Successful Management & Eradication of Nuisance Aquatic Plants

Lars Anderson, PhD
Waterweed*Solutions*
Inverness, CA- USA

Parrotfeather in Pt Reyes National Seashore- Estero Trail *Februrary 2015*

***Topics*:**

- ✧ Water, Human Behavior & Attitudes
- ✧ Defining the Problem and Setting Goals
- ✧ Examples of Management & Eradication

- *Hydrilla (Ca. vs. Florida and most of SE US)*
- *Caulerpa (marine invasive alga- California)*
- *Brazilian waterweed (California Delta system)*
- *Eurasian watermilfoil, Curlyleaf pondweed- at Lake Tahoe*
- New Technologies: Management and Monitoring

WATER is Personal!

WATER: is Essential !

Water from the Sacramento-San Joaquin Delta, California:
> 25 million Californians drink it!

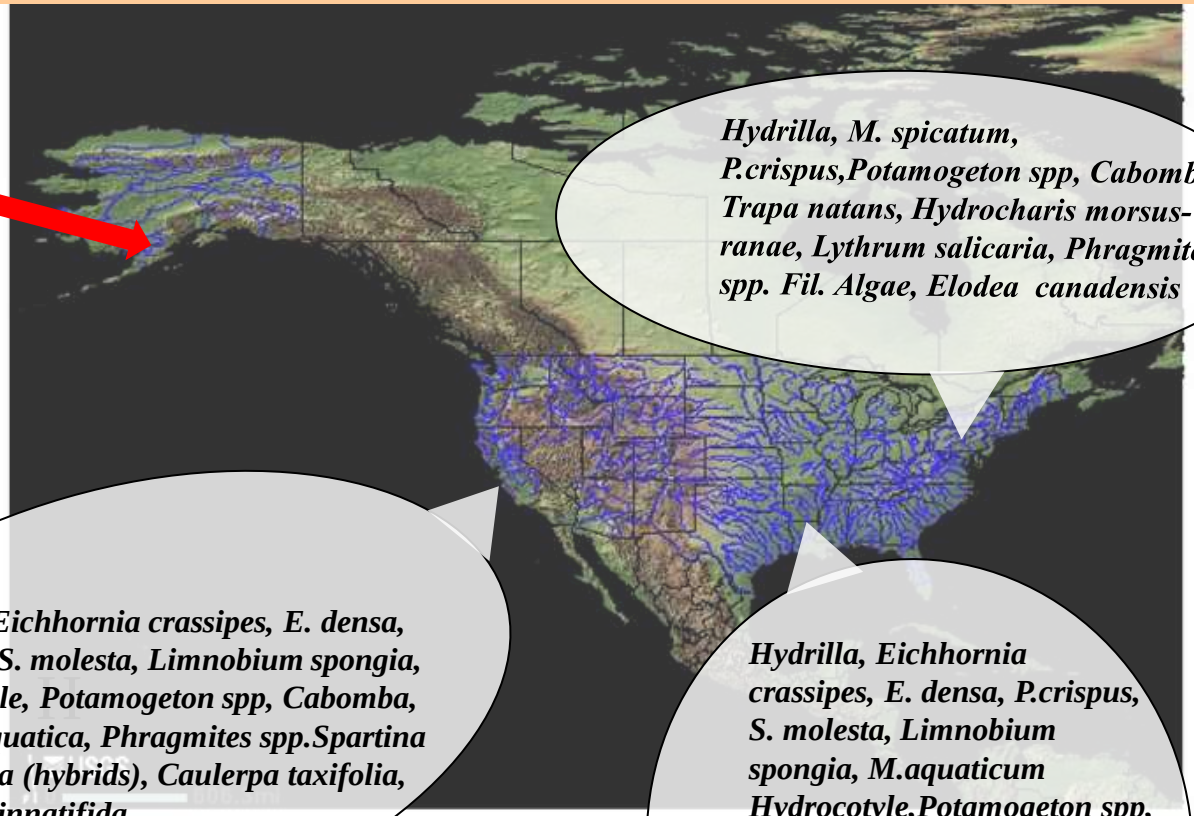
Egeria densa covered with algae- 2005

Myriophyllum spicatum

We Actively Protect Our Precious Waters:

- US EPA - Clean Water Act, FIFRA, as amended (Pesticide uses)
- NOAA & USFWS (Endangered species)
- Army Corps of Engineers (Physical, bottom disturbance)
- US BOR (Storage, Irrigation, Flood Control)
- USDA: APHIS, Forest Service & Agricultural Research Service
- State and Local Agency Statutes and Ordinances
- Non-profit Groups and Private Stakeholders
- Voluntary Public Stakeholders

General US Distribution of Major Aquatic Weeds



Elodea canadensis

Hydrilla, M. spicatum, P.crispus,Potamogeton spp, Cabomba, Trapa natans, Hydrocharis morsus-ranae, Lythrum salicaria, Phragmites spp. Fil. Algae, Elodea canadensis

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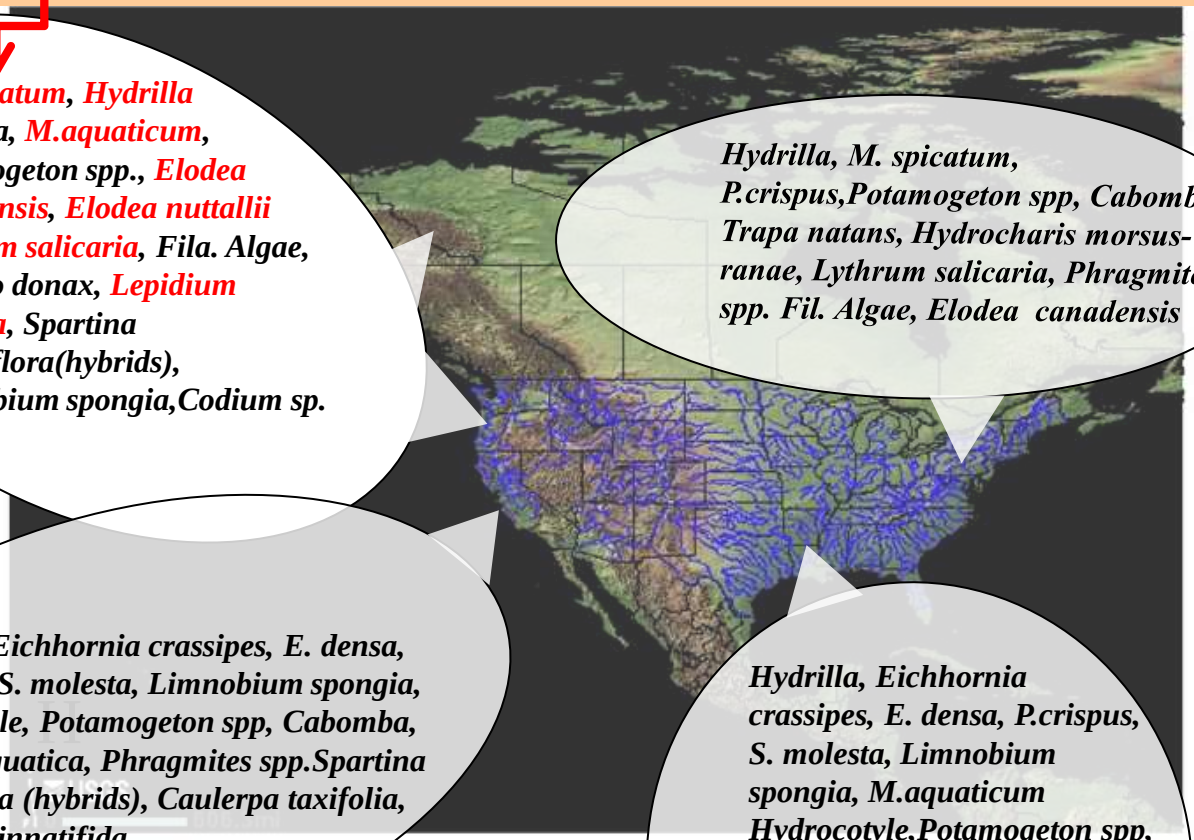
Hydrilla, Eichhornia crassipes, E. densa, P.crispus, S. molesta, Limnobium spongia, M.aquaticum Hydrocotyle,Potamogeton spp, Cabomba, Panicum repens, Hygrophila polysperma, Pistia stratiotes, Lythrum salicariaColocasia esculeta, Ipomoea aquatica, Landoltia punctata, Caulerpa spp.

General US Distribution of Major Aquatic Weeds

Look Who's Knocking on Alaska's Doors?



***M. spicatum*, *Hydrilla* E.densa, *M.aquaticum*, Potamogeton spp., *Elodea canadensis*, *Elodea nuttallii* *Lythrum salicaria*, Fila. Algae, Arundo donax, *Lepidium latifolia*, Spartina alterniflora(hybrids), Limnobium spongia,Codium sp.**

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Northeast USA Only

NOT IN USA YET (?)

Trapa natans

Lagarosiphon major

Negative Impacts of *Nuisance Aquatic Plants and Algae*

- ✓**Biodiversity: Lakes, Reservoirs, Rivers, Streams, Wetlands, Marsh**
- ✓**Flood control**
- ✓**Navigation (recreational, law-enforcement and commercial vessels)**
- ✓**Recreational : swimming, fishing, skiing, sailing**
- ✓**Native habitats (waterfowl, fish, invertebrates, plants)**
- ✓**Water quality (dissolved oxygen, pH, nutrients, organic loading)**
- ✓**Sediment loading and erosion (nutrients and metals loading)**
- ✓**Health (mosquito habitat > arthropod-borne diseases)**
- ✓**Economy: Property values, Commerical uses, Tourism Revenue**
- ✓**SOURCES OF CONTINUED SPREAD**

Examples of Costs for Aquatic Plant Management/ Eradication Projects

- ✓***Hydrilla verticillata*: $50 million/yr (Management)**
  >Eradication in Calif. & Washington: $3 million/yr
- ✓***Egeria densa*: $5 million per year (Management)**
- ✓***Myriophyllum* spp.: $25 million per year (Management)**
- ✓***Eichhornia crassipes*: $20 million per year (Management)**
- ✓***Lythrum salicaria*: $200,000 per year (Management)**
- ✓***Salvinia molesta*: $100,000 per year (Management/eradication)**
- ✓***Spartina alterniflora*: $200,000/yr (Calif., Wash. Management)**
- ✓***Caulerpa taxifolia*: $7 million (7-years> Eradication declared in 2006)**
- ✓**Others (*Arundo donax*, *Maleleuca*, *Shinus*, *Solanum viarum*, *Potamogeton*, *Panicum repens*, *Phragmites*, and algae): $100 million??**

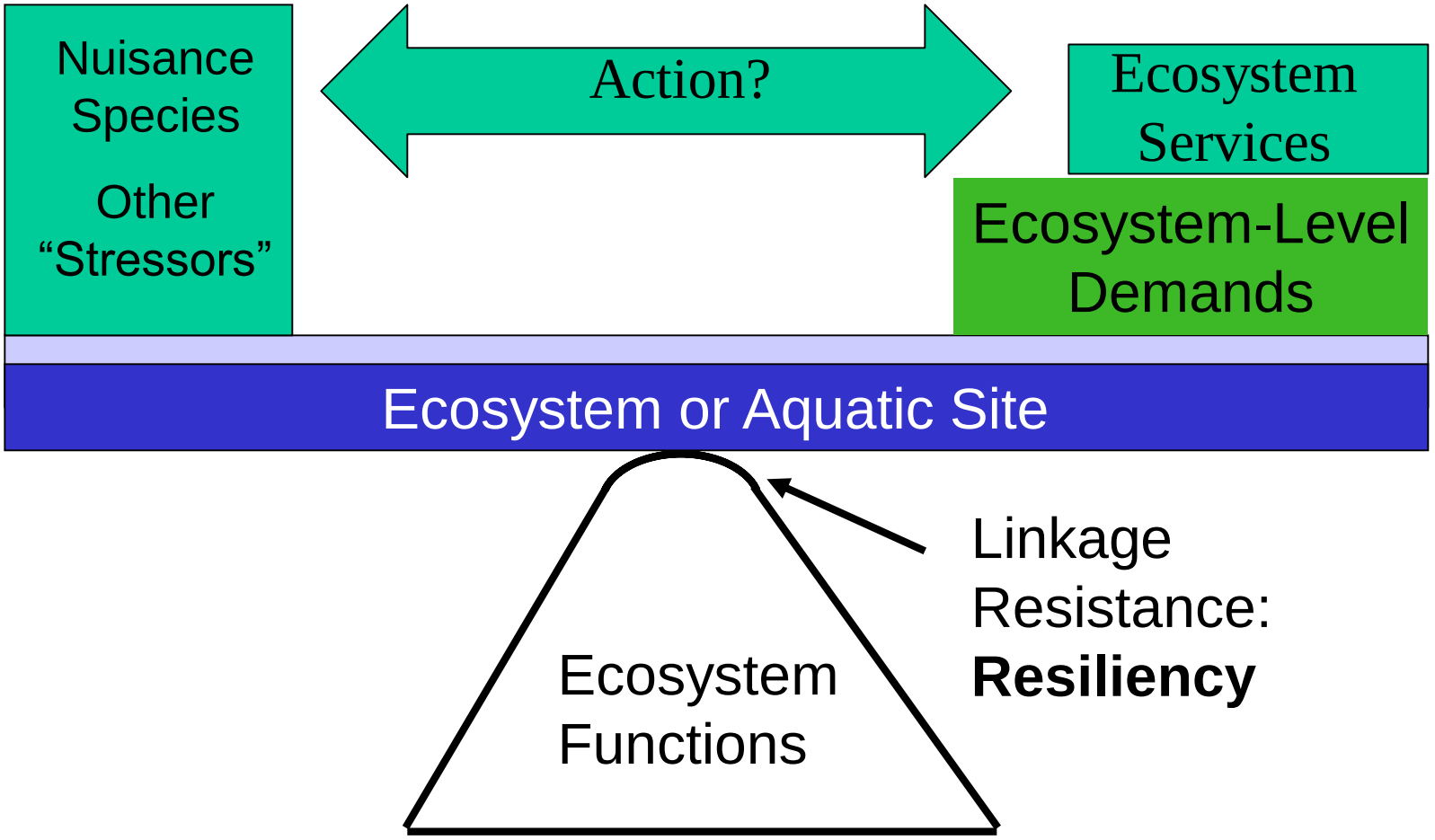
***This adds up!* $300 million per year**

