The Use of Genetically Modified Organisms

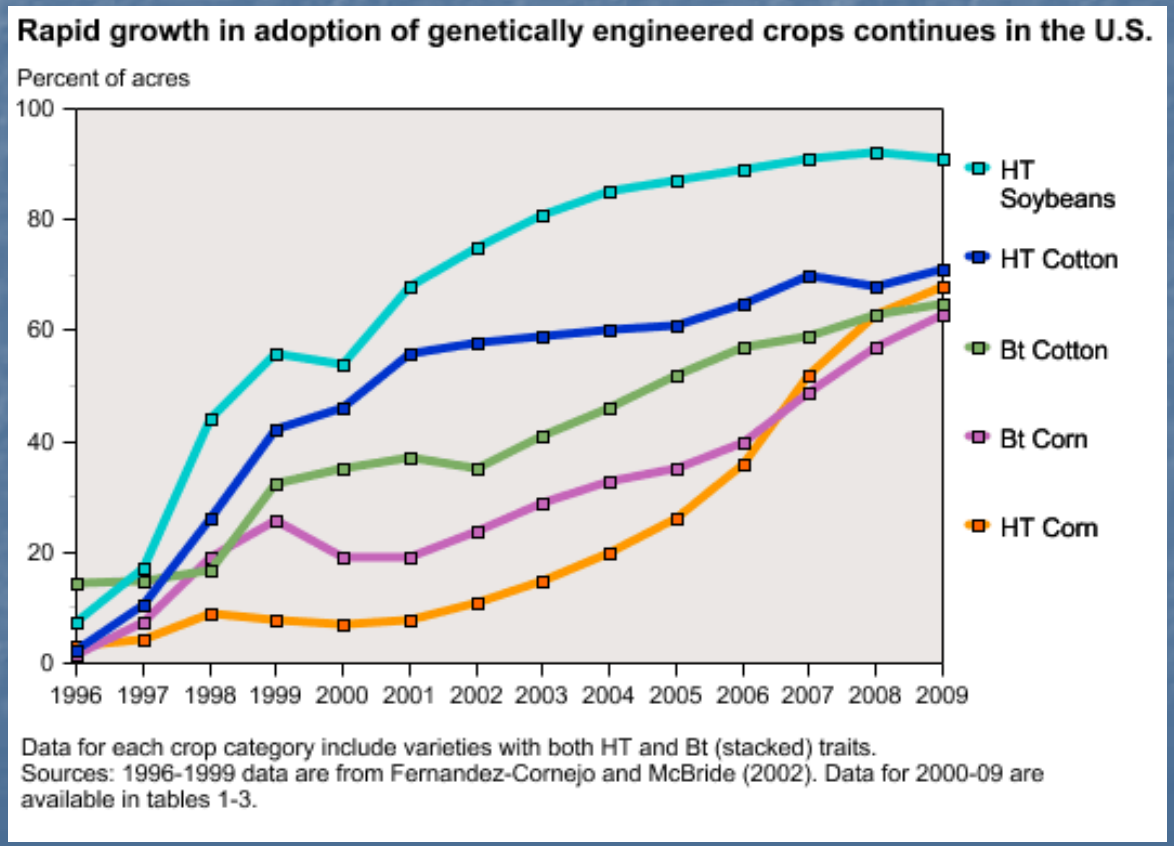
ECS 3119 – Pesticides and Fish & Wildlife Resources

Source: USDA ARS

What are GMOs??

