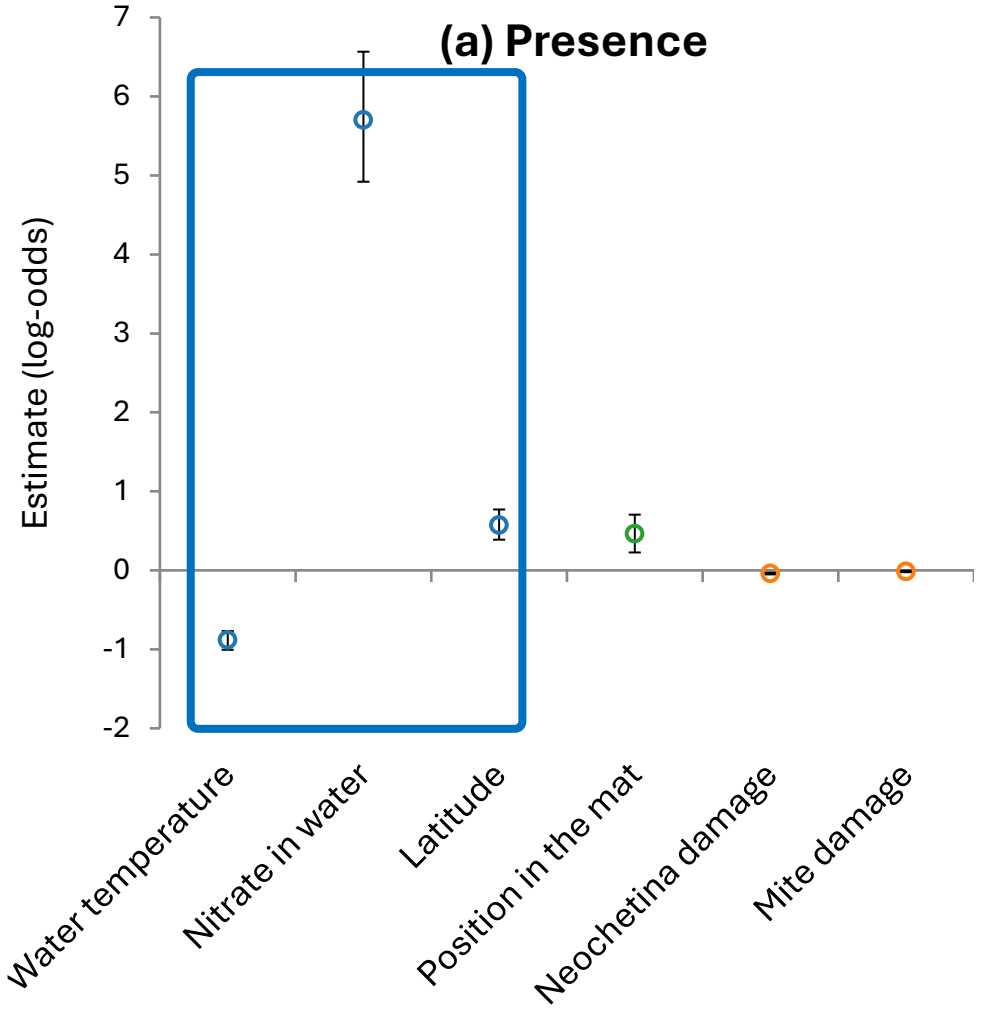

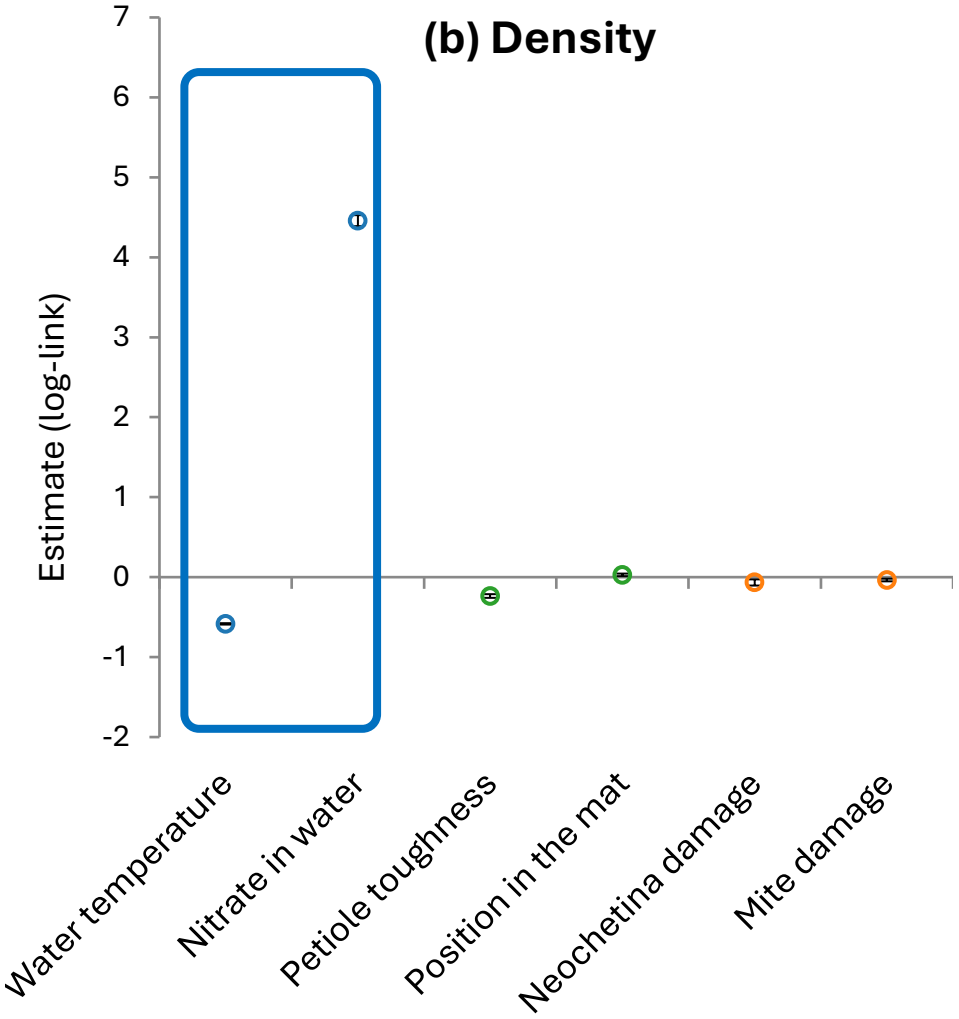

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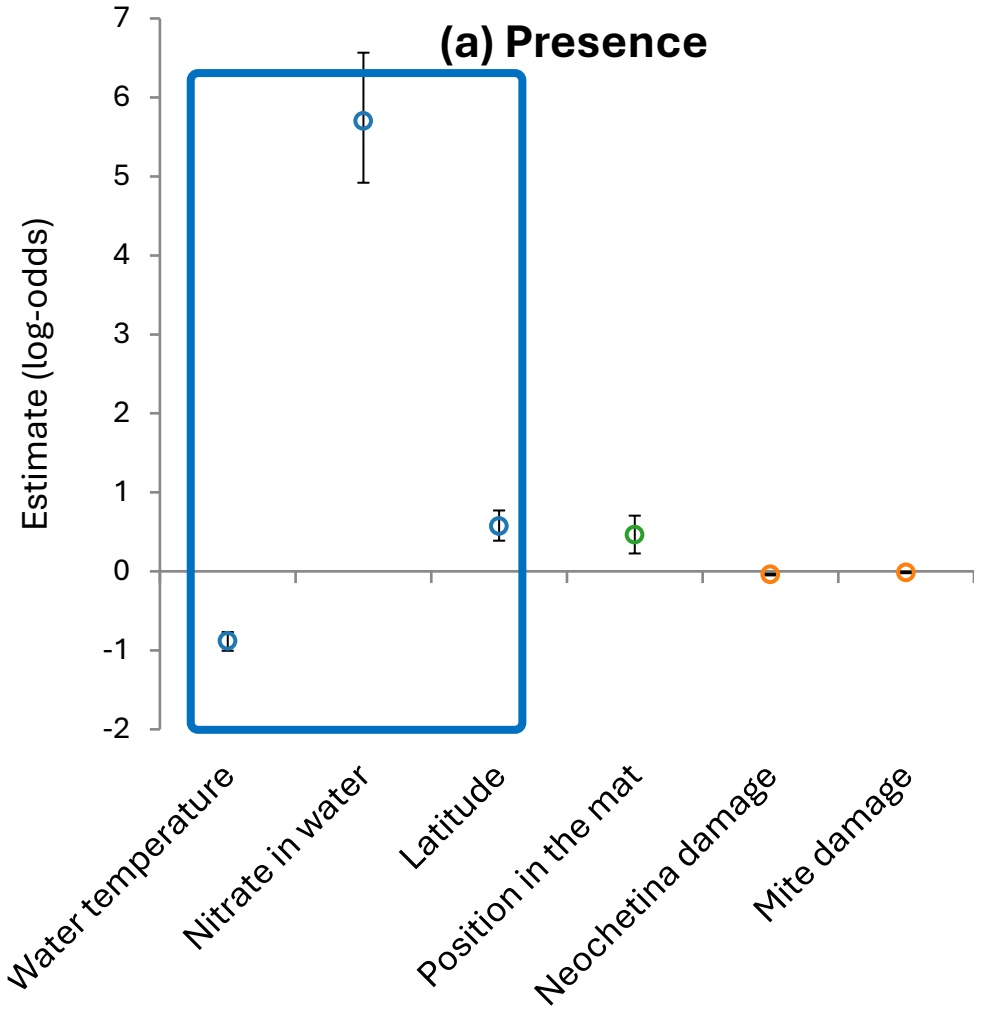