Examples of ***Losses*** Caused by Aquatic Weeds in the US

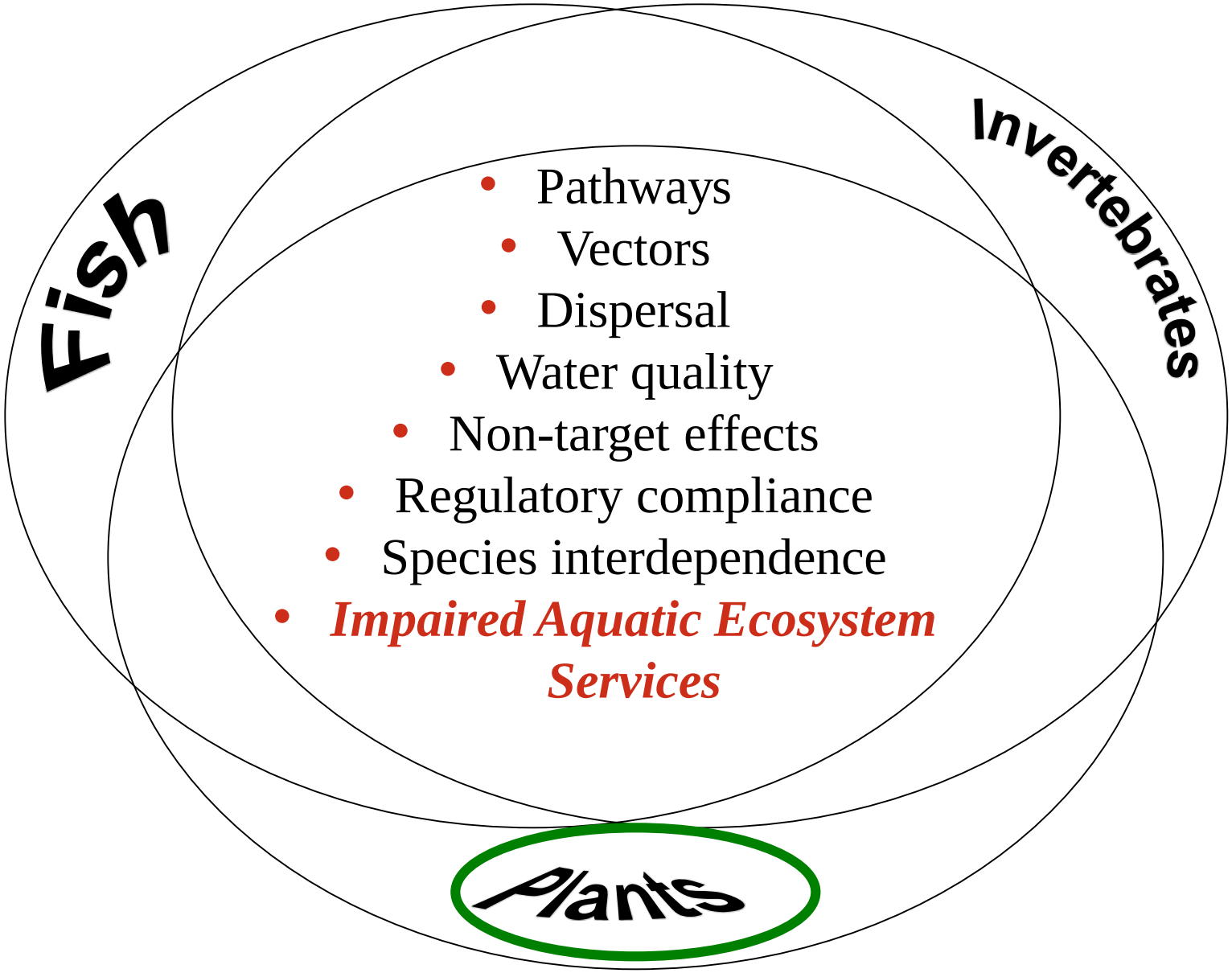
- **Loss of water delivery (capacity, timing, quality)**
- **Loss of bio-filtration "services": e.g. marshes and costs associated with pollutant cleanup and remediation**
- **Loss of revenues/jobs from *decrease in recreational uses:* (boating, fishing, hunting, retail sales, taxes, associated lodging, "guide/services")**
- **Decreased property values.**
- **Loss of native plant/community habitat structure ($?)**
- **Regulatory and compliance (state, federal)**
- **Lost economic "opportunities" (*Where would money have been used more productively?)* >>>TOTAL Estimated Loss: 1-2 $ Billion Per Year!**

Beliefs:

We Can Balance Risks and Benefits of Management



Common Aquatic Plant *Management* Concerns



Biological, Emotional and Economic Connections to water

↓

Perceptions of Risk from

Invasive and Nuisance Plants

&

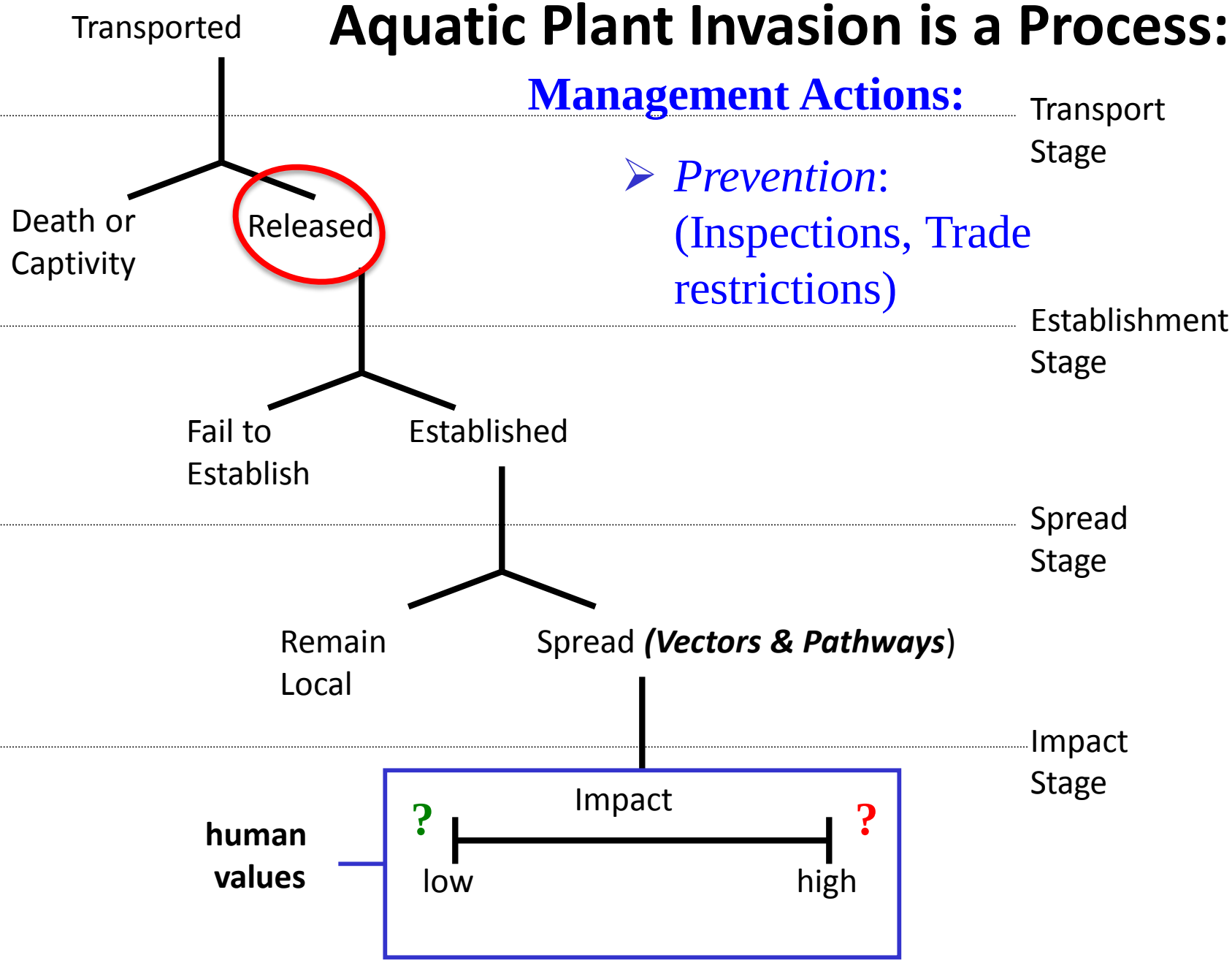
Perceptions of Risk from

Management Actions

↓

Science-Based **Balance of Risk and Benefit** → ***CONSENSUS FOR ACTIONS***

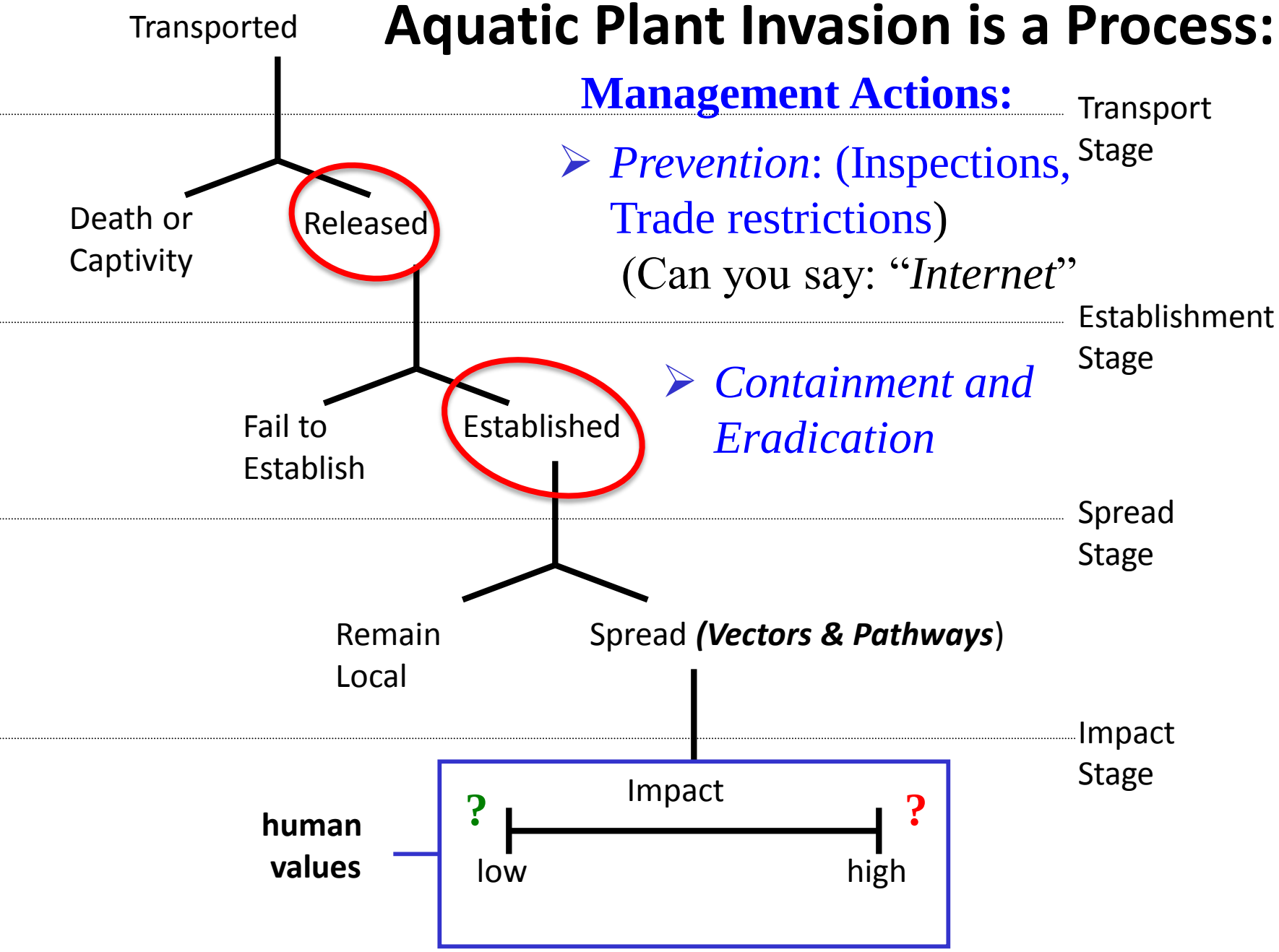
Aquatic Plant Invasion is a Process:



Management Actions:

- *Prevention*: (Inspections, Trade restrictions)

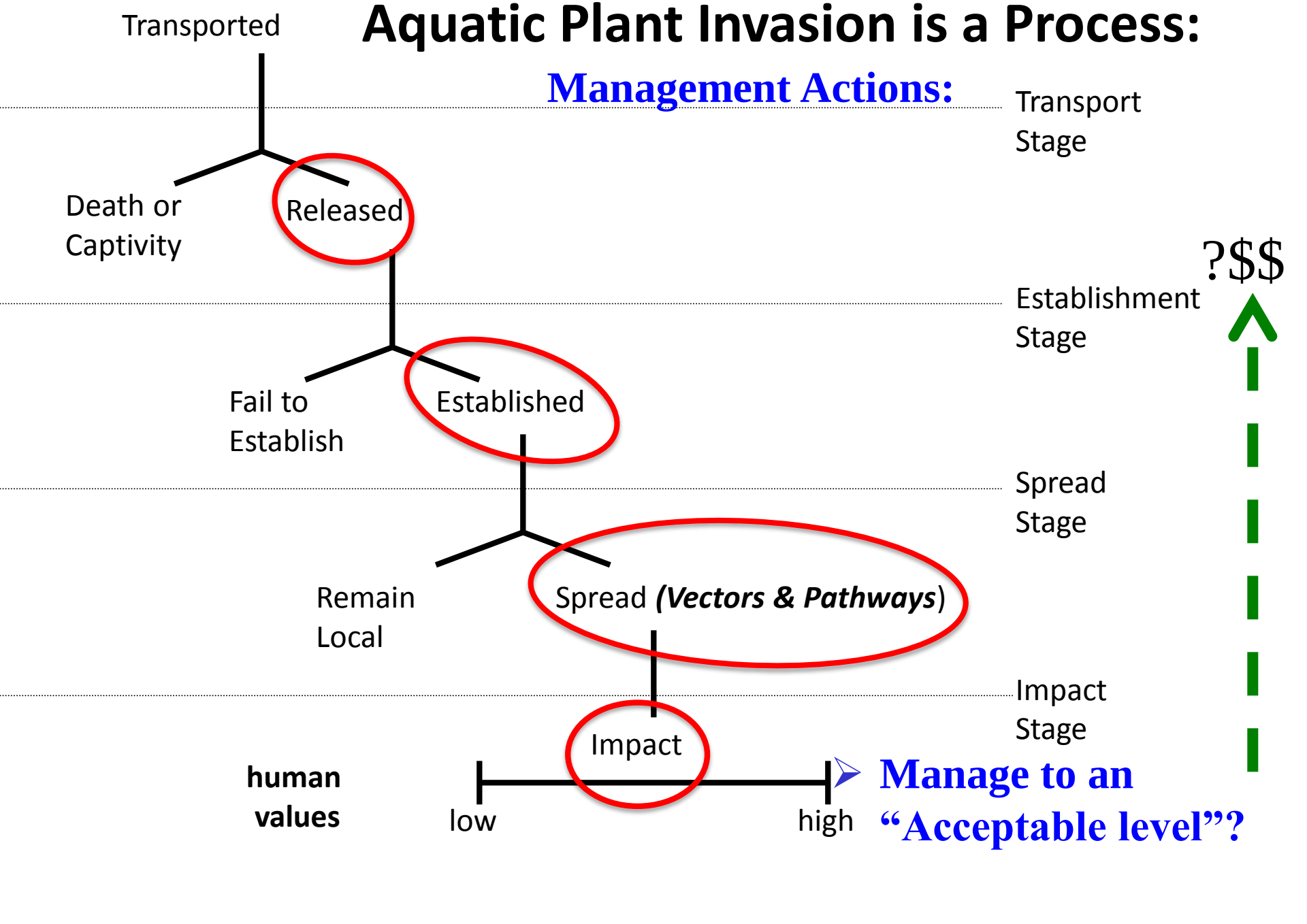
Aquatic Plant Invasion is a Process:



Management Actions:

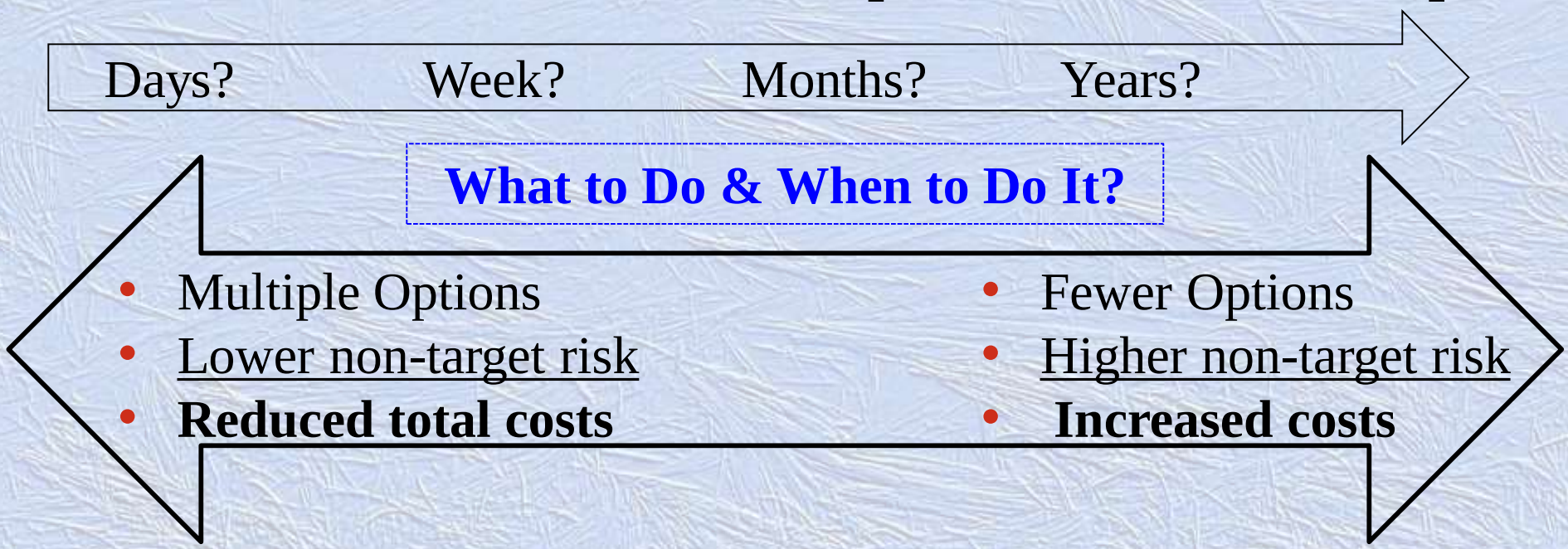
- *Prevention*: (Inspections, Trade restrictions)
  (Can you say: "*Internet*"
- *Containment and Eradication*

Aquatic Plant Invasion is a Process:



Response to Invasion Process:
Time Drives Everything!

Introduction>Establishment>Spread>Increased impacts



Aquatic Plant Resource Requirements for Establishment, Growth and Dispersal

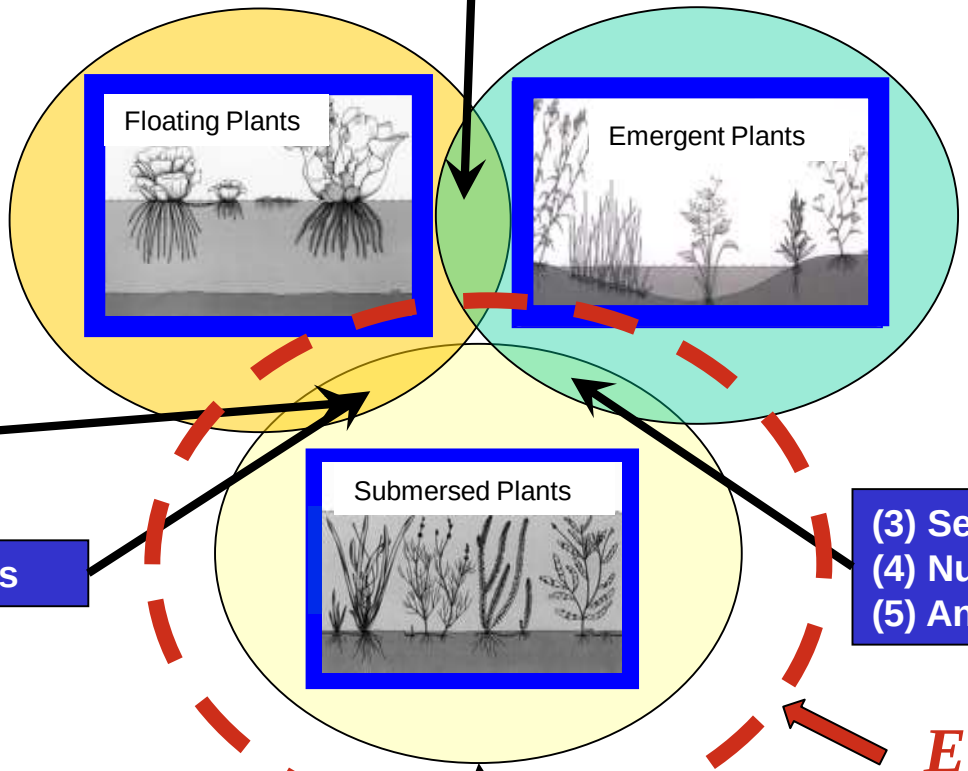
Management Actions Can act on any of these "drivers" to shift population abundance

Arrows show resources acquired through common driver-pathways (overlapping circles) among the three ecological/ growth forms of aquatic plants: Emergent, Floating and Submersed. Overlaps occur where the plant types share access to resources and where drivers Impact both plant types.

Temperature

Temperature

(1)High Light Levels
(2) Atmospheric $C0_2$



(9) Water Quality
(10) Nutrients in Water

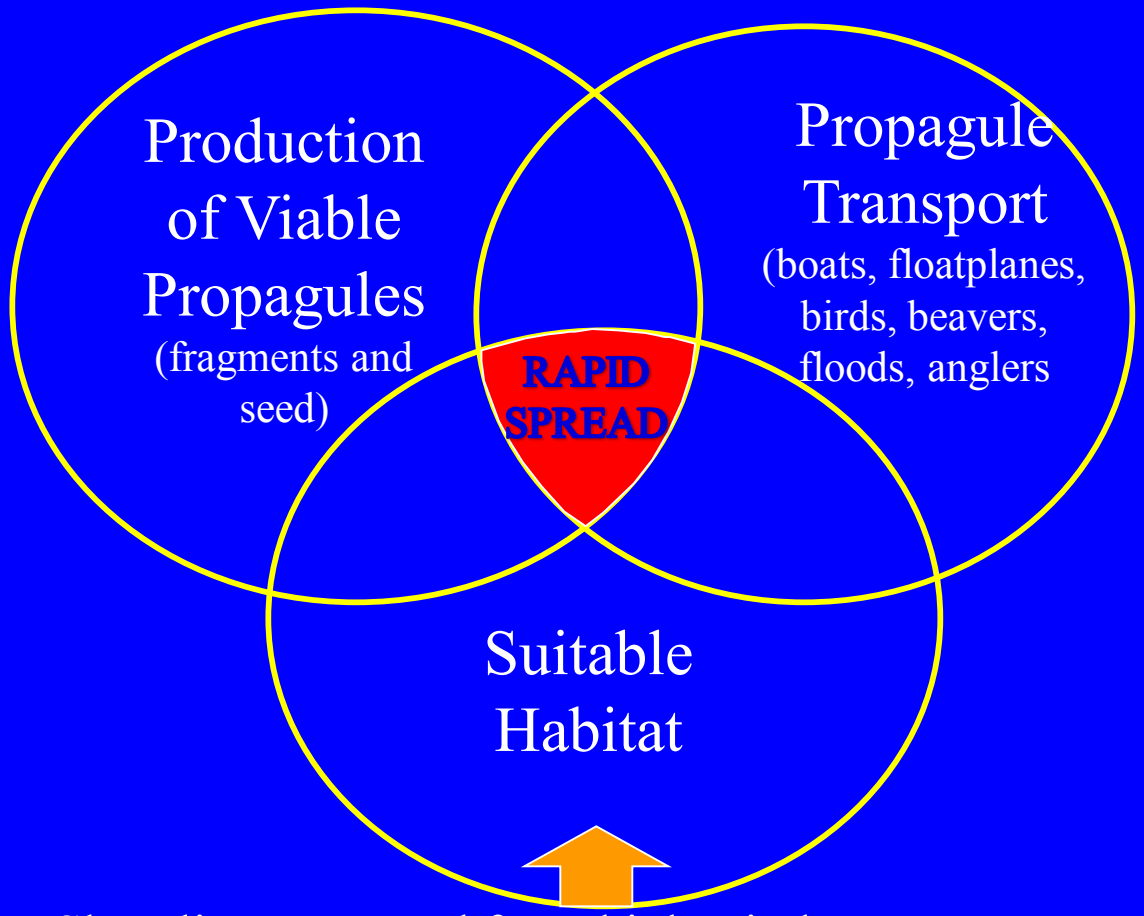
(8)Local Flow Conditions

(3) Sediment Characteristics
(4) Nutrient in sediments
(5) Anchoring

(6) Low Light Levels
(7) Dissolved Carbon (DIC) Sources

***Elodea* species & Hybrids: "Opportunists"**

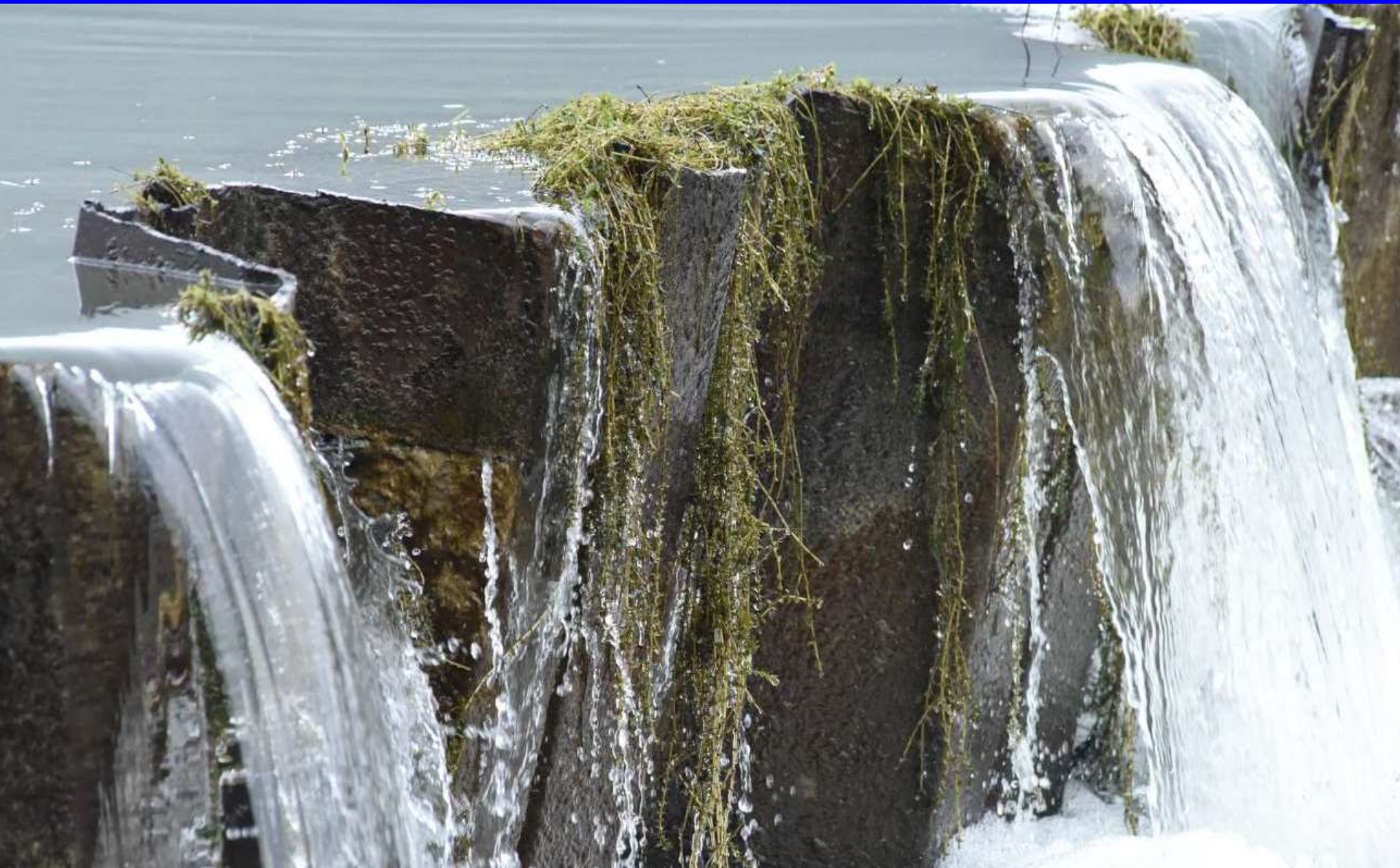
What Causes Spread of *Elodea and other Aquatic Weeds?*