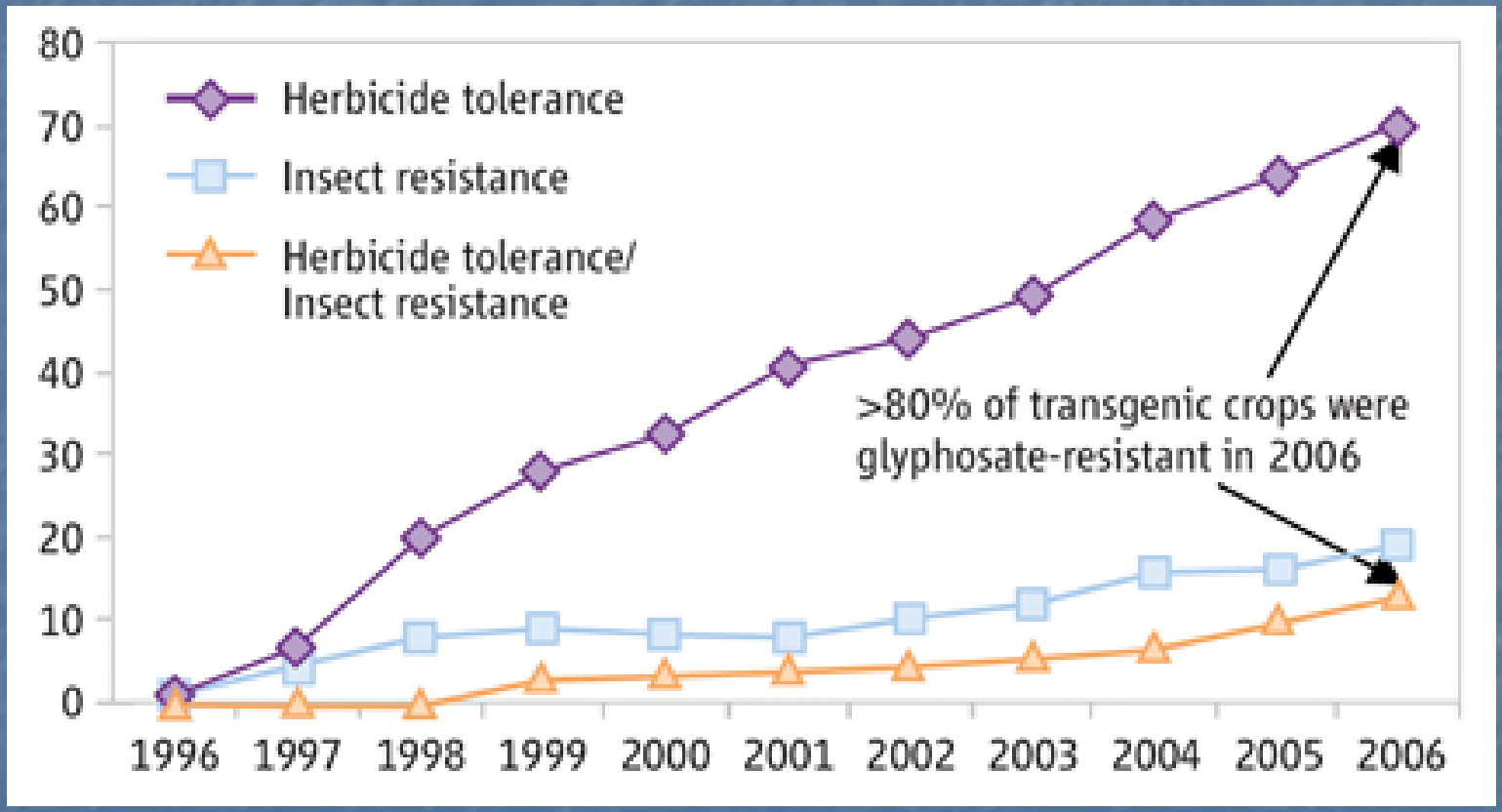
- Transgenic crops: Plant that contains a gene or genes that have been artificially inserted
- Foreign gene (transgene) can come from different sources (plant, animal, virus, bacteria),
- HTC (Herbicide Tolerant Crops)
  - Ex. Roundup Ready soybeans, cotton, canola, etc.
- Bt (*Bacillus thuringiensis*)
  - Ex. Corn, cotton

Use of genetically engineered crops in the United States



Source: USDA Economic Research Service

Global Area of Biotech Crops by Trait (Million Hectares)



Source: Robert F. Service (25 May 2007). "A Growing Threat Down on the Farm." *Science* **316** (528),

Regulation of GMOs

- Environmental Protection Agency
  - Plant Incorporated Protectants
  - FIFRA, TSCA, and Federal Food, Drug and Cosmetics Act
  - Assessment of environmental risk
- Food and Drug Administration
  - Assess nutrient level changes, allergen potential
- US Department of Agriculture
  - Determine if the transgenic may become a pest
  - Plant Protection Act
- US Regulatory Agencies Unified Biotechnology site
  - National Biological Information Infrastructure
  - http://usbiotechreg.nbii.gov/

EPA Oversight on GMOs

- Examines data characterizing the plant-incorporated protectant
- Reviews environmental effects (both risks and benefits) of the proposed plant-incorporated protectant
- May require a resistance management plan
- May require toxicity testing in animals
- Sets tolerance levels for pesticide residues, if there is evidence of toxicity
  - Because of lack of toxicity in plant-incorporated protectants evaluated to date, they have been exempt from this requirement.
- Regulates new uses of existing pesticides, such as use of herbicides together with herbicide-resistant transgenics

