Integrated Pest Management and Biological Control

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Important Questions

• What is IPM?
• What is biocontrol?
• Underlying concepts?
• Safety?
• Effectiveness?
• Integration?
• Players – Agents?
• Future?
What is IPM???

In simple terms:

A procedure to manage pest populations by HARMONIZING all available control methods.

Complement - Match - Balance
What is IPM?
Process of evaluating all available tools and then using those tools in a combination that will achieve management objectives for a given aquatic system (Hoyer and Canfield 1997).
What is IPM???

• Definition more detailed:
  – Examine if infestation impairs or benefits
  – Understand plant and water body ecology
  – Set management goals
  – Consider all tools and select the best options
  – Develop monitoring strategy
  – Implement educational program
While this approach can be effective it tends to provide only short term control by neglecting the underlying reasons for the formation of the infestations.
Example: ‘Successional’ history of Caddo Lake, Texas

- Waterhyacinth
- American lotus
- Brazilian elodea
- Eurasian watermilfoil
- Giant salvinia
- Hydrilla
Ecological Approach to Aquatic Plant Management

Integration of approaches and methods into a pest management system, which takes into consideration the ECOLOGY of the environment and all relevant interactions that management practices may have upon the environment.
Ecological Approach to Aquatic Plant Management

- **Ecosystem approach**
  - Ecosystem management & restoration

- **Addresses underlying causative factors**

- **Which leads to management:**
  - Sustainable
  - Long-Term
Reasons for Invasiveness???

• Beyond the scope…
• But certain characteristics stand out
• Bottom-line
  – Not dealing with:
  – “Killer plants”
  – “Super plants”
  – Goes against all science
Invasiveness Characteristics

- Disturbance specialists
  - r-strategists or ruderal
- For example - Hydrilla
  - Rapid growth rates
  - Broad tolerance ranges
  - Early maturation and reproduction (fragmentation)
  - Dispersal adaptations (fragmentation)
  - Long-term survival (tubers)
Environmental Factors

Man-made and natural systems that lack vegetation

...Space to proliferate...
Unvegetated systems ...

- Man-made systems
  - Reservoirs - flooded land
  - Mainly in 1950’s and 1960’s
  - No provisions for aquatic vegetation
- Natural systems
  - Many have only minimal vegetation
    - Due to continual disturbance
    - Management practices

invite colonization!
Environmental Factors

Man-made and natural systems with high nutrient loads

...Ingredients to proliferate...
High Nutrient Loads

- Recognized since early 1960’s
- Point source
- Non-point source
  - Sewers/septic systems
  - Fertilization
    - Homes
    - Farms
    - Industry
  - Erosion
- Human population increases
Underlying Causative Factors
Biological

• Most problem species are non-native
• Introduced with no competent herbivores and diseases
• A biological factor that can have profound impacts
Melaleuca quinquenervia – U.S.
Melaleuca quinquenervia – Australia
Casuarina spp. – U.S.
Casuarina spp. – Australia
Hydrilla verticillata – U.S.
Hydrilla verticillata – China
Biological Control

• Differences due to:
  – Environmental factors

• More importantly:
  – Presence of herbivores
  – Impact of diseases
  – Not present in U.S.

• Example:
  – Melaleuca - > 150 herbivores
  – Hydrilla - > 110 herbivores/diseases
What is Biocontrol?

Introduction, by man, of parasitoids, predators, and/or pathogenic microorganisms to **SUPPRESS** populations of plant or animal pests.
Suppression

- Reestablish herbivores & diseases with plants
- Release small numbers
  - Population increase
  - Expansion in distribution
- Suppression is key
  - Stress the target
    - Reproduction
    - Growth
    - Height
    - Opening canopy
  - Long-term process
    - Takes years
  - Bring into lowered equilibrium
- Long-term sustainable control
Tremendous Capacity for Increase

Exponential Curve

TIME
POPULATION INCREASE
• Average generation time about 10 days
• Each female deposits about 120 eggs

• Resulting offspring in just three months would number >325 trillion individuals
• Encircle the equator >57,000 times
Factors regulating populations

- **Abiotic**
  - Weather
  - Climate
  - Shelter availability
  - Geographic barriers

- **Biotic**
  - Mortality
  - Various competitive effects (intra/inter)
  - Development
  - Predators and parasites
Maintenance at Realistic Levels

Logistic Curve

Regulatory Factors

TIME

POPULATION INCREASE
Biocontrol

- Minimize characteristics of disturbance specialist
- Decrease photosynthesis --- decrease growth
- Decrease reproduction
- For example:
  - Waterhyacinth weevils
    - Smaller height
    - Decreased flowering – less seeds
    - Less productivity
  - Purple loosestrife agents
    - Reduced shoot/root growth
    - Fails to produce seeds
Impact can be tremendous!