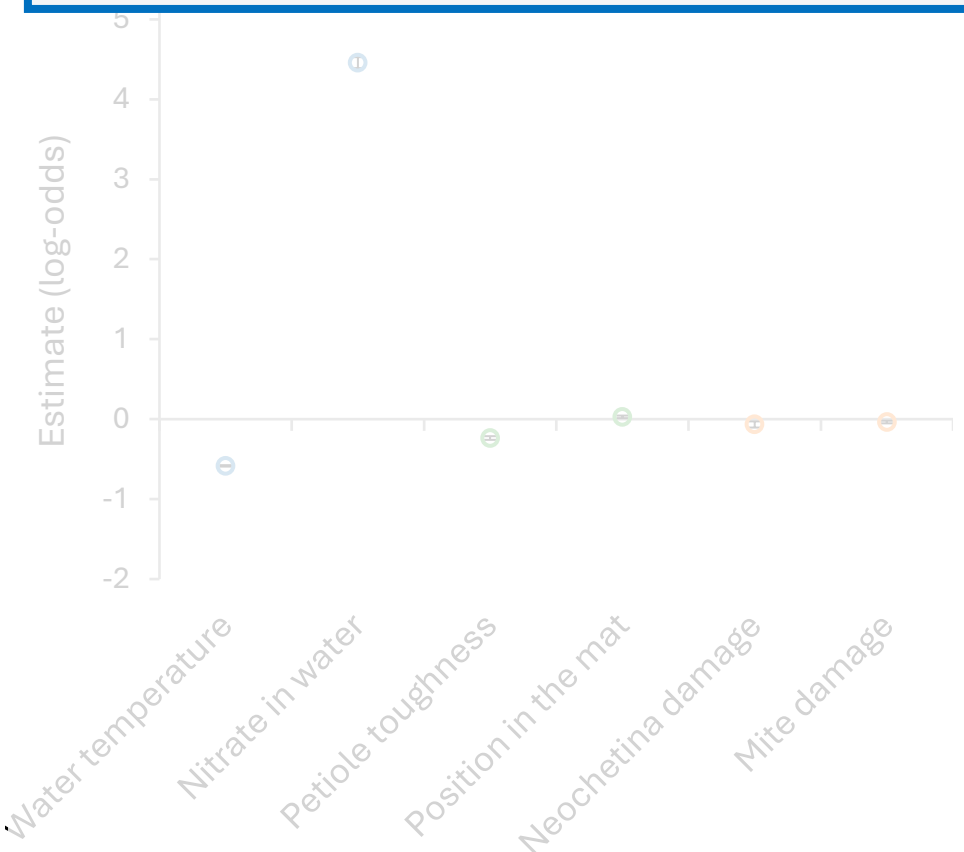


Higher nitrate levels likely indicate nutrient-rich plants → more attractive for larvae.