Service Policy Regarding GMOs

- Refuge Chapter 3, Biological Integrity, Diversity, Environmental Health 601 FW 3 (http://www.fws.gov/policy/library/01fr3809.pdf)
  - No genetically modified organisms in refuge management unless use is essential to accomplishing refuge purpose(s) and the Director approves the use.
- Updated Service Policy for Region 4 (2007) and 6 (2008)

Service Policy Regarding GMOs

- Delegate GMO approval authority from Director to Regional Refuge Chief
- Considerations in the use of GMO's
  - Practicality of growing crops
  - Consideration of all applicable laws/policies
  - Presence of wild related species
  - GMO use versus conventional pesticide use
  - T & E Species and appropriate Section 7

Litigation Related to GMO Use on Prime Hook NWR, DE

- Complaint filed by Center for Food Safety
- FWS failed to perform compatibility determinations required by the NWR Administration Act for farming
- FWS failed to prepare EA required by NEPA to assess effects of GM crops, and associated pesticide applications
- Court ruled no future GMO plantings on the refuge until compliance with NWRAA and NEPA
  - Preparation of Comprehensive Conservation Plan

USDA-APHIS related litigation regarding transgenic crops

- Center for Food Safety
- Complaints filed based on NEPA:
  - RR Alfalfa
  - RR Sugar beets
  - RR Creeping bentgrass
  - Cold tolerant eucalyptus trees

Potential Benefits of GMOs

- Increased Yield
- Improve resistance to pests
- Improve hardiness (drought and salinity)
- Reduced maturation time
- Incorporation into IPM plans

Potential Benefits of GMOs

- Decreased Use of Pesticide Applications
  - Insecticides
    - Benefits in Bt cotton (unclear in corn)
  - Herbicides (results mixed)
- Soil and Water Conservation
  - Reduction of herbicides in surface water runoff

Cotton Bollworm/Budworm Insecticide Reductions After the Introduction of Bt-cotton: AR,MS,AZ,LA

Insecticide	Use of Pesticide Active Ingredient (1000s Pounds)
Amatraz (Ovasyn)	−42
Cyfluthrin (Baythroid)	−35
Cypermethrin (Ammo)	−81
Deltamethrin (Decis)	+11
Esfenvalerate (Asana)	−19
Lambdacyhalothrin (Karate)	−58
Methomyl (Lannate)	−156
Profenofos (Curacron)	−1014
Spinosad (Tracer)	+19
Thiodicarb (Larvin)	−665
Tralomethrin (Scout)	−4
ζ-Cypermethrin (Fury)	+1
Total	−2044

Potential Environmental Concerns and GMO's

- Invasive Species
- Beneficial insects
- Endangered species (karner blue butterfly)
- Soil microorganisms/aquatic organisms
- Weediness (volunteer crops and native vegetation)
- Resistance (RR and Bt)
- Biodiversity

Invasive species concerns

- Cold tolerant *Eucalyptus*
- Biofuel production in the US
- Fast growing tree that is a non-native
- Potential soil quality impacts

Pollinators and Transgenic Plants

- Bacillus thuringiensis
- Protease Inhibitors
  - Inhibits digestion
- Exposure potential
  - Pollen, nectar
- Assessment of lethal/sublethal impacts
  - Adults/larvae