Herbivores Present  
Herbivores Removed

Master’s Thesis – Julie Nachtrieb
Herbivore Impact to Native Plants

Entire ecology of pond was altered
Hydrilla Agents
Leaf-Mining Flies

- Two species established
  - *Hydrellia pakistanae* (1987)
  - *Hydrellia balciunasi* (1990)
- *H. pakistanae*
  - Widespread US distribution
  - Most damaging
  - Southeast
  - Northern Alabama
Hydrellia pakistanae

Adult

Larva feeding
Model: $v_1 = (0.647 + c \cdot v_2)^{0.059}$

$P_{\text{max}} = ((.647047) + (.059096) \cdot \% \text{ Damage})^{-.40575}$

$r = 0.997$
Hydrilla Only

Hydrilla + Natives

Current effect: $F(1, 116)=31.260, p=0.00000$

Vertical bars denote 0.95 confidence intervals

32% reduction in tuber numbers
2-fold reduction in tuber numbers

Current effect: $F(1, 116) = 7.8673, p = .00590$

Vertical bars denote 0.95 confidence intervals
Lake Seminole, FL
1999
SPECIES RICHNESS = 1.3358 + 0.01801 * PERSDAM
Correlation: r = .90606
Current effect: $F(1, 116)=.48237, \ p=.48874$

Vertical bars denote 0.95 confidence intervals

Hydrilla Only

Hydrilla + Natives

a

ab

b

c

a

b

c

TUBERS PER m$^2$

NO HERBIVORY

HERBIVORY
Control Low Medium High
Leaf Damage
Percent Rooted

L (0-30%)
M (40-60%)
H (70-100%)
What is the Role of Biocontrol?

- Think IPM in ecosystem context
- Reduce or eliminate underlying causative factors
  - Environmental factors
    - Nutrient loads
    - Empty niche
  - Biological factors
    - Host-specific agents
    - Suppresses weedy characteristics
      - Reduces photosynthesis
      - Decreases productivity
      - Impacts reproduction
      - Allows natives to compete more favorably
What is the Role of Biocontrol?

- **Combine with native plant restoration**
  - Reduce availability of space
  - Decrease nutrient loads – act as nutrient sinks
  - Alters competitive pressures

- **Use traditional options in:**
  - High priority areas
  - When other methods not feasible
  - To reduce overall biomass
  - Followed by biocontrol
Is it safe?  Host-specificity

Insects exhibit a range of feeding habits

Polyphagous – many food items - Generalist
Oligophagous – few food items
Monophagous – one food item - Specialist
Is it safe?
Host-specificity

- Thousands of species
  - Monophagous
  - Feed on single species
- Mechanisms
  - Nutritional
  - Defensive chemicals
- Millions of years of association
- Strong and binding relationship
Biological Control "Pipeline"
Overseas

• Surveys
  – Lists of potential agents
• Field records
  – Host-specificity
  – Damage potential
• Host-specificity testing
  – Less expensive
  – Specimens available
Quarantine

- Safe?
- Host-specific?
  - Feed & develop
  - Only on target plant
- US and overseas locations
- Assess agent potential
- Gather information
  - Release petition
  - TAG request
- Environmental assessment?
Approval for Release

- Approval from:
  - Animal and Plant Health Inspection Service
  - Plant Protection and Quarantine
  - APHIS, PPQ

- APHIS, PPQ solicits recommendations from Technical Advisory Group (TAG)

- Major Areas of Concern
  - Taxonomy
  - Test Plant List
  - Host Range Tests
  - Impact to Non-Target Plants
Technical Advisory Group
TAG

• Recommendations only to APHIS, PPQ
• TAG Membership
  – Bureau of Land Management
  – Bureau of Reclamation
  – Fish and Wildlife
  – National Park Service
  – National Biological Survey
  – Bureau of Indian Affairs
  – Canada & Mexico
TAG Membership Continued

- USDA, ARS
- USDA, APHIS
- USDA, CSREES
- Forest Service
- Documentation Center
- Corps of Engineers
- Environmental Protection Agency
- Weed Science Society
- National Plant Board
TAG Process

**Petitioner**
- Prepares petition for release
- Sends to APHIS-PPQ

**TAG Executive Secretary**
- Establishes time lines
- Sends to petition to TAG members

**TAG Members**
- Review and evaluate
- Synthesize comments from subject matter specialists
- Submit comments and recommendations

**TAG Executive Secretary**
- Logs and files comments and recommendations
- Sends to Chair

**TAG Chair**
- Consolidates recommendations
- Submits TAG recommendations to APHIS-PPQ, Petitioner, TAG members, and other interested parties

**Petitioner**
- Conducts more research, and
- Resubmits petition or test or plant list
- Discontinues effort, or
- Elects to submit application to APHIS anyway

Does TAG recommend release?  