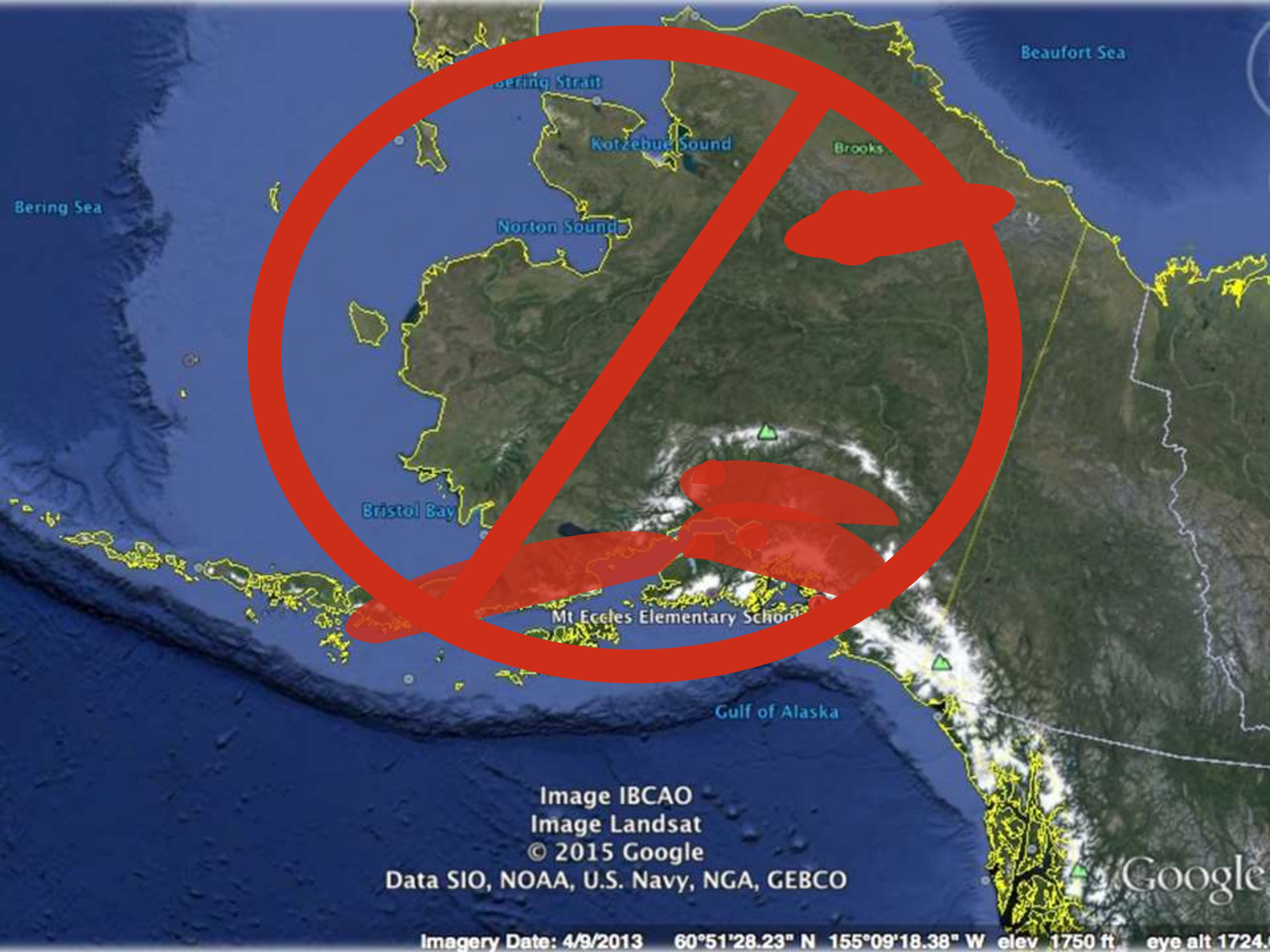


Shoreline protected from high wind, extreme waves;
Sandy/Organic/Silty Bottom; Temperature range;
Adequate Nutrients and Light, freshwater

Eyak Lake March 3, 2015

Eyak Lake March 3, 2015



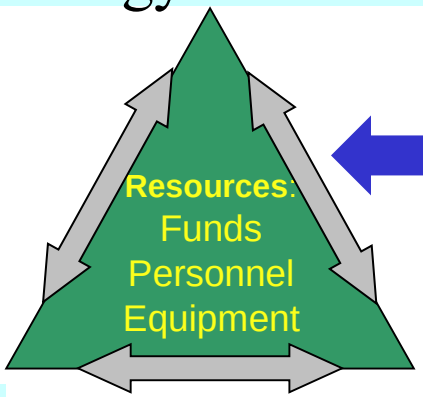

Beaufort Sea
Bering Strait
Kotzebue Sound
Brooks
Bering Sea
Norton Sound
Bristol Bay
Mt Eccles Elementary School
Gulf of Alaska
Image IBCAO
Image Landsat
© 2015 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google
Imagery Date: 4/9/2013 60°51'28.23" N 155°09'18.38" W elev 1750 ft eye alt 1724.

Components of Successful Science Based Management and Eradication Projects

Knowledge of the Target Nuisance Plant
Biology & Phenology

Science and Technical Committee

Public Outreach Committee

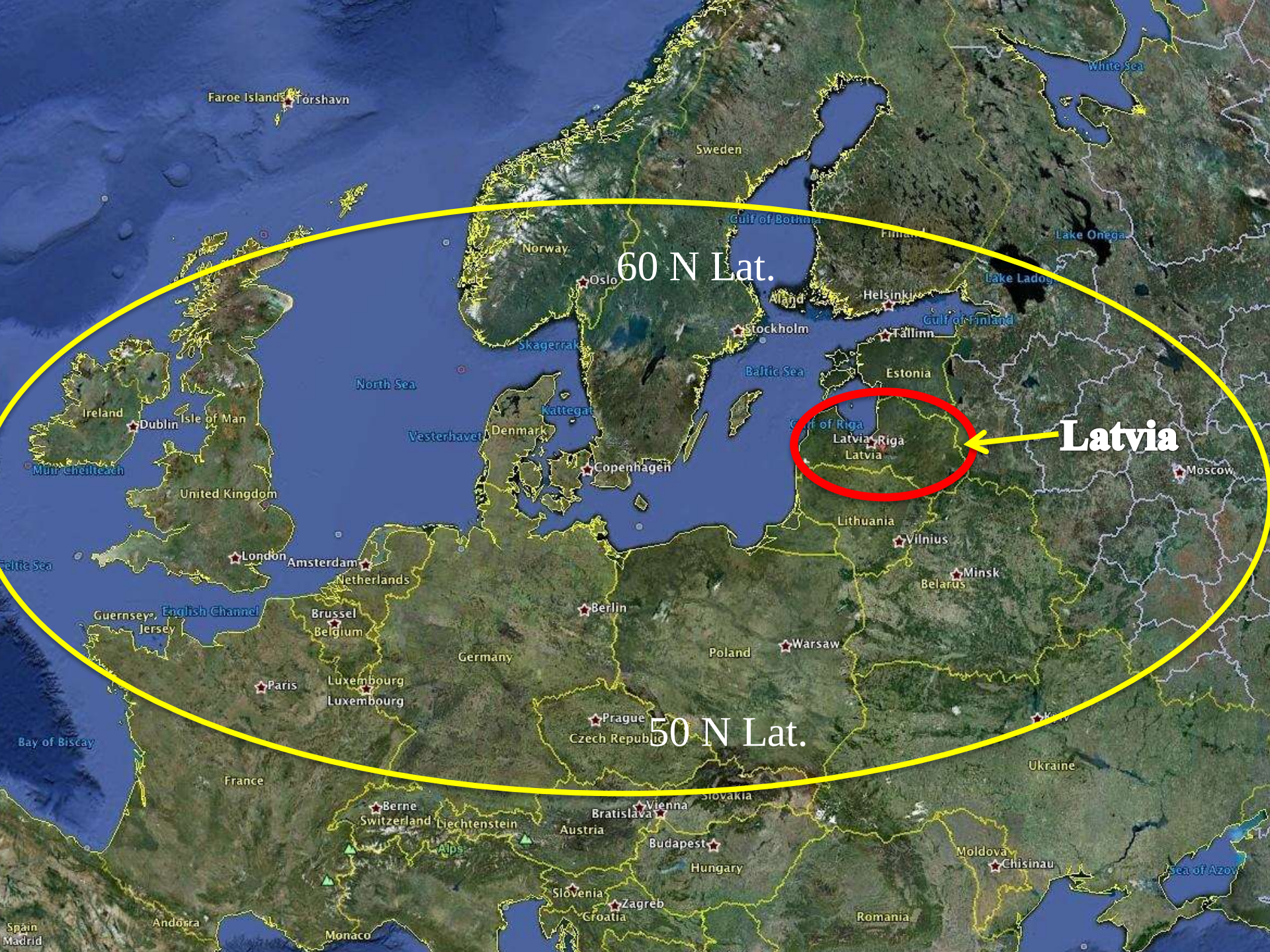


External Review (International and State level)

Knowledge of infested site(s):
Invasion pathways, Habitats, Uses, Nontarget effects, Laws, Stakeholders

Capacity to Act: Experience and knowledge
Containment, Control or Eradication, Monitoring

after Anderson 2005


60 N Lat.
50 N Lat.
Latvia
Faroe Islands
Torshavn
Sweden
Norway
Oslo
White Sea
Lake Onega
Lake Ladoga
Gulf of Bothnia
Finland
Aland
Helsinki
Gulf of Finland
Stockholm
Tallinn
Estonia
Skagerrak
Baltic Sea
North Sea
Kattegat
Vesterhavet
Denmark
Gulf of Riga
Latvia
Riga
Copenhagen
Moscow
Ireland
Dublin
Isle of Man
Muir Cheilteach
United Kingdom
Lithuania
Vilnius
London
Amsterdam
Netherlands
Celtic Sea
Minsk
Belarus
Guernsey
Jersey
English Channel
Brussel
Belgium
Berlin
Germany
Poland
Warsaw
Paris
Luxembourg
Luxembourg
Prague
Czech Republic
Bay of Biscay
Ukraine
France
Slovakia
Berne
Switzerland
Liechtenstein
Bratislava
Vienna
Austria
Budapest
Hungary
Alps
Moldova
Chisinau
Sea of Azov
Slovenia
Zagreb
Croatia
Romania
Andorra
Spain
Madrid
Monaco

Elodea canadensis
In Latvia (<1900-2008)*

*From: Grinberg, L. and Priede A. 2012. *Elodea canadensis* Mishx in Lativia. Acta Biol. Univ. Daugavp. 10: 43-50.

NOTE: First reported in 1872 (Associated with timber transports)

>Found in low and high nurtrient conditions

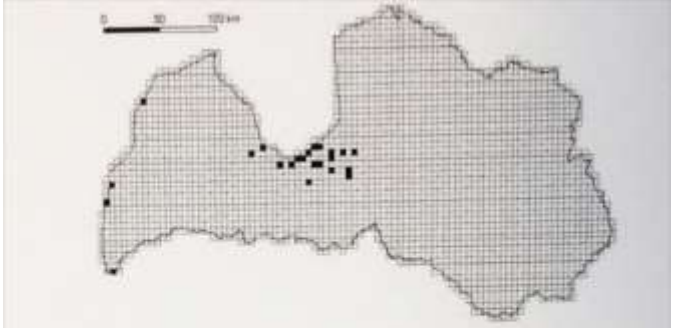


Fig. 1 Distribution of *E. canadensis* before 1900.

Prior to 1900

Fig. 2 Distribution of *E. canadensis* (1901-1950).

1901-1950

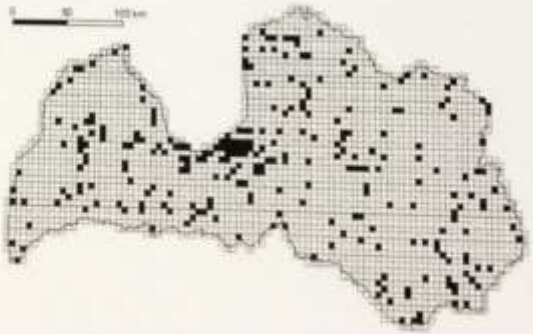


Fig. 3 Distribution of *E. canadensis* (1951-2008).