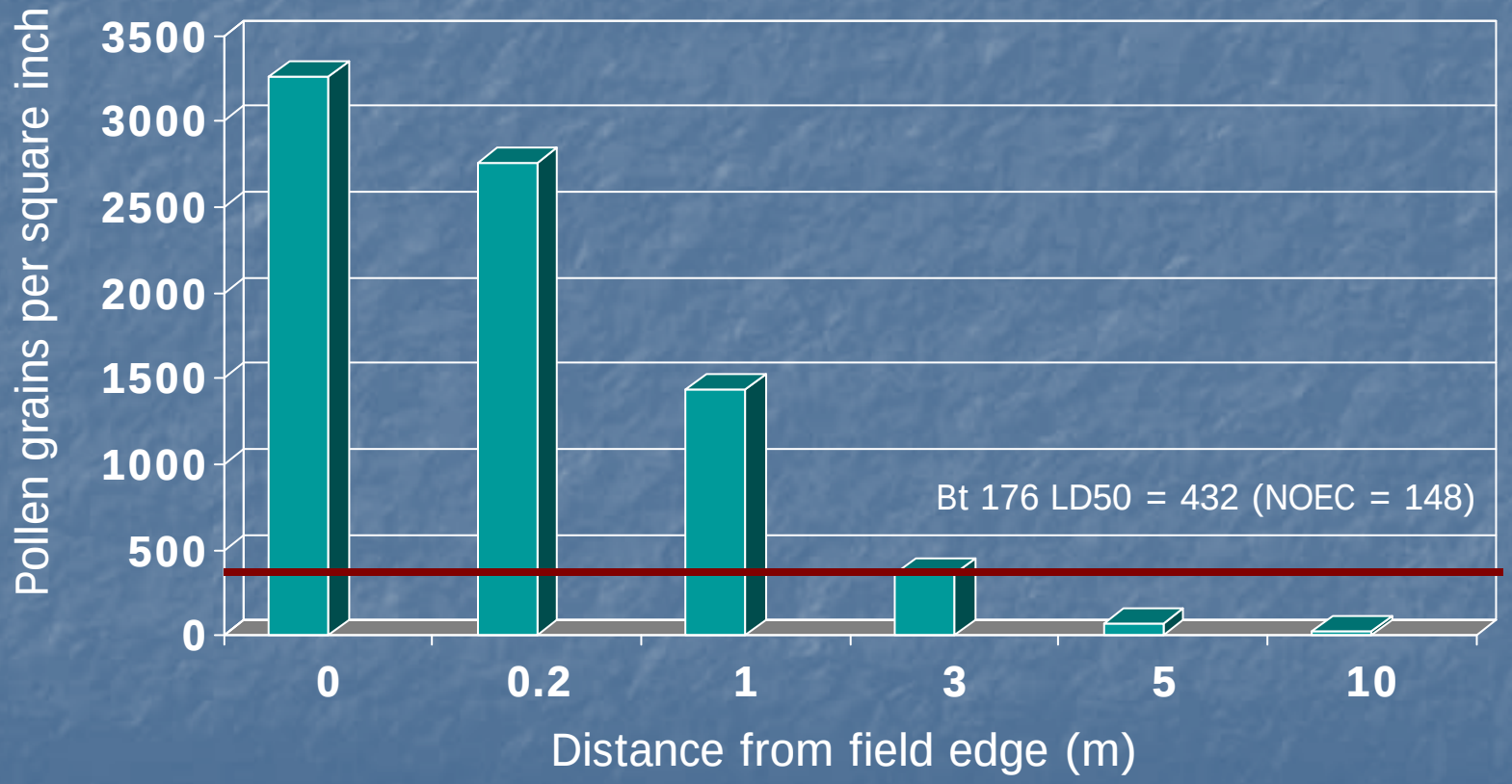
Bt Corn Impacts to Monarch Butterflies

- First reported in 1999 Nature publication
- Additional studies conducted to determine effects
  - US and Canadian agencies, states, industry
- Monarchs more sensitive to Bt 176 events when compared to others
- Bt corn used today appears to be of low risk to monarch/black swallowtail larvae

Factors Affecting Exposure of Bt Corn to Monarch Butterflies

- Corn pollen shed for about two weeks while monarchs will reproduce throughout summer
- Proportion of Monarchs laying eggs on milkweed inside or near fields is low
- Rainfall events will remove pollen
- Corn pollen levels drop dramatically as you move away from a corn field
  - Dependent on site conditions but generally greater than 98% deposition w/n 5-m from field edge