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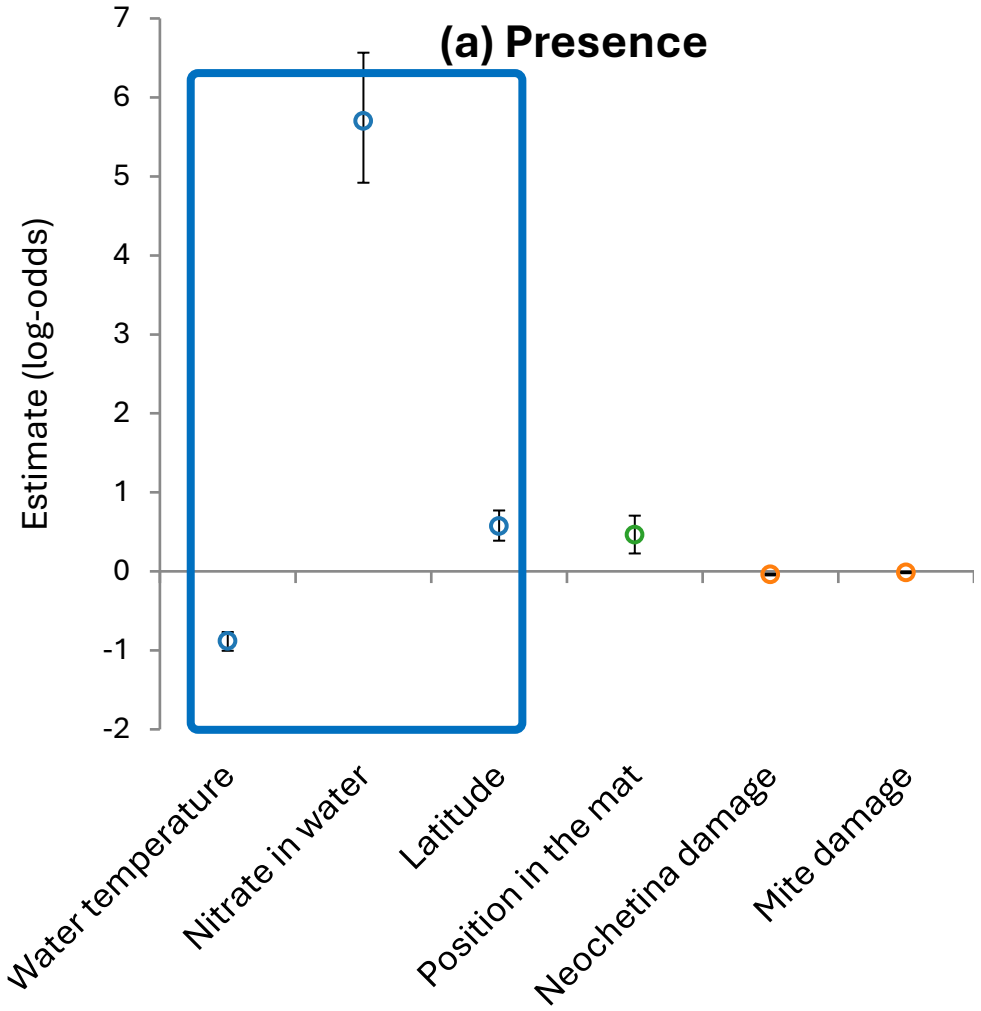

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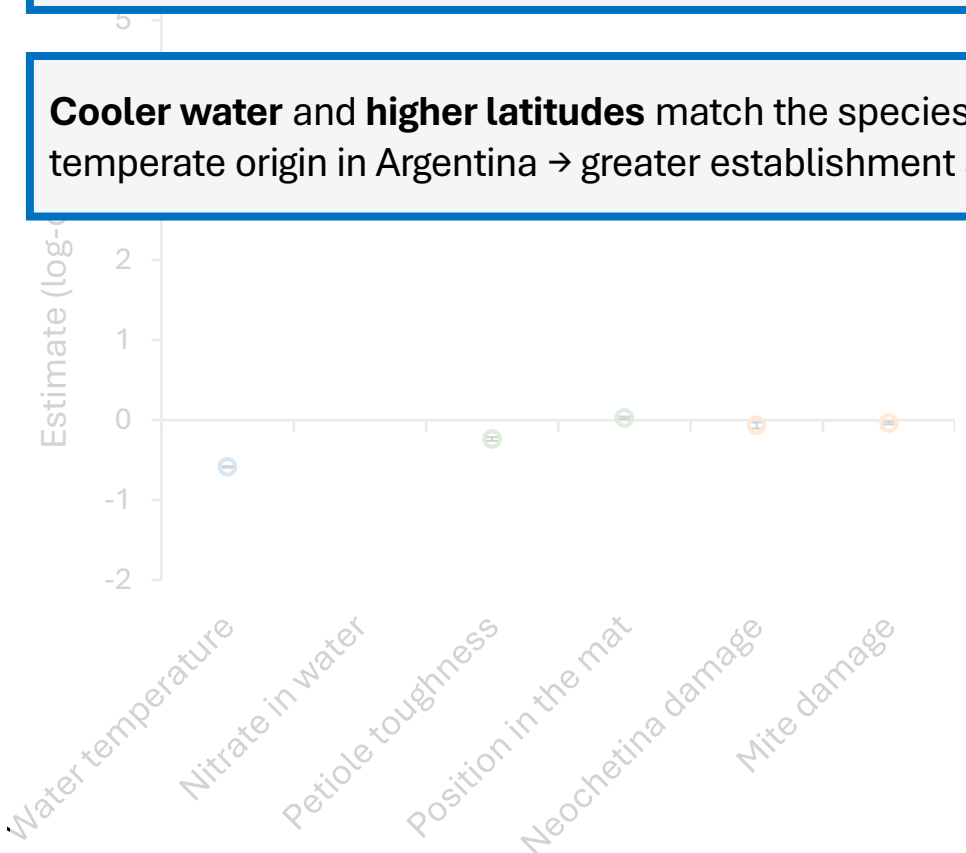
Cooler water and **higher latitudes** match the species' temperate origin in Argentina → greater establishment success.