1951-2008

Successful Responses to Aquatic Invasive Species

- ✓ *Hydrilla verticillata* (**Eradication** in California)*
- ✓ *Caulerpa taxifolia (Marine alga)* (**Eradication** in Calif.)
- ✓ Sabellid worms in abalone (**Eradication**)
- ✓ *Eichhornia crassipes* (Management, world-wide)*
- ✓ *Salvinia molesta* (Management, **some sites eradicated**)*
- ✓ *Egeria densa* (Management, US, Brasil?)
- ✓ ***Elodea canadensis*** **(**Australia, Europe, US**)** (Management**)**
- ✓ Alligatorweed (**near-eradication** in California)*
- ✓ Weeds in irrigation systems (Management, worldwide)*

* *Included use of biological control agents*

Responses to Aquatic Plant Infestations:

Three Options for **"Risk Management"**

Action >

Probable Outcomes

Option 1

Do Nothing:

- Further spread locally
- Spread to more lakes, rivers, streams
- Reduced fish and waterfowl habitat
- Impaired water quality
- **Long-term very high cost**
- **Liability ($)?**
- **Degraded Ecosystem Services**

Option 2

Manage to some "threshold":

- Reduction locally
- Initially lower cost
- Continued source for further spread
- Localized major impacts and costs
- **Long-term, continued and growing cost and liabilities**
- **Unclear what is "acceptable" infestation?**

Option 3

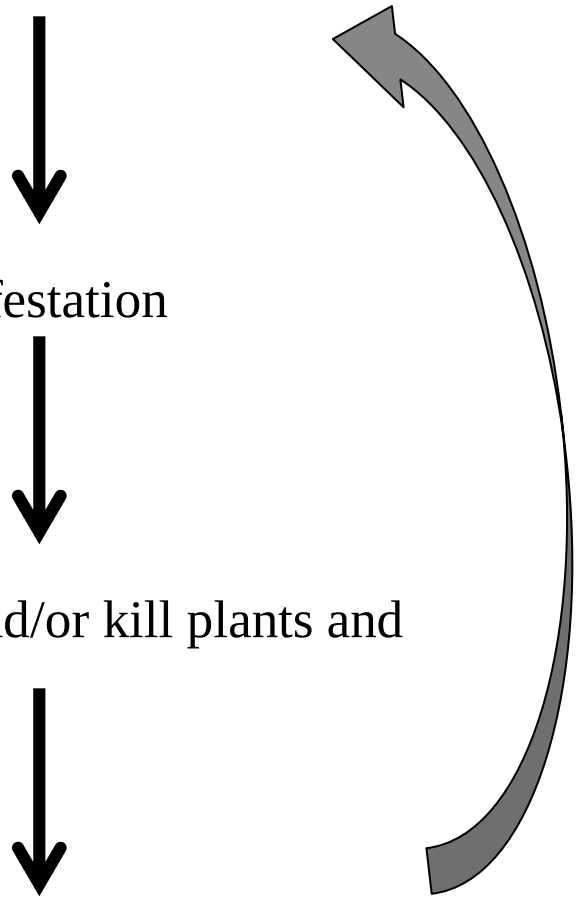
Eradicate:

- **Stop further spread**
- **Initially higher cost**
- ***Protection of suceptible sites***
- ***Improved Readiness for the next invasions***
- **Public credibility**
- **Reduced liability**
- **Clear, consistent goal and endpoint**
- **Lower long-term cost**

Eradication Strategies and Tools

Strategies and Objectives:

- Delineate scale of infestation
- Contain infestation
- Remove and/or kill plants and propagules
- Assess efficacy and progress against established criteria for "end point"



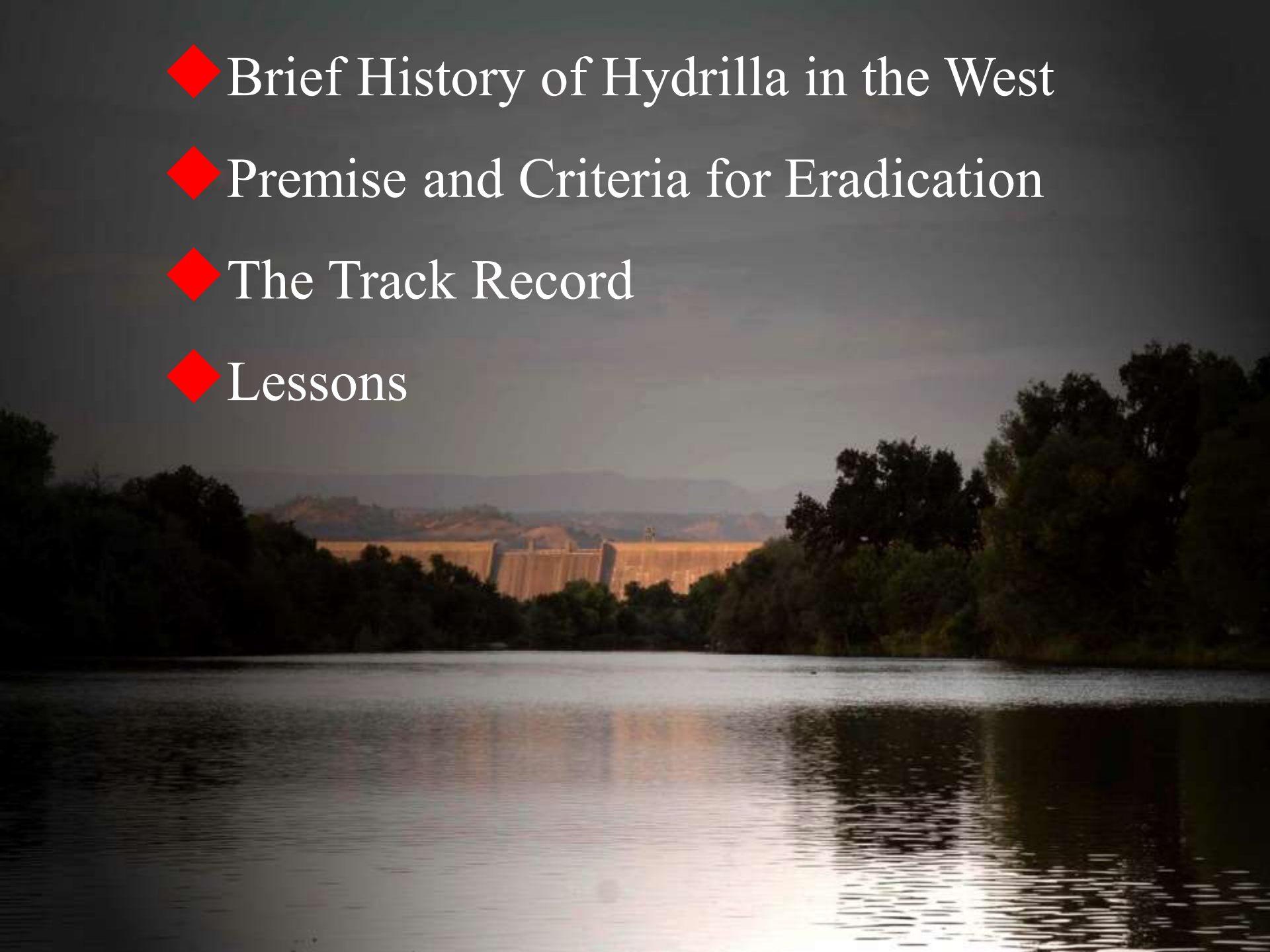
Tools/Methods:

On-water **surveys**: point sampling; hydroacoustic; diver surveys, "reverse-source" investigations: Who bought what where, when?

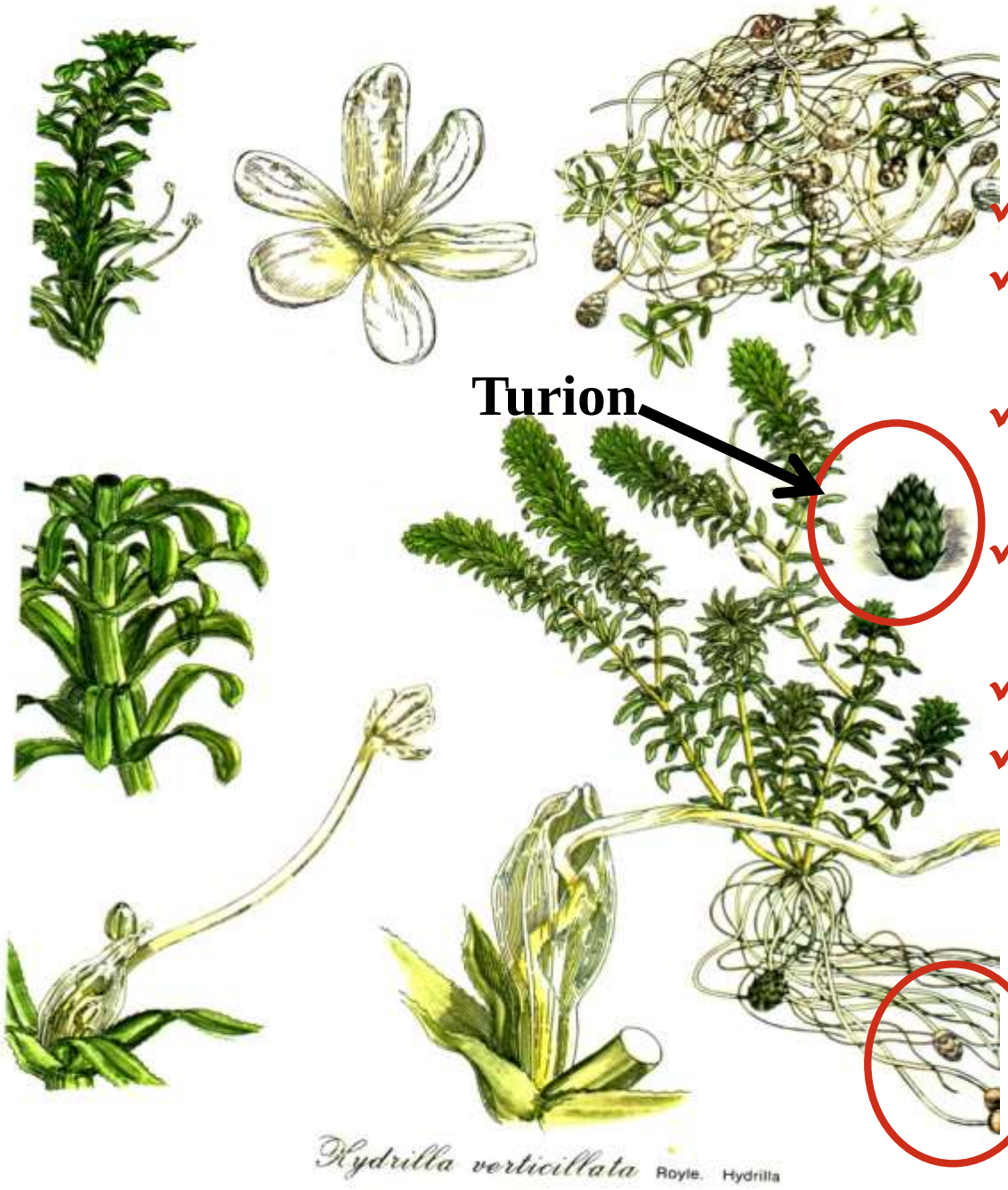
Physical barriers (curtain) ; quarantines; bottom barriers; stop pathways to/from infestation; public outreach and education

Dredge, hand removal, bottom barrier, dewater, excavate, fill, use EPA registered herbicides or (***rarely***) biological control

Propagule and biomass survey & sampling; environmental compliances; outside review of program, adapt based on assessments



- Brief History of Hydrilla in the West
- Premise and Criteria for Eradication
- The Track Record
- Lessons



Hydrilla verticillata

- ✓ Same family as *Elodea*
- ✓ Spreads by fragments,rootcrowns
- ✓ Spreads by “turions” and “tubers” (viable 7yrs!)
- ✓ Same pathways and vectors as *Elodea*
- ✓ Flowing or still water
- ✓ Sandy, mud, silt

Hydrilla Overview

- **Formal eradication since 1976**
- Active infestations (2012): 7 of 10 have no hydrilla (5+ years)
- 4 more reach eradication in 2012;
- Clear Lake: hydrilla on run; dredging coming on line

Eradication is possible: approx. 22 (26) of 32 infestations eradicated

COUNTY*	YEAR**	WATER BODY	SIZE
LOS ANGELES	1980 1983 1985	Eight ponds One pond One pond	2 acres <1 acre <1 acre
MONTEREY	1978	Private pond	0.01 acre
RIVERSIDE	1977 1984 1985	One pond One pond Three ponds	<1 acre <1 acre <1 acre
SAN BERNARDINO	1988	One pond	<.01 acre
SAN DIEGO	1977 1977	Lake Murray One pond	160 acres <1 acre
SAN FRANCISCO	1988	One pond	2 acres
SANTA BARBARA	1977 1993	One pond One pond	0.12 acre <.01 acre
SHASTA*	1985 1986	Seven ponds Four ponds	133 acres 23.5 acres
SONOMA	1984	Spring Lake	72 acres
SUTTER	1985	One pond	<.01 acre
TULARE*	1993	Three ponds	0.6 acre
YUBA*	1976 1990	Lake Ellis One pond	30.8 acres 6.0 acres

Western Hydrilla History

- **First Identified 1976: California Marysville & Imperial Irrigation Dist.)**
- **Declared "A" rated pest/ eradications begun 1977.**
- **About 34 sites have been found in 38 years**
- **No hydrilla found in Sacramento/San Joaquin Delta**
- **Washington Sucessful eradication (Pipe/Lucerne Lakes)**
- **No hydrilla has been documented for Oregon**
- **Idaho populations under eradication**
- **Eradication has been achieved in most sites and is on-going (few plants left) in nearly all the active eradication sites**

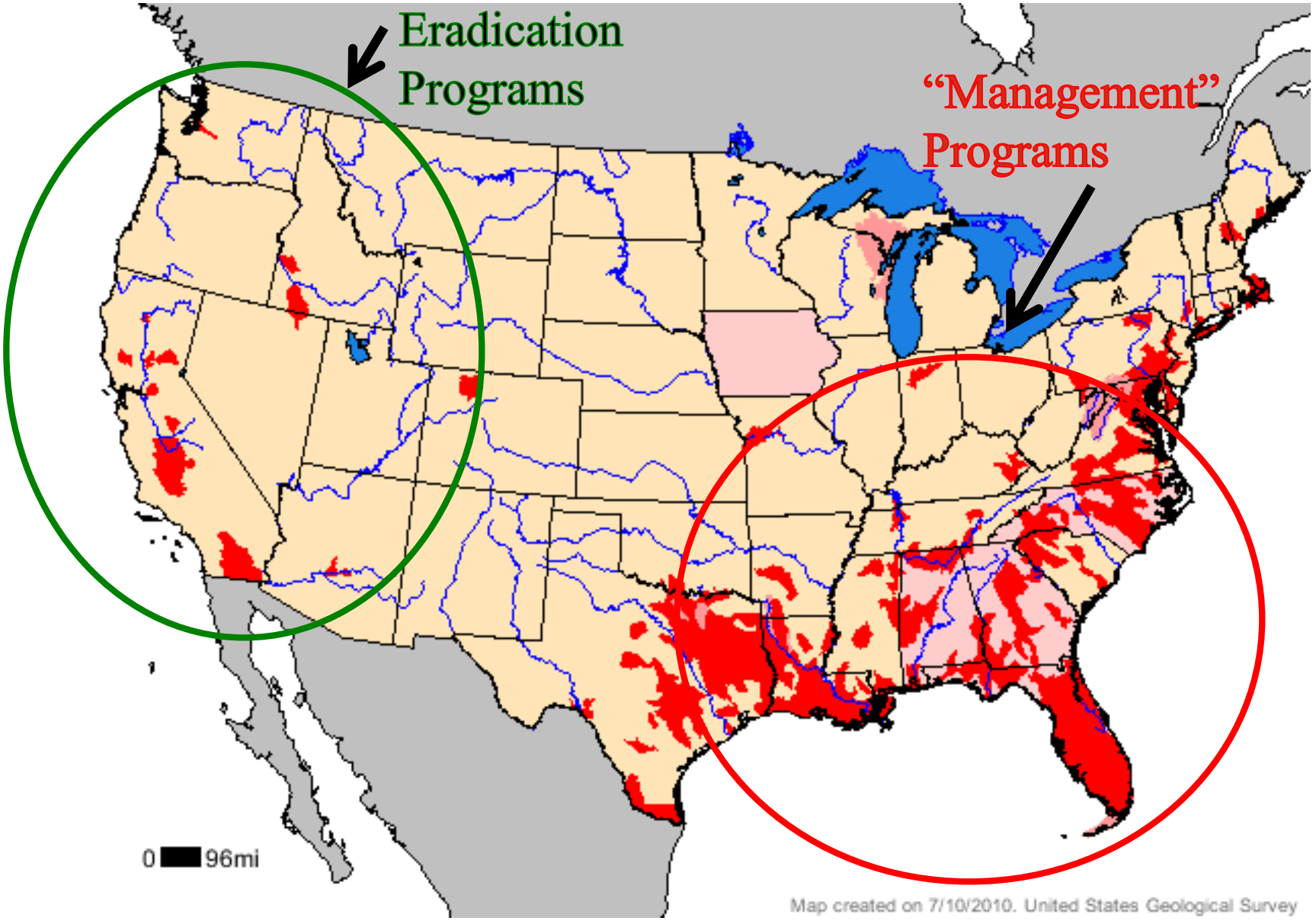
Diversity of Sites Where Hydrilla Has Been Eradicated