Effect of Distance on Pollen Levels from Corn Fields



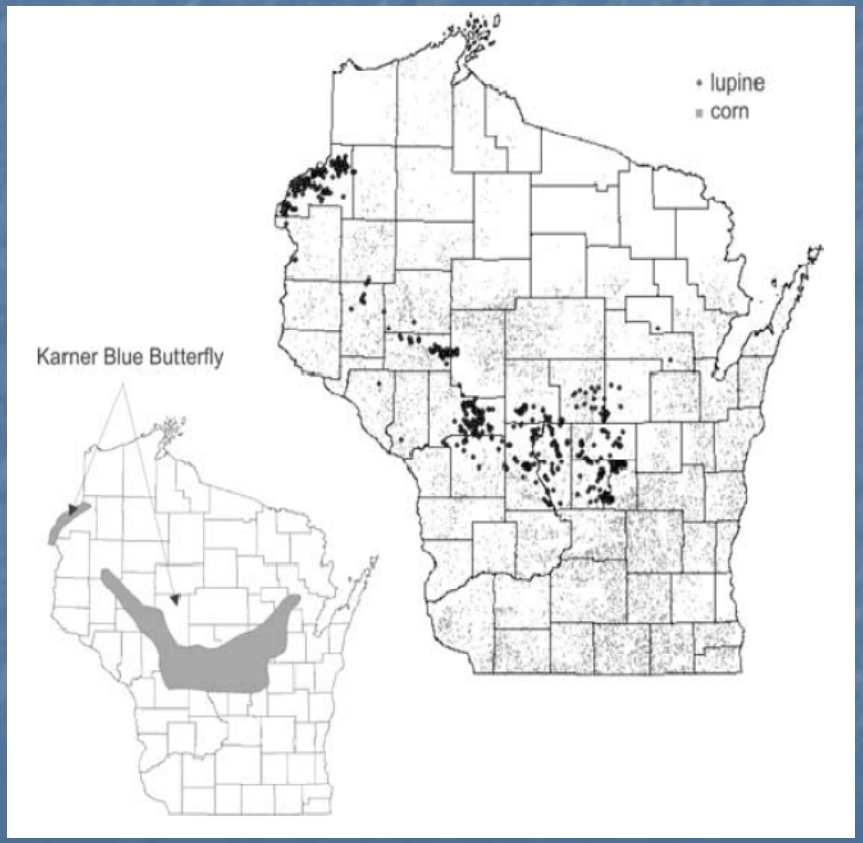
Source: Hansen-Jesse and Obrycki, 2000, Sears et al. 2001.

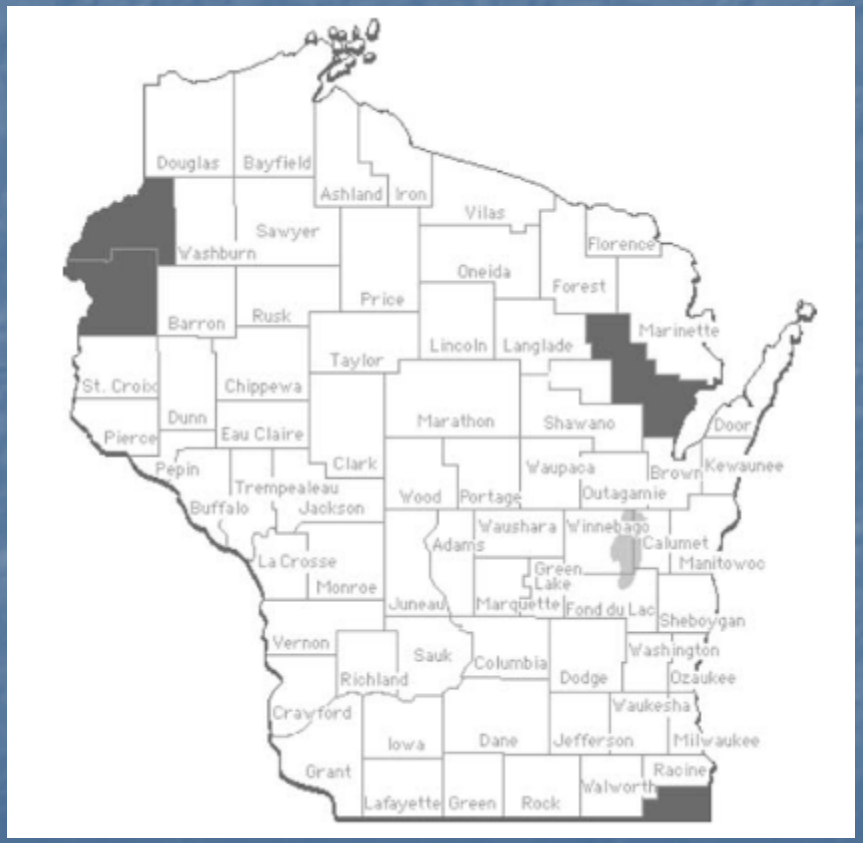
Assessing the risk to ES from genetically engineered plants

- Determine potential temporal and spatial exposure to the karner blue butterfly
- Utilize degree-day modeling for butterflies and pollen shed

Karner blue butterfly
Photo by Paul Labus.