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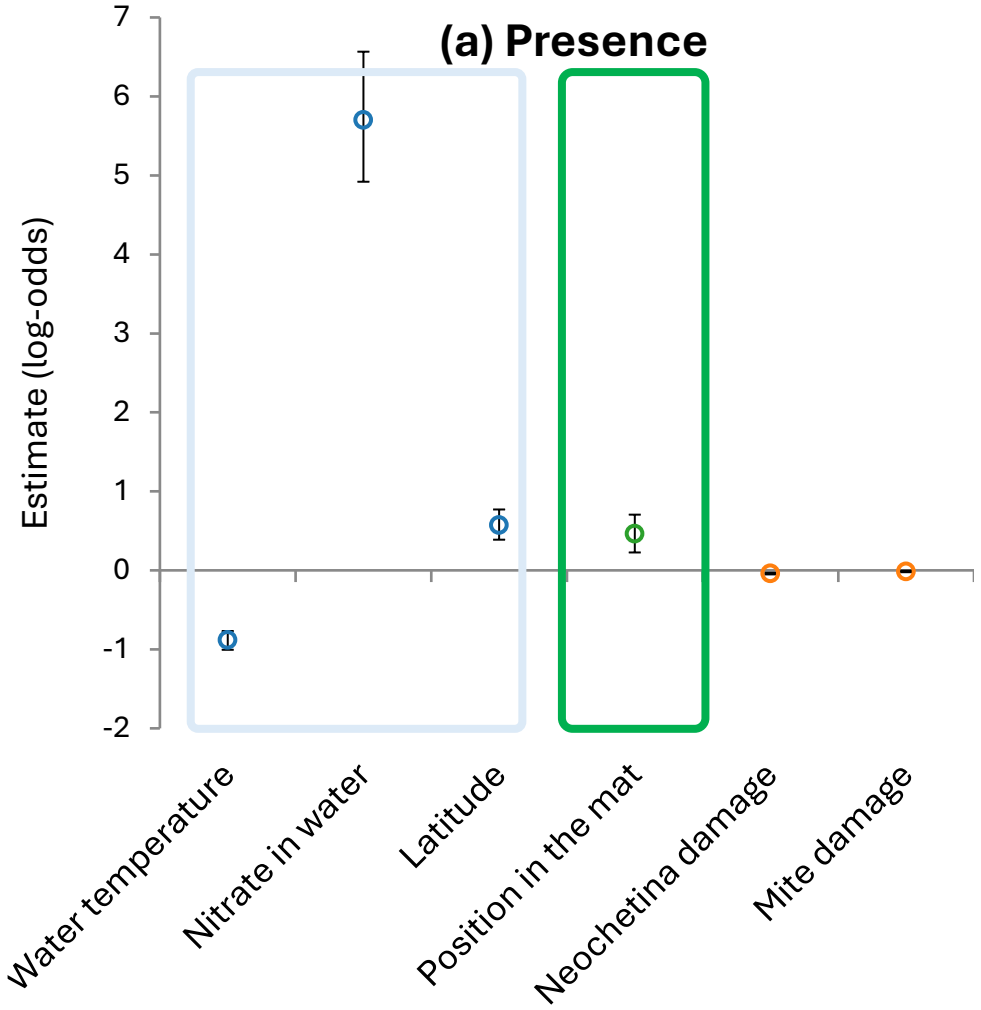