Yes

**Petitioner** submits permit application to APHIS. APHIS coordinates with State Plant Regulatory Officials

No

Subject matter specialists evaluate
Foundational Research

Biological Control "Pipeline"

Overseas
Quarantine
Release/Establishment
Evaluation
Technology Transfer
Large Numbers for Release

• Classical biocontrol
  – Small numbers direct from overseas populations
  – Limitations – dependant on natural dispersal

• Move toward mass-rearing

• Large-scale efforts using:
  – Ponds
  – Greenhouse
  – Salvinia agents
  – Hydrilla agents
  – Waterhyacinth agents

• Quantity versus Quality
Several state and Federal agencies
- DWF-LA
- Corps Districts
- LSU Ag Center

Considerations
- Environmental conditions
  - Temperature
- Plant impacts
- Plant nutrition
- Herbivores
- Population size
- Shipping
- Monitoring
- Quality

Large Numbers for Release

Genetic Bottleneck

Impacts
- Reproduction
- Dispersal
- Mating
- Feeding
- Host selection
- Development time
Determining Efficacy

- Determine establishment
- Assess impact
  - Numbers of agents
  - Plant damage
- Monitoring important consideration
  - Standardized
  - Consistent
  - Repeatable
- Numbers of agents
  - Released and Present
Salvinia Weevil Rearing Pond
LSU: Near Houma, LA

- Characterize weevil distribution
- Changes over time
  - Plants
  - Weevil numbers
- Sampling efficiency
Importance of Sampling

• Distribution has considerable impact
• Sample size extremely importance
• Important to know how many released
  – Gauge establishment
  – Determine impact
    • How long it takes?
    • How big an area will be affected?
  – More released the better – but:
    • Agents cost money
    • Best to release the minimum to get the job done!
Objectives
What is Success?

- Establishment
- Range Expansion
- Population Increase
- Impact
  - Minimal
  - Biomass Decrease
  - Propagule Decrease
Evidence Types

- Laboratory/Greenhouse Experimentation
- Field Observations
- Abiotic/Biotic impacts
Criteria for Success

• Important that ALL agree what is success!!
  – Project managers
  – Property owners
  – Fishermen
  – Researchers
  – Lake Managers

• Compare to Realistic Expectations
Technology Transfer

- Reports
- Scientific Literature
- Oral Presentations
- Posters
- Videos
- Fact Sheets
- Information Systems
APIS Online

Players - Agents

- Insect agents available
- Variety of plants
  - Alligatorweed*
  - Waterhyacinth*
  - Waterlettuce*
  - Hydrilla*
  - Eurasian Watermilfoil
  - Salvinia*
  - Purple Loosestrife
  - Salt Cedar
  - Melaleuca
- Biology, ecology, impact
Alternanthera philoxeroides (Alligatorweed)

- Three agents released
- Highly effective
- Months instead of years
Agasicles hygrophila
(Alligatorweed Flea Beetle)

- Others include
  - Alligatorweed Thrips
  - Alligatorweed Stem Borer
Eichhornia crassipes
(Waterhyacinth)

- Three agents
- Effective
  - Height
  - Seeds
  - Biomass?
- Long term
- Controversial
Neochetina eichhorniae/N. bruchi (Waterhyacinth Weevils)
Niphograpta albicuttalis  
(Waterhyacinth Moth)

Formerly
Sameodes albicuttalis
Waterhyacinth

- **Effectiveness**
  - Long-term process
    - 3 to 5 years
  - Reduce plant height
  - Reduce flowering
  - Decrease biomass
    - Occurs
      - Flow
      - Winter conditions
      - Waterbody
      - ???

- **Disease**
  - Microsporidia
  - Reduce longevity
  - Egg production
Megamelus scutellaris
(Waterhyacinth Planthopper)
Megamelus scutellaris (Waterhyacinth Planthopper)

- Approval Feb. 2010
- Colonies established
  - Florida
  - Vicksburg
  - Louisiana
  - California
- Releases in Florida, Texas, Louisiana, California
- Tentative establishment – FL, CA
- Monitoring establishment success
- Probable high temperature limits???
- More work needed
Waterhyacinth

• Future
  – Of no use:
    • True bug, moth
    • Both fed on pickerelweed
  – Possible new agents
    • *Thrypticus* spp.
    • *Taosa inexacta*
    • Warm strain hopper
  – Implementation
    • Patience is a virtue
    • Use on low priority sites – source infestations
    • Release large numbers
    • Minimize use of chemicals
    • Monitor
Hydrilla verticillata
(Hydrilla)
Hydrilla Agents
Leaf-Mining Flies