- ✓Small ponds (1 to 10 acres)
- ✓Lakes (e.g. Spring Lake; Lake Ellis, Lake Murray) (100's of acres)
- ✓Aquascapes
- ✓Nurseries
- ✓Irrigation Systems (small, medium, large>>500 miles of canals)
  (***Thanks to triploid Grass Carp!)***
- ✓Reservoirs (Eastman); Sheldon Reservoir

Sites Under Eradication:

- ○Clear Lake, CA. (44,000 acres)

Hydrilla Distribution in US



US- Waterways (Rivers, Reservoirs)

Hydrilla Eradication in California and Washington states has kept it out of nearly all western US waterways

Submersed plants:

- *Egeria densa**
- *Myriophyllum spicatum*
- *Myriophyllum aquaticum*
- *Potamogeton crispus*
- *Cabomba carolinana*
- *Ceratophyllum demersum*
- *Potamogeton nodosus*
- *Potamogeton pussilus*
- *Stuckenia pectinata*
- *Stuckenia filiformis*
- *Elodea canadensis*

Floating plants:

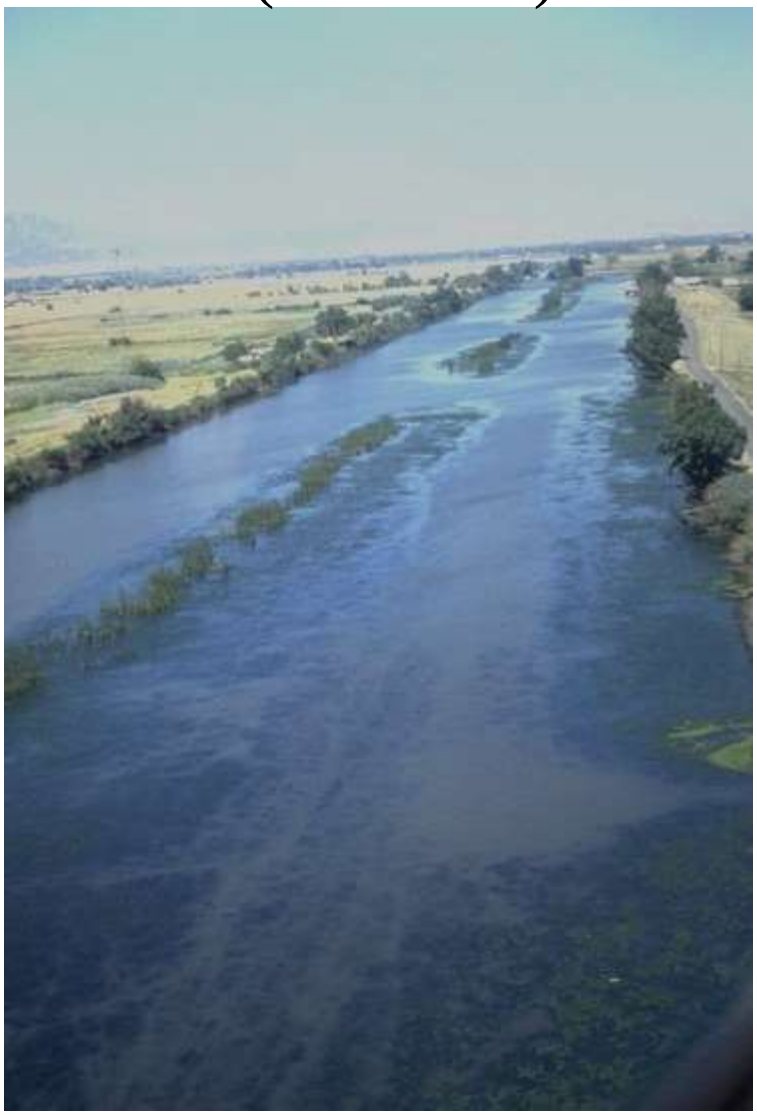
- *Eichhornia crassipes**
- ***Limnobium laevigatum***
- *Ludwigia spp.*
- *Hydrocotyle rannuculoides*

Emergent plants:

- *Arundo donax*
- *Phragmites (?- hybrid?)*
- *Lythrum salicaria*
- *Lepidium latifolia*
- *Typha latifolia*
- *Schoenoplectus californicus*
- *Spartina alterniflora**

Eichhornia crassipes: Delta Slough (California)

Egeria densa: Main Delta Channel (California)



“Main” Canal, Stanislaus Co., Califorina

Photos from late September, 2010. Canal personnel report that they noticed no spongeplant in this area as late as July.

(Photo courtesy of CDFA)

Cleaning Main Canal, Stanislaus Co., Califorinia

That's all spongeplant. Water hyacinth is rare to uncommon in these canals.

(Photo courtesy of CDFA)

Lake Tahoe:
A Cautionary Story about Invasive Species

Tahoe Keys Marina-
South Shore of Lake Tahoe

Photo credit: Lake Tahoe Real Estate www.laketahoerealestateblog.com

Lake Tahoe Exotic Aquatic Species Introduction (Detection) Timeline

Establishment of lake trout

brown, rainbow, brook, lake trout

Mysis

crayfish

kokanee

Tahoe Keys Built

Eurasian watermilfoil

?

bass spp.

Curlyleaf pondweed

?

1st Zebra mussel Interdiction on boat- prevented from launching

Asian clam

Asian clam Removal begun

1880 1900 1920 1940 1960 1970 1980 1995 2003 2006 2007 2008 2011

RESPONSES

extirpation of cutthroat trout

& *Daphnia* spp.

USDA-ARS:Whole Lake Plant Surveys

AIS Working Group

ARS-TRCD Org. AIS Workshop

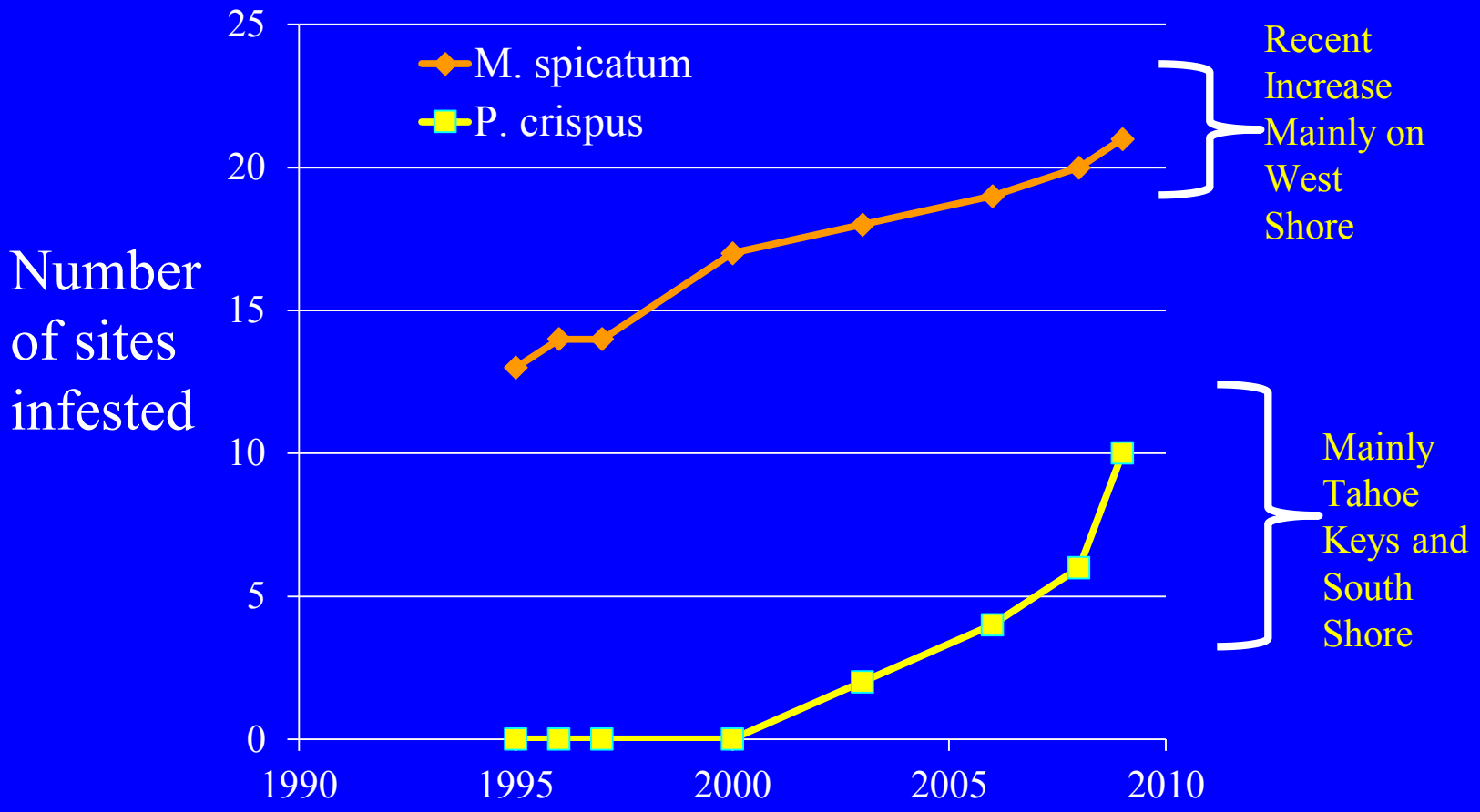
AIS Coordinating Committee; TRPA & USFWS Coordinators

AIS Plan Approved 2009, TRPA and USFWS appoint AIS coordinator

Tahoe Keys Project Started

After Sudeep Chandra (Univ.Nev-Reno); modified and updated by Lars Anderson (USDA-ARS-Davis, CA)

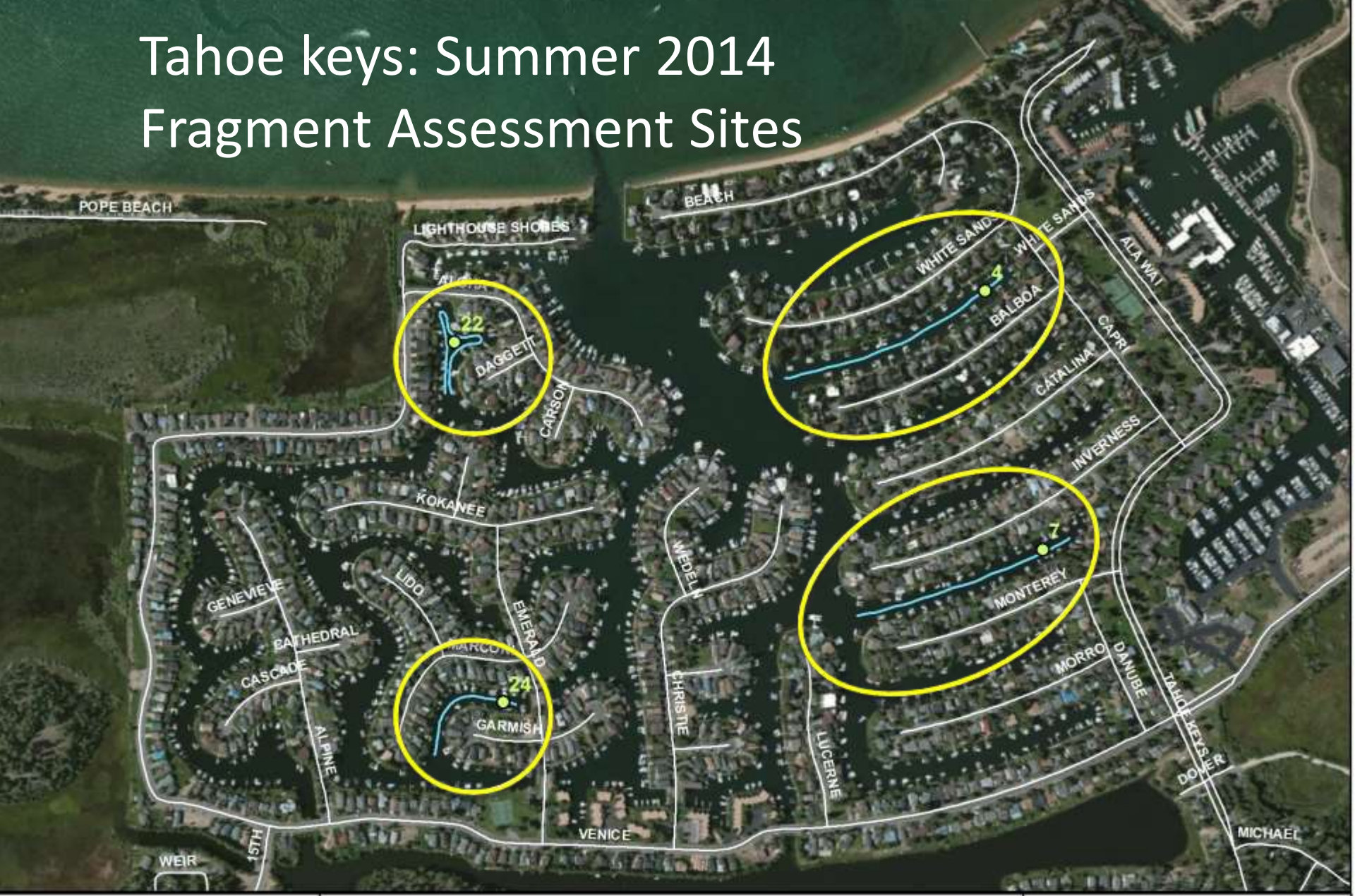
Spread of *M. spicatum* and *P. crispus* at Lake Tahoe*