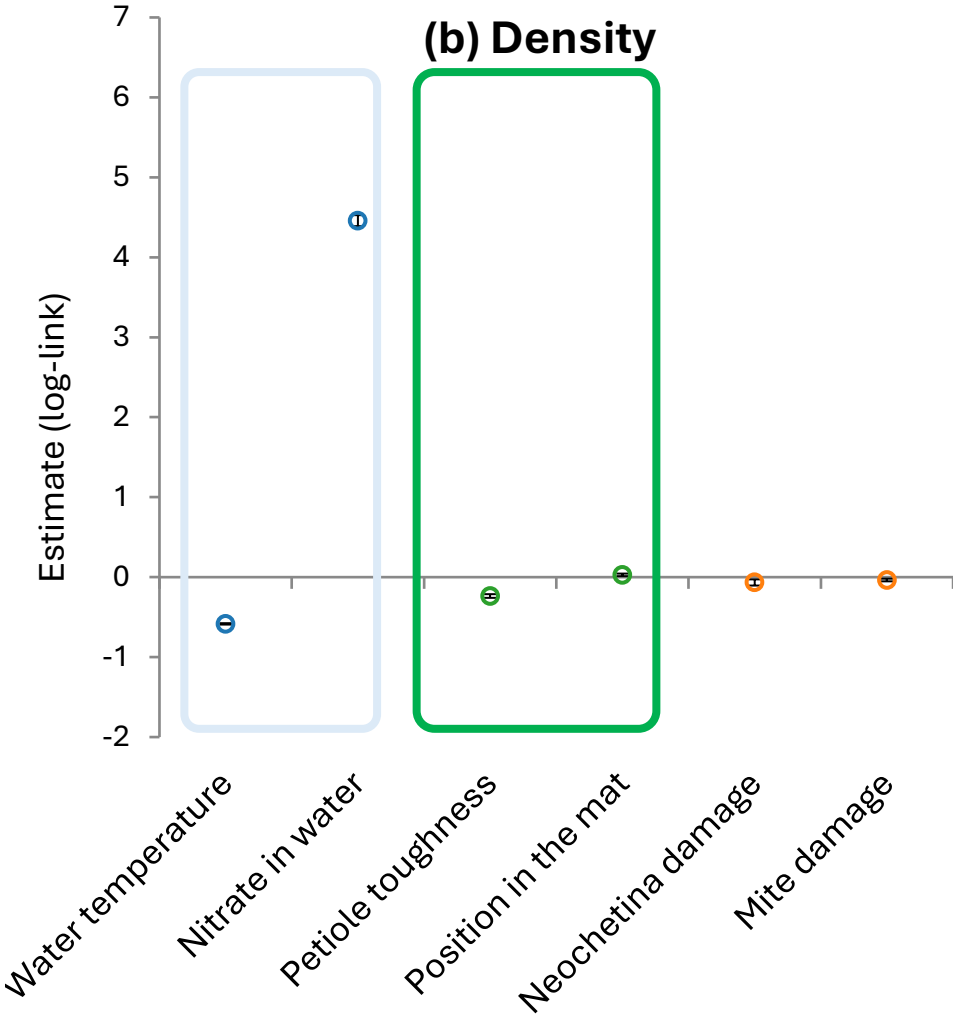

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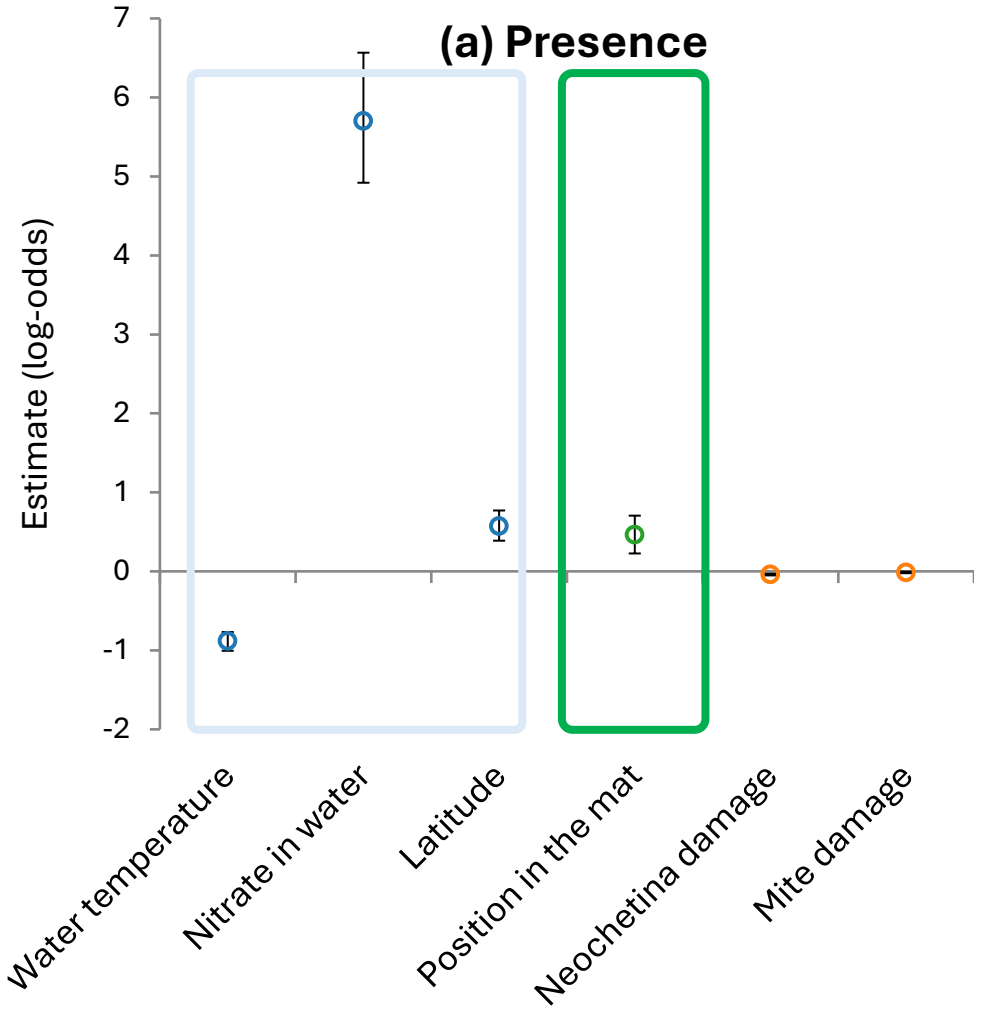
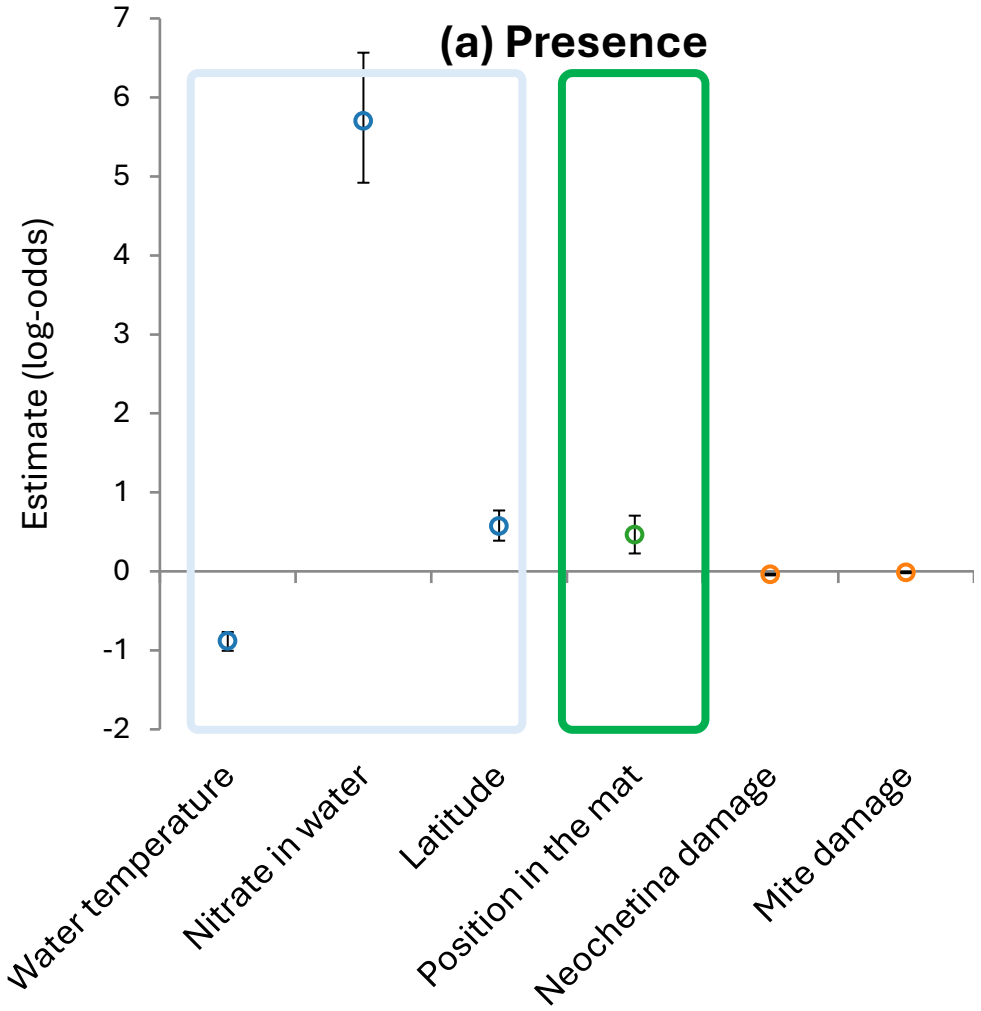


Higher nitrate levels likely indicate nutrient-rich plants → more attractive for larvae.

Cooler water and **higher latitudes** match the species' temperate origin in Argentina → greater establishment success.

Internal position in the mat offers a stable, protected microclimate → higher larval survival.

Generalized models for **presence** and **density** identified the same drivers



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Cooler water and **higher latitudes** match the species' temperate origin in Argentina → greater establishment success.

Internal position in the mat offers a stable, protected microclimate → higher larval survival.