- *Hydrellia pakistaniae*
- *Hydrellia balciunasi*
- Established
- Larva Damaging Stage
- Feeds on Internal Leaf Tissues
- Widespread U.S. Distribution
Hydrellia pakistanae

Adult and Eggs

Larva feeding
Is it effective?
Lake Seminole, FL

1994
Lake Seminole, FL
1999
How do you implement?

- Learn to identify agents/damage
- Examine field sites
  - Presence/absence
  - Assess populations/damage
- Augment – if needed
  - In the past flies were expensive
    - > $0.50 per fly
    - < $0.01 per fly
  - Modern mass-rearing facilities
    - Lewisville, TX
    - Vicksburg, MS
    - Arkansas
    - Released > 30 million
- Continue to monitor field sites
Salvinia molesta
(Giant Salvinia)
Cyrtobagous salviniae (Salvinia Weevil)
Sepik River, Papua, New Guinea

Before
Sepik River, Papua, New Guinea

After
Mass Rearing Efforts

- Research
  - High numbers/quality
  - Lowered costs
- Several rearing facilities
- Pond-based
  - South Louisiana (LSU)
  - Vicksburg (ERDC)
- Box-Based
  - Texas (LAERF, Caddo)
  - Northern distribution
  - Cold frames
Pistia stratiotes
(Waterlettuce)
Neohydronomus affinis

Waterlettuce

- Highly effective
- Used throughout the world
- Method of choice
- Used extensively in Texas
- Active use in Louisiana
- Excellent control Orlando, FL
Neohydronomus affinis
Waterlettuce

• **Identification**
  – Small (1.5 – 2.4 mm) weevil
  – Brown and blue coloration
  – Characteristic “smiling face” on wing covers
  – Larvae – cream color, acute angle at rear

• **Damage**
  – Adults – shotgun blast on leaves
  – Larvae – Tunneling in leaves
  – Very effective throughout the world
  – Biomass reduction typically 1.5 to 2 years

• **Collection techniques**
  – Berlese funnel extraction
  – Moving infested plants
  – Can be mass-reared
Fungal Pathogens

• Foundational/Basic
  – Biology/Ecology
  – Mechanisms of Control

• Applied
  – Development
    • Culturing
    • Formulation
  – Effectiveness
Applied

- Formulation development
- Cooperators
  - USDA, ARS – Peoria, IL
  - SePro – Rocky Mount, NC

- Agar Culture
- Liquid Culture
- Dry Granule
Foundational/Basic

1 g dry Mt  2 g Mt+Gl  2 g Mt+CMC  Control
Applied

Integration with Chemicals
Synergistic Effect

Graph showing the dry weight hydrilla shoot biomass/g for different treatments:
- Control
- Fluridone 21 day
- Fluridone 35 day
- Mt liquid
- Mt dry
- Mt liq + 35 day Fluridone
- Mt liq + 21 day Fluridone
- Mt dry + 35 day Fluridone
- Mt dry + 21 day Fluridone
Future Directions

• In-country surveys
• Thirty three strains identified
  – Mean disease value of 3 or greater
• Further testing warranted
• Five strains
  – Mean disease value of 4
  – Four - *Mycoleptodiscus terrestris*
  – One - *M. roridum*
• Testing in progress
• Monoecious hydrilla pathogens
Active vs. Passive

- Biocontrol is **NOT** a passive technology
- Takes active participation
- Just like any traditional technology
- However, this rarely occurs
- Knowledge is the key
- Willingness to apply knowledge
  - Identification of agents and damage
  - Biology and ecology
  - Surveys
  - Re-release and augmentation
- Louisiana and Texas
Potential Future Directions

• **Overseas**
  - Eurasian watermilfoil
    - 2014
  - Hydrilla
    - ARS: 2009 – 2013
    - Indonesia, southern China
    - New stem weevils?
    - Monoecious hydrilla
      - Northern China
      - Korea – 2014
      - Origin - Genetics
  - Lack of funding

• **Waterhyacinth Planthopper**

• **Mass-rearing**
  - State/local level
  - Quantity vs Quality
  - Reduce costs

• **Use of Pathogens**
• Biocontrol
  – Agent approval
  – APHIS
  – Risk/Benefit
  – Tightened standard
  – FONSI
  – Harder to get agent approvals

• Overseas
  – Countries more reluctant
    • Allow potential agents to leave country
    • Protection of biodiversity
    • Money
    • Argentina
    • Impact - Warm climate strain – waterhyacinth planthopper