*Based on USDA-ARS Surveys

Aquatic Plant Harvester- Transferring a load to the shore- ***Immediate "Solution", but Spreads plants***

Tahoe keys: Summer 2014 Fragment Assessment Sites



Fragment Study Area

Cove Designations

Transect Lines

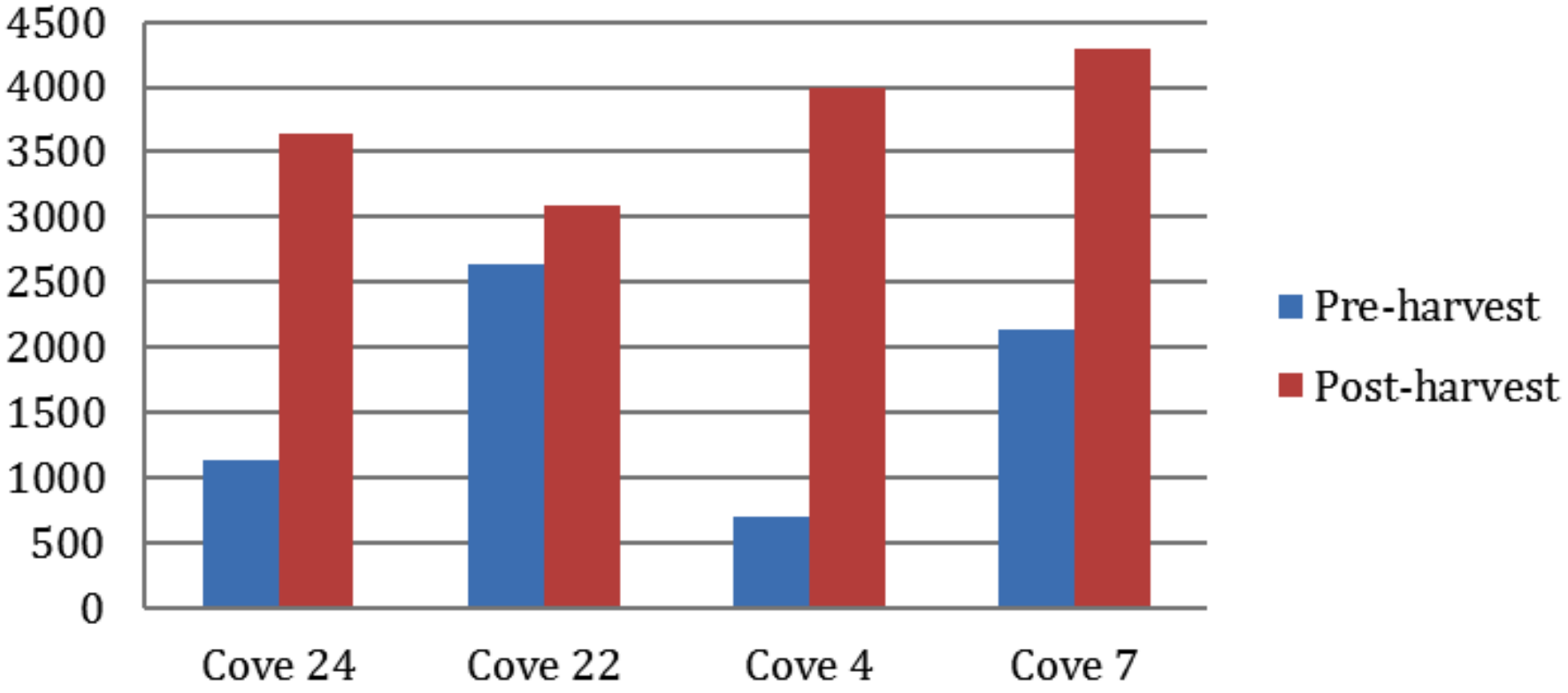
0 250 500 750 1,000 Feet

Sierra Ecosystem Associates

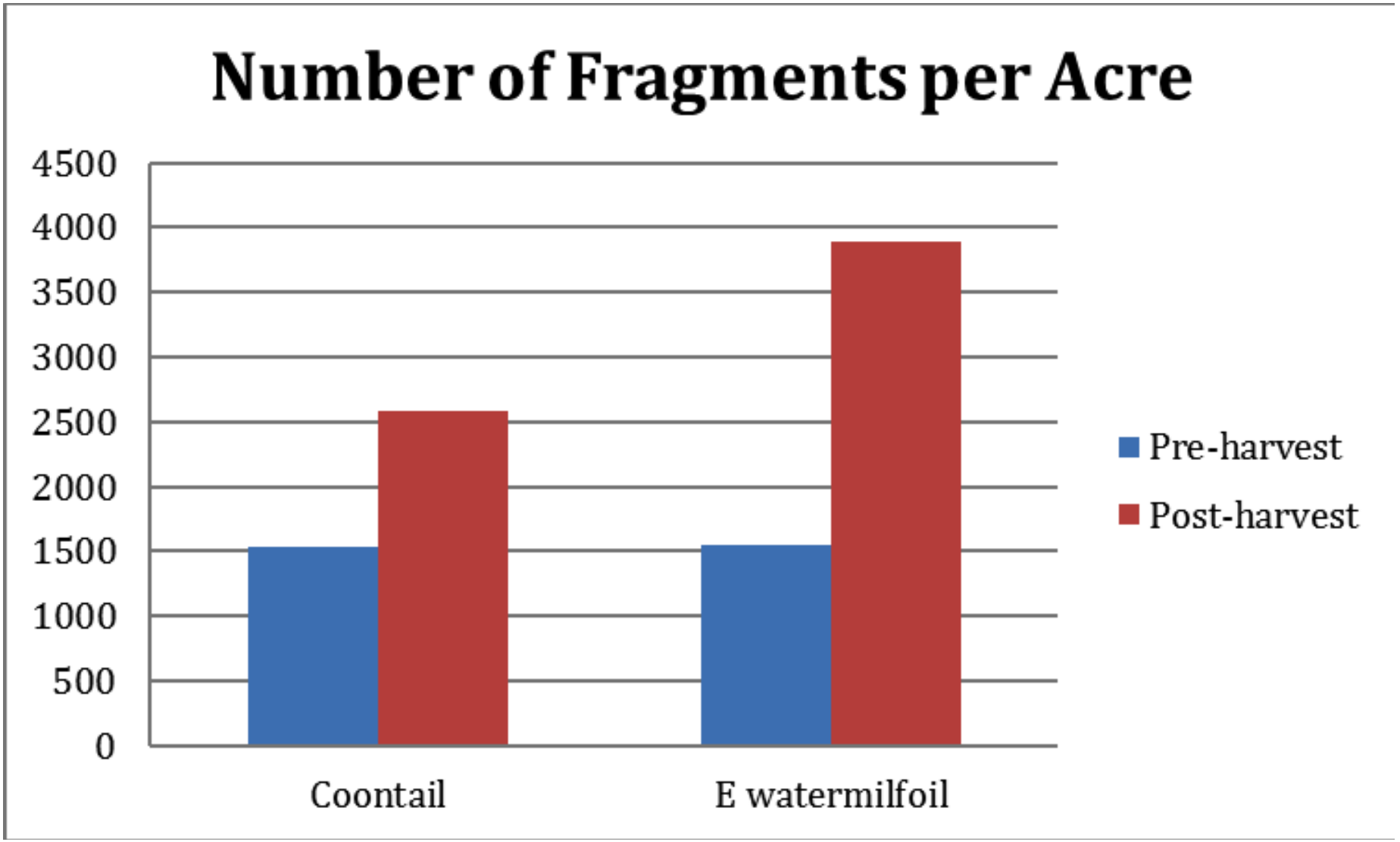
Author: Krystle Heaney

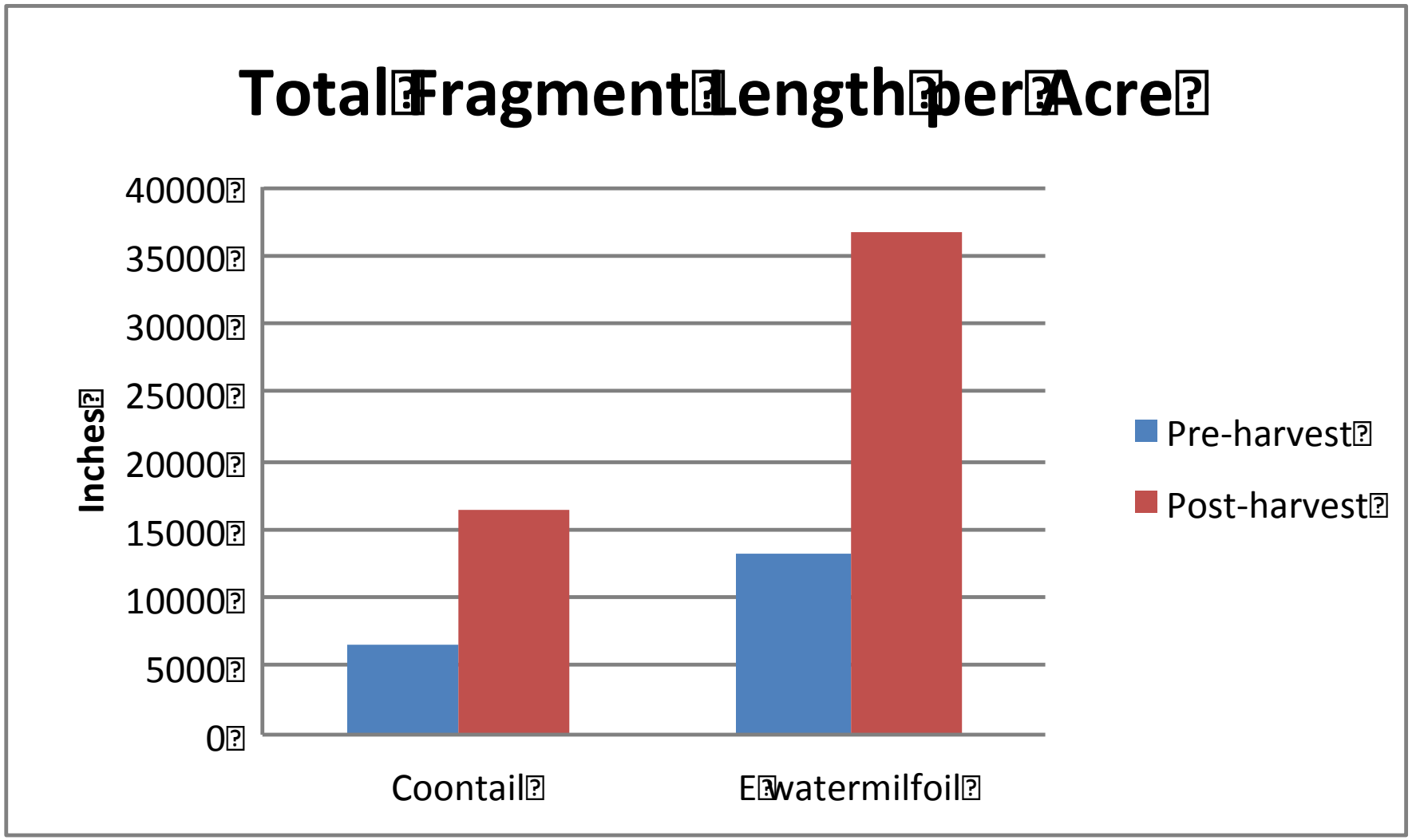
Date Saved: 10/13/2014

E. Watermilfoil Fragments per Acre

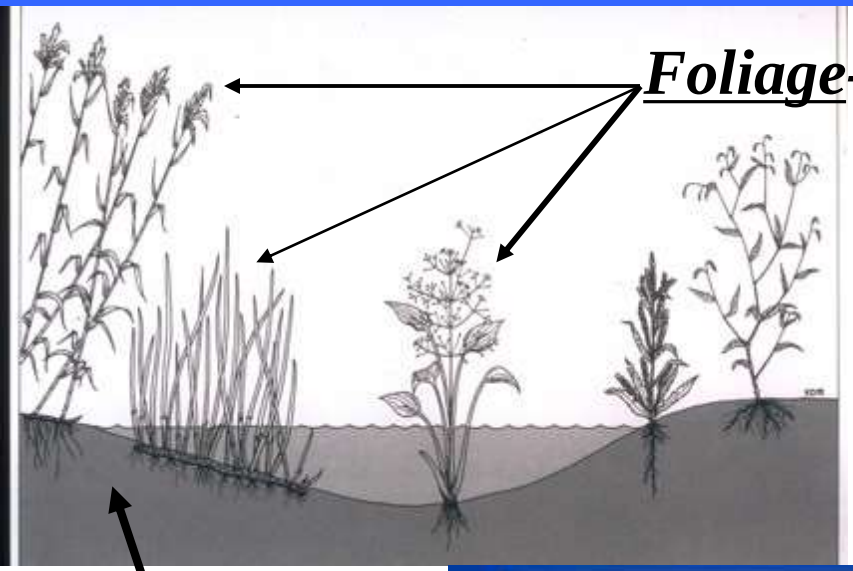


Mean: All Four Sites

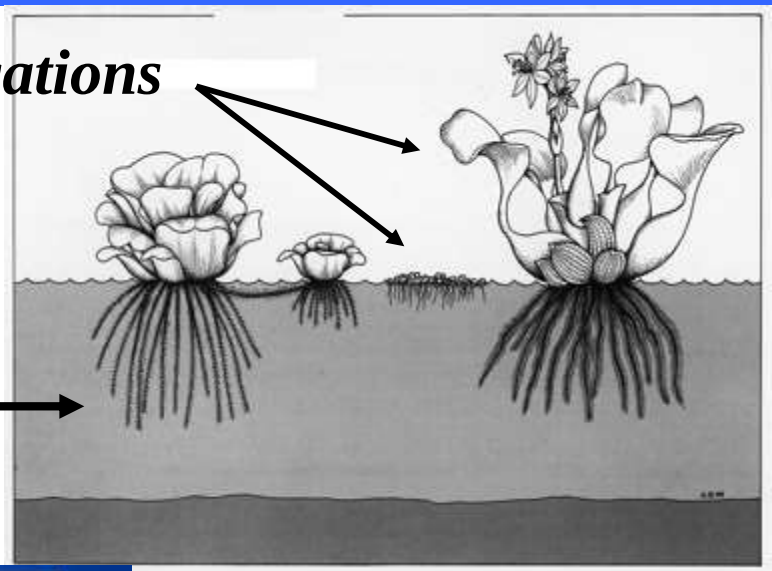



Total Fragment Length per Acre
Inches
40000
35000
30000
25000
20000
15000
10000
5000
0
Coontail
E watermilfoil
Pre-harvest
Post-harvest