Softer plant tissues → easier feeding and and bore for larvae

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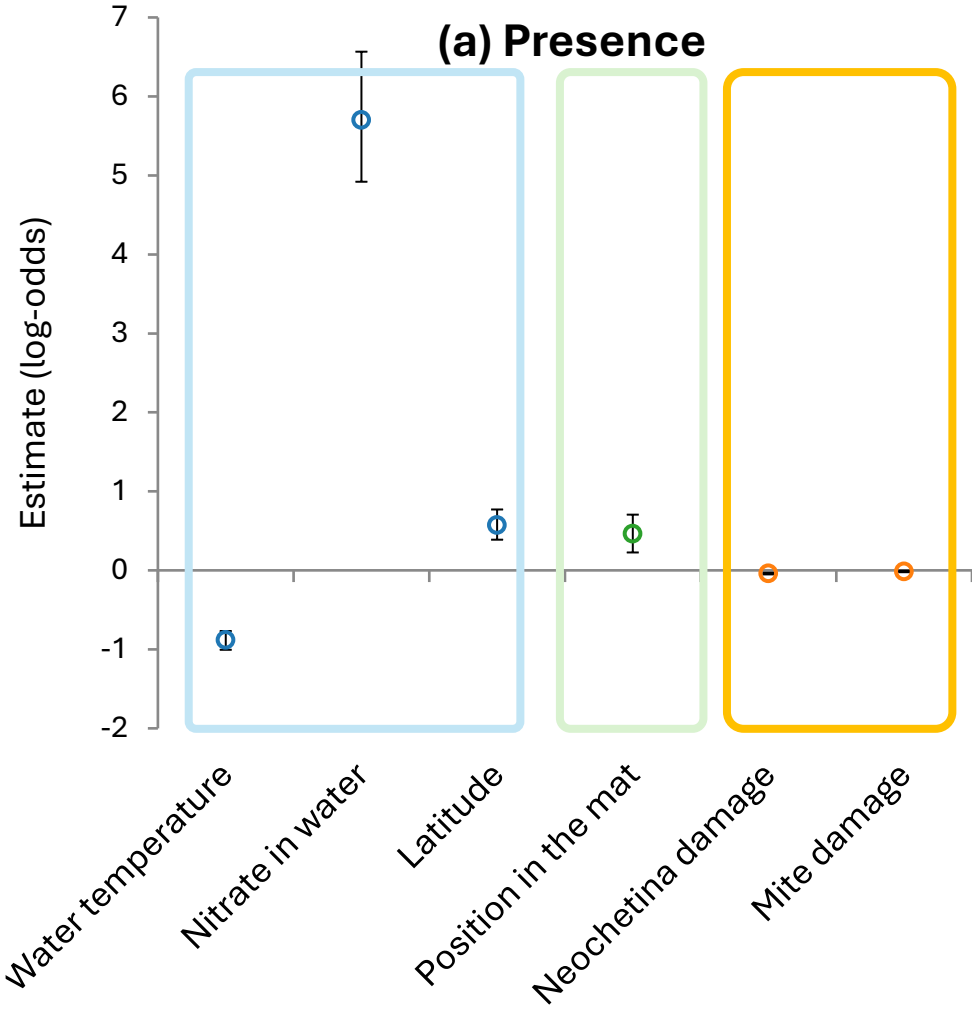
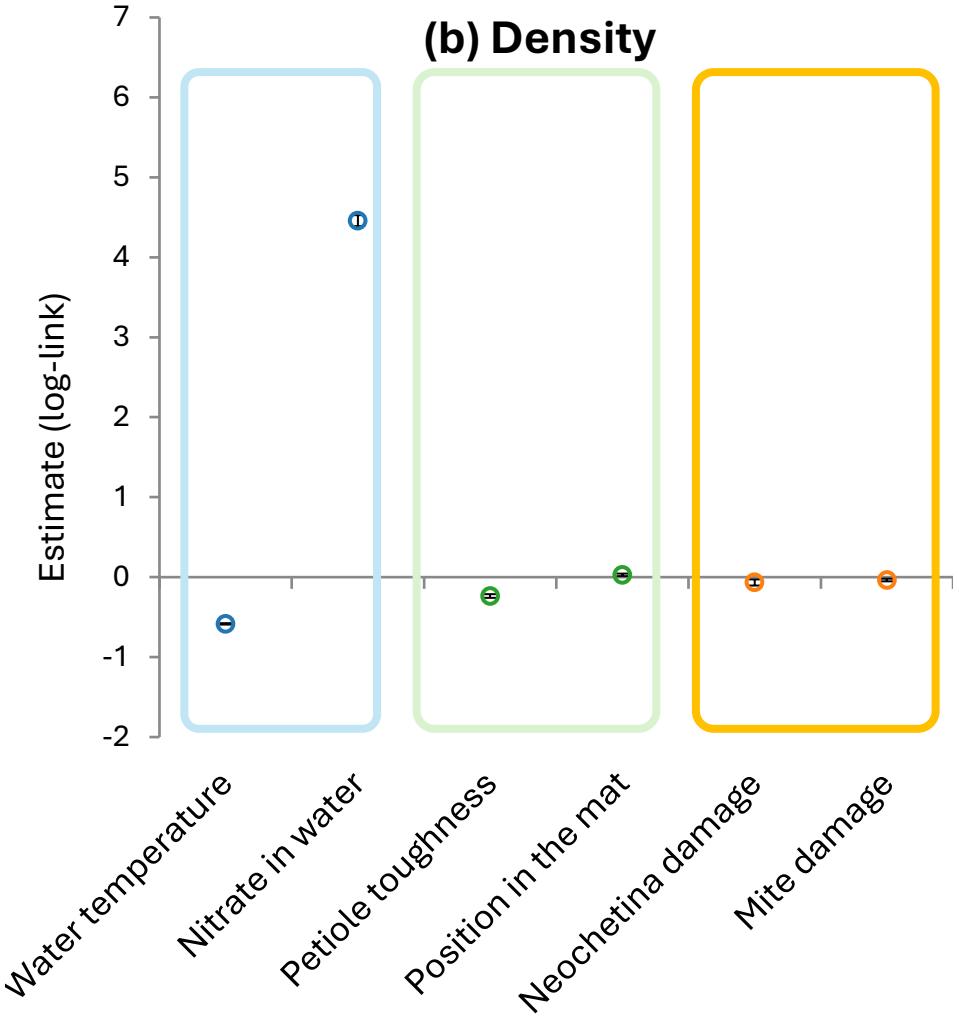
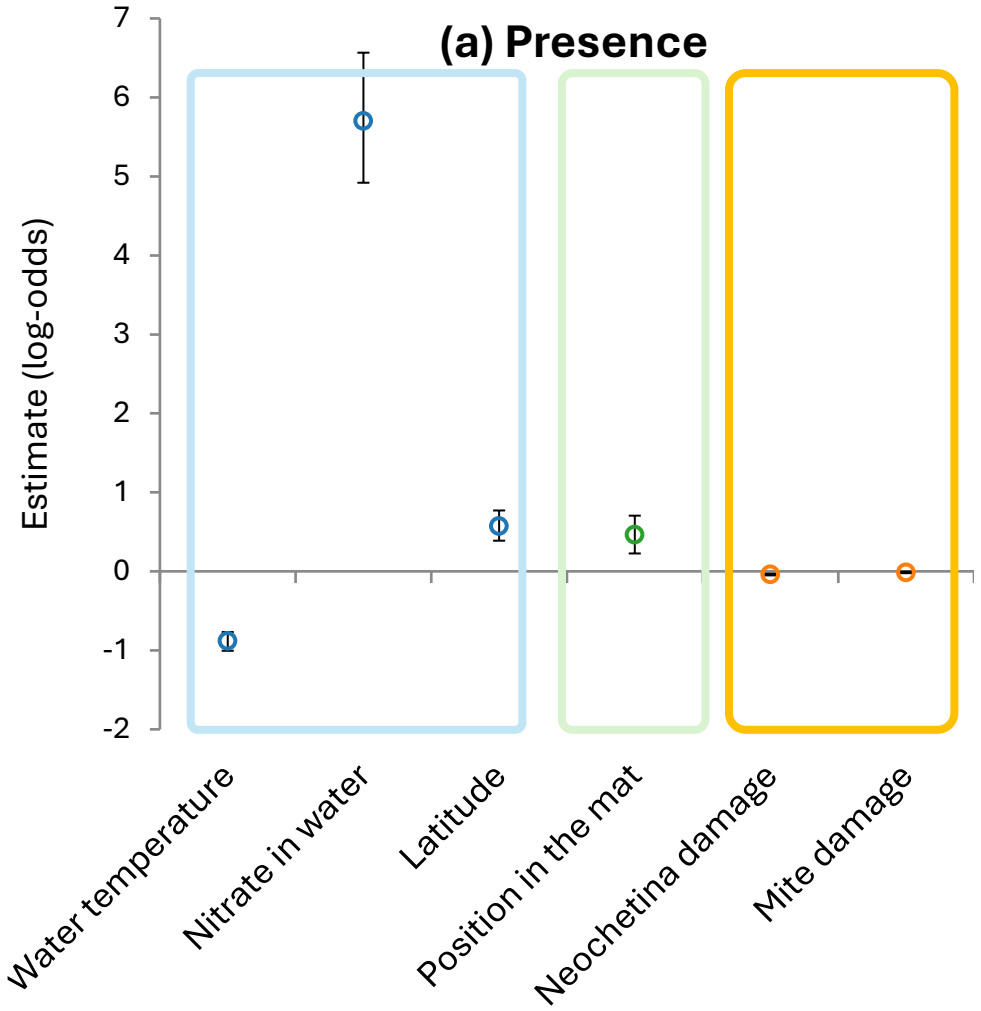




Generalized models for **presence** and **density** identified the same drivers



Higher nitrate levels likely indicate nutrient-rich plants → more attractive for larvae.

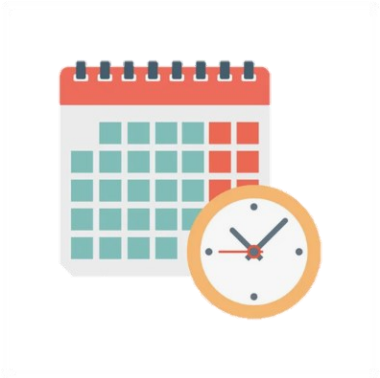
Cooler water and **higher latitudes** match the species' temperate origin in Argentina → greater establishment success.

Internal position in the mat offers a stable, protected microclimate → higher larval survival.

Softer plant tissues → easier feeding and and bore for larvae

Weevil and **mite damage** → hardened tissues and reduced larval establishment (Wright and Boland, 1989)

Management recommendations for *Niphograpta* release in the Sacramento–San Joaquin Delta



Timing of release
Plan timing of releases to coincide with periods when **water temperature** reaches **25–26 °C**



Plant and site selection
Target **soft, nutrient-rich** water hyacinth plants, in the **internal part of the infestation** mat for release of larvae.



Biotic interactions
Avoid release in areas with **visible mite or weevil damage**, as existing herbivores may **interfere with *Niphograpta* establishment**.

Lessons from *Niphograpta*: future directions for water hyacinth management in the Delta

1 MATCH RELEASE CONDITIONS

Select suitable sites, host plants, and release timing.

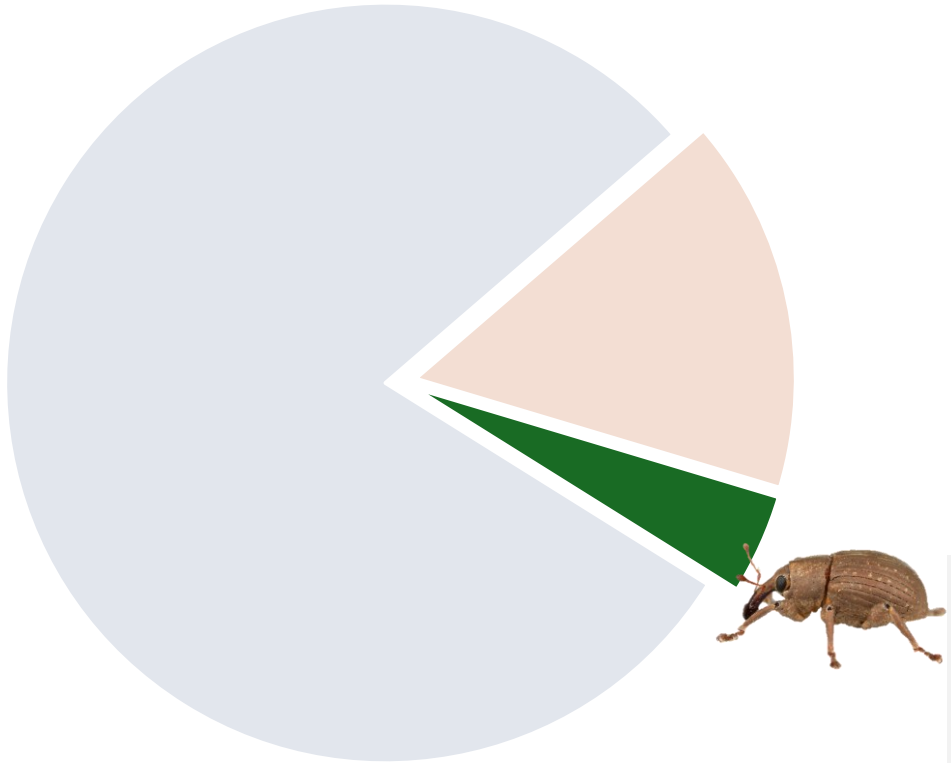


2 AUGMENTATION

Develop mass rearing to support repeated, strategic releases.