Entry Routes for Aquatic Herbicides

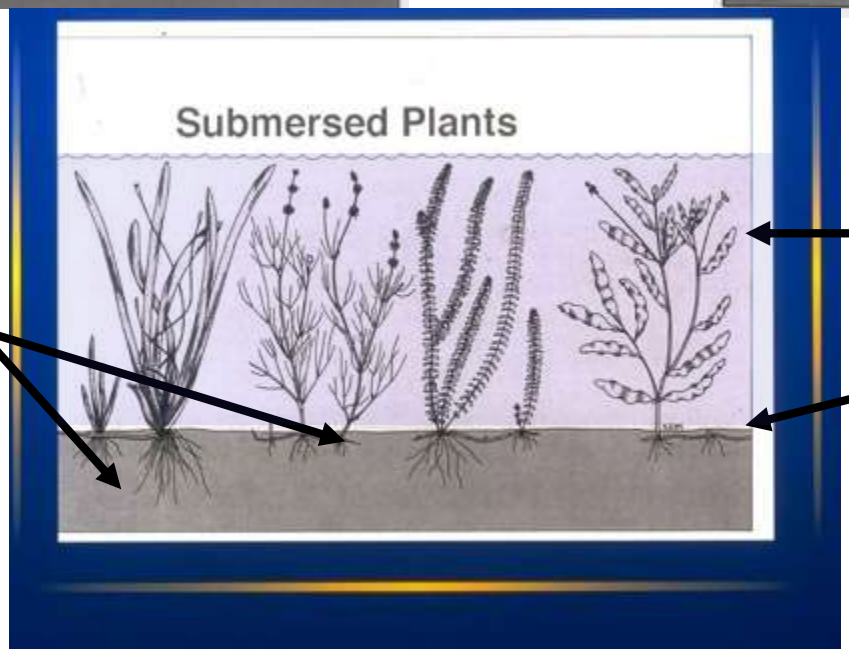


Foliage- Air Applications



Roots in Water

Roots, Rhizomes and Propagules in Sediment



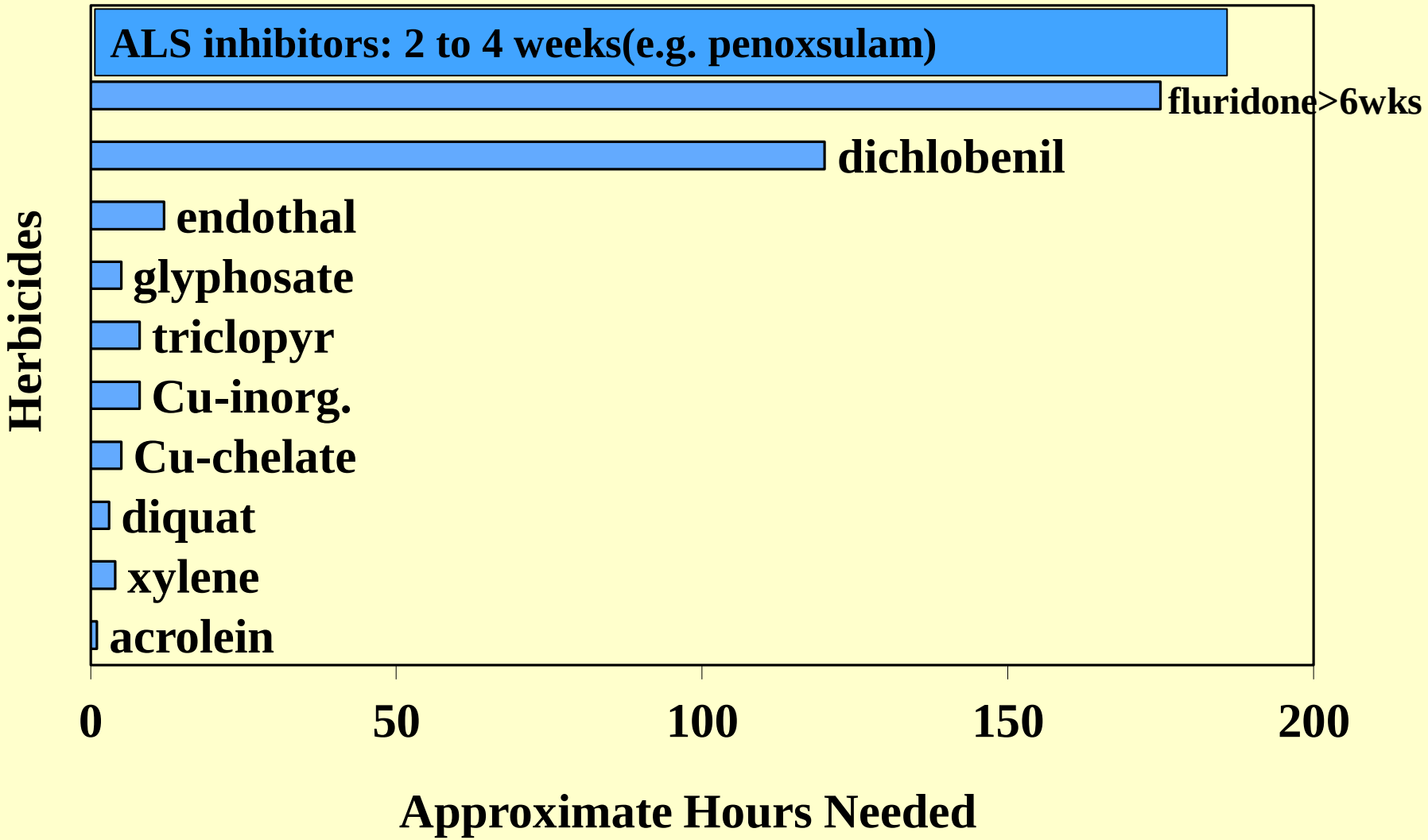
Foliage- in Water

Bottom Placement (pellets)

What Dissipates Herbicides in Water?

- ✓ **Diffusion >>> Dilution**
- ✓ **Breakdown to metabolites**
- ✓ **Uptake by target plant**
- ✓ **Uptake by non-target organisms**
- ✓ **Adsorption to particles and surfaces**
- ✓ **Combinations with other chemicals (e.g. carbonates)**
- ✓ **Volatilization**
- ✓ **Transport by currents (convection and other movement)**

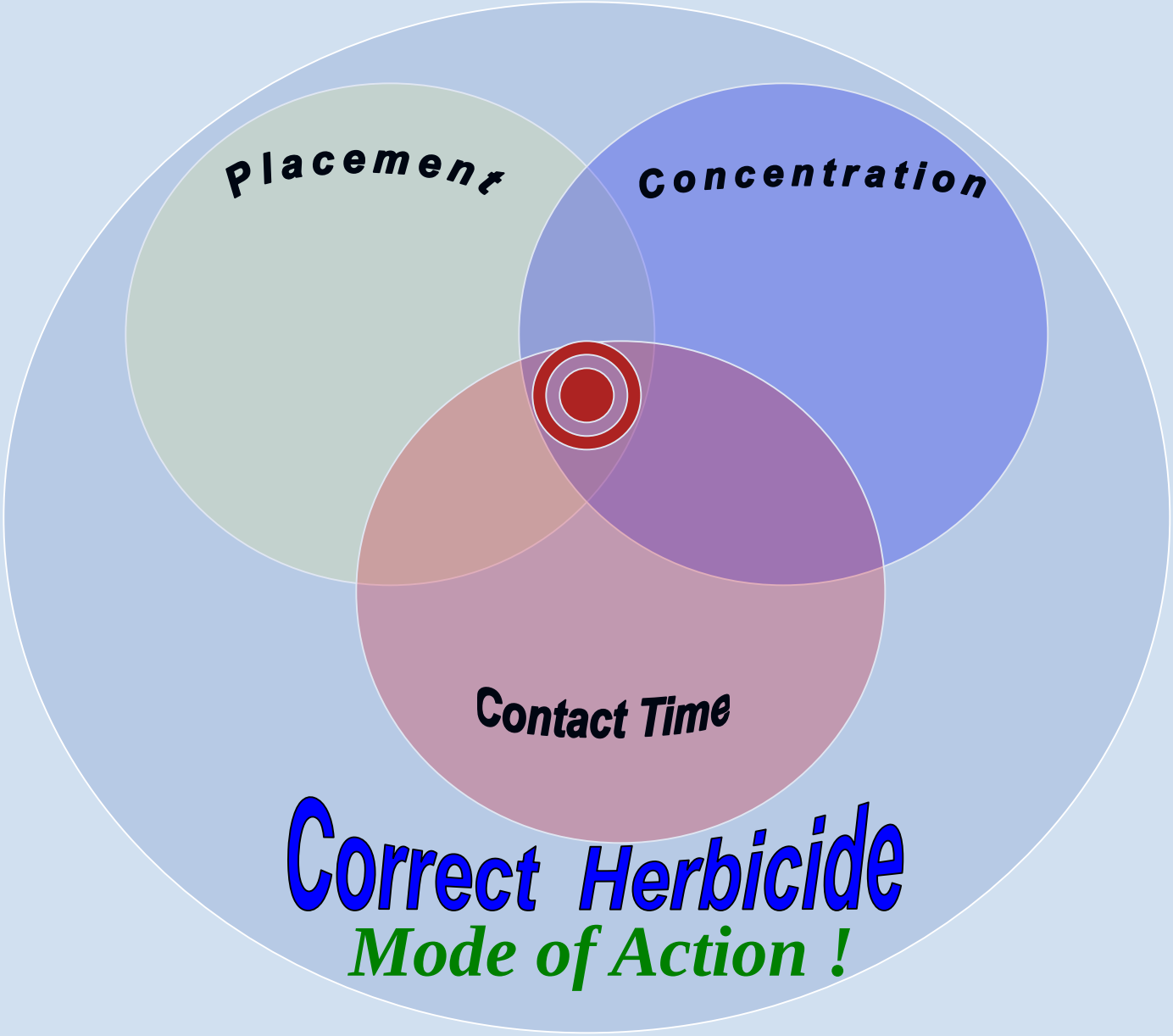
Required Herbicide Contact Time



Aquatic Herbicide Active Ingredients

Herbicide C= Contact S= Systemic Green= Elodea efficacy	Typical Use Rate
Copper products-**C**	0.25-1.0 ppm
Penoxsulam- S (and other ALS inhibitors)	100 to 200 ppb
Acrolein-**C**	1-10 ppm
Carfentrazone-ethyl C	0.05 – 0.2 lb/acre
Endothall-**C**	0.1-3.0 ppm
Diquat-**C**	0.1-0.37 ppm
Dichlobenil-**S**	0.1-0.5 ppm
Fluridone-**S** (various formulations)	0.006-0.160 ppm
Glyphosate-S	0.5-2 %

Targeting for Optimal Efficacy of Aquatic Herbicides



US-EPA Registered Aquatic Herbicides

- Acrolein (Magnecide-H)
- 2,4,-D (Weedar)
- Endothall (Aquathol-K, **Cascade, Teton**)
- Copper elemental & Chelates
- Diquat Dibromide (Reward)
- Gylphosate (Rodeo, Aquamaster etc.)
- Trichlopyr (Renovate) (2003)
- Imazapyr (Habitat) (2003)
- **Penoxsulam (Galleon) (2007)**
- **Imazamox (Clearcast) (2005)**
- **Cafentrazone ethyl (Stingray) (2007)**
- **Bispyribac sodium (Tradewind) (2007)**
- **Flumioxazin (Clipper) (2007)**
- **Quinclorac (2007)**

New Aquatic Herbicides: Modes of Action

Mode of Action>>>> **Acitve:**	Group 2/ALS **(B)**	PPO (Protox inhibitor) (Group 14) **(E)**	Systemic (Group 12) **(F1)**	Systemic (Group 9)	Systemic (Group 4) **(O)**	Contact (Group 22) (**D**)	Contact (Nucleic acid inhbib?)
Bispyribac-sodium	x						
Carfentrazone		x					
Flumioxazin		x					
Imazamox	x						
Penoxsulam	x						
Fluridone			x				
Triclopyr					x		
2,4-D					x		
Diquat						x	
Endohall							x
Imazapyr	x						

Strategy for Management of *Egeria densa* in the Sacramento-San Joaquin Delta Using Herbicide

Pre- and Posttreament Monitoring

- **Use physical point sampling and hydroacoustic analysis (Species distributions, "biovolume", plant canopy height)**
- **Implement site-specific, weekly applications of controlled-release granular formulations of fluridone ("Sonar").**
- **Comply with all monitoring requirements**

Herbicide Application Technologies

Granular Applications (controlled release pellets)

Boat-Mounted Hopper/ Spreader for Granular Formulations

Boat-Mounted Hose for Applications of Liquid Formulation Underwater

Weighted Hoses for Injection

Sacramento- San Joaquin Delta

Egeria densa Management:

Apply Fluridone Weekly for 8-10 weeks

Methods for Applying Liquid or Granular Fluidone

Herbicide Application Technologies

GPS Referenced-Liquid Applications: Weighted hoses

The Marine "Commons" is affected by Invasive Species

- **"Seaweeds" >270 Invasive species worldwide**

Caulerpa taxifolia

Undaria pinnatifida

Eradication of *Caulerpa taxifolia*: A Timely Consilience of Science and Societal Values

Successful Rapid Response Approach

- ***Detection*** **in field (June 2000)**

Time Line

- ***Confirmation*** **of species (24-48hr)**
- **Calls to action agencies (24 hr)**
- **Calls to aquatic invasive species experts (48 -72hr)**
- ***First agency/stakeholder meeting*****: 7 days, then weekly/biweekly, monthly, quaterly.**
- **Decisions by consensus:**
  - **>Unacceptable threat**
  - **>Assessment of Resources**
  - **>Support/approvals by Water Board**
  - **>$100K by Cabrillo Power, LLC**
  - **>Formation of "SCCAT"**

- **Delineate infestation**
- **Tarp, inject chlorine (sodium hypochlorite)**

3 weeks after discovery

- **Proposals for $$$$**
- **Assessment efficacy**
- **Monitor/Surveillance**
- **Develop criteria for "Eradication"**

Smart Management and Monitoring

Summary

Use Integrative and Consensus-Driven Approaches

- Create interdisciplinary teams
- Promote culture & ethic of "transparency"
- Combine and integrate ***proven methods*** for maximum efficacy and minimum non-target effects
- Consult with stakeholders at *EVERY* phase
- Promote flexibility and adapt to changes
- Invite outside reviews and assessments
- Readjust actions based on reviews & results


Winter, Tomales Bay
Pt. Reyes
Thanks for your attention