Developing a biological control plan for water hyacinth in the Delta

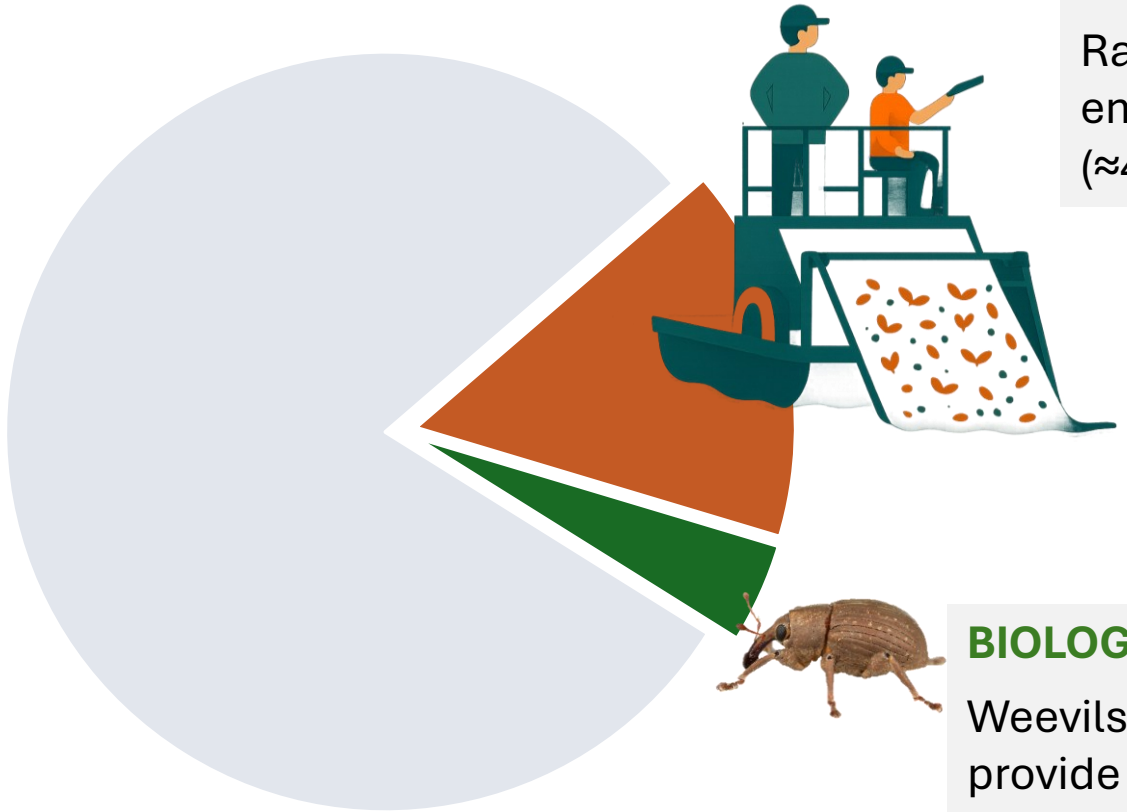


BIOLOGICAL CONTROL

Weevils are present, but provide no measurable suppression

(Caudill et al., 2021)

Developing a biological control plan for water hyacinth in the Delta



MECHANICAL CONTROL

Rare, only in emergencies (≈4 ha in 2018)

BIOLOGICAL CONTROL

Weevils are present, but provide no measurable suppression

(Caudill et al., 2021)

Developing a biological control plan for water hyacinth in the Delta

CHEMICAL CONTROL

Herbicides remain the foundation of Delta management





MECHANICAL CONTROL

Rare, only in emergencies (≈4 ha in 2018)

BIOLOGICAL CONTROL

Weevils are present, but provide no measurable suppression

(Caudill et al., 2021)

Our goal:



Shifting from reactive, short-term control to sustained, system-level management

Developing a biological control plan for water hyacinth in the Delta

MOTTLED WATER HYACINTH WEEVIL

© 2015 G. Montgomery

Neochetina eichhorniae

- Released in 1972, Florida

Damage

Adults feed on leaves, creating characteristic scars that reduce plant vigor

CHEVRONED WATER HYACINTH WEEVIL

© 2009 J. Ott

Neochetina bruchi

- Released in 1974, Florida

Damage

Similar feeding behavior to *N. eichhorniae, c*omplementary in impact (Heard and Winterton, 2000)

WATER HYACINTH MOTH

Niphograpta albiguttalis

- Released in 1977, Florida

Damage

Larvae tunnel into petioles and stems, weakening the plant structure and buoyancy

WATER HYACINTH PLANTHOPPER



© 2025 T. Sparks

Megamelus scutellaris

- Released in 2013, Florida

Damage

Nymphs and adults feed on sap, reducing plant growth and reproduction

Why *Megamelus*? The South African experience



Hartbeespoort Dam

- Hypertrophic system
- Herbicides stopped (2017)
- Water hyacinth ~40% cover

(Miller et al. 2020, Coetzee et al. 2022, Miller et al. 2023, Moffat et al. 2024)

Why *Megamelus*? The South African experience





Hartbeespoort Dam

- Hypertrophic system
- Herbicides stopped (2017)
- Water hyacinth ~40% cover

Augmentative *Megamelus* releases

- 6–10k every 2 weeks
- Cover: **37% → 3%** **in the growing season**

(Miller et al. 2020, Coetzee et al. 2022, Miller et al. 2023, Moffat et al. 2024)

Sustainable Management of Water Hyacinth in the Sacramento–San Joaquin Delta

MASS REARING AND RELEASES

Repeated releases **early** in the season



LOWER HERBICIDE RATES

Identify effective lower rates with biocontrol



FIELD EVALUATION

Test strategies in the Delta





A DELTA-SPECIFIC INTEGRATED MANAGEMENT STRATEGY FOR WATER HYACINTH

Thank you!

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