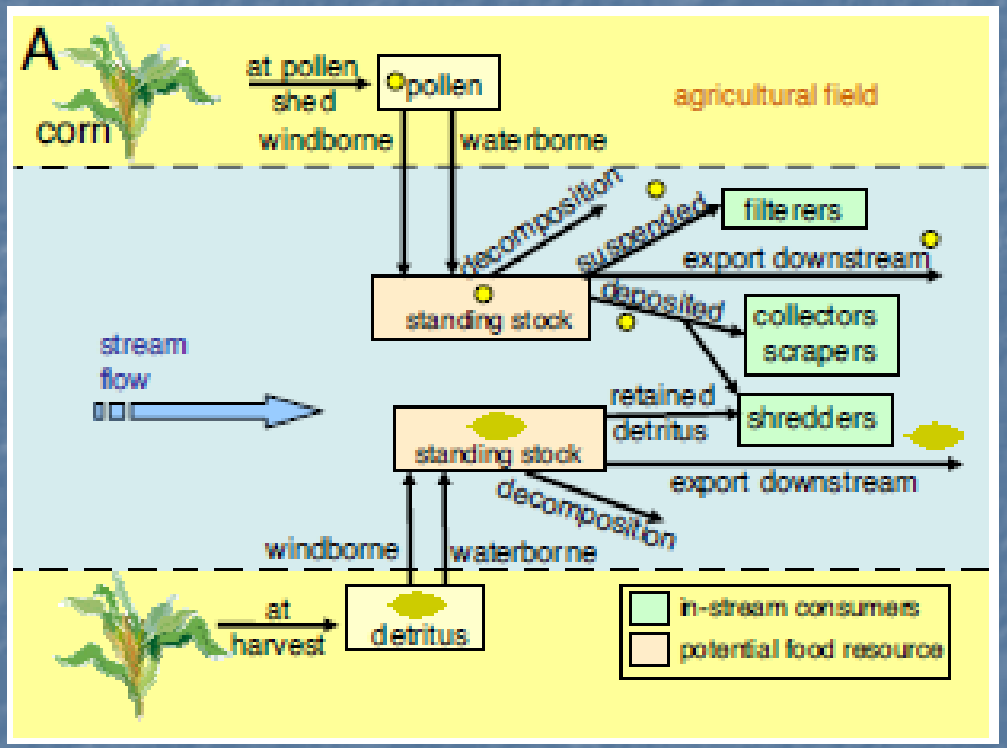
Potential temporal overlap between maize pollen shed and presence of the Karner blue butterfly





Source: Peterson et al. 2006 *Risk Analysis*

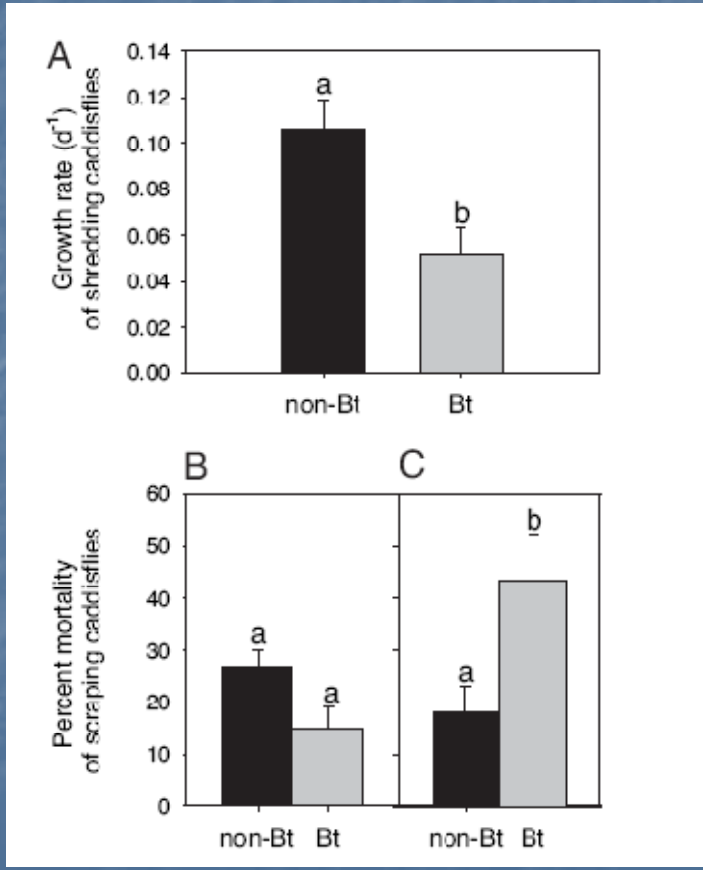
Transgenic Bt corn exposure in aquatic systems



Source: Marshall et al. 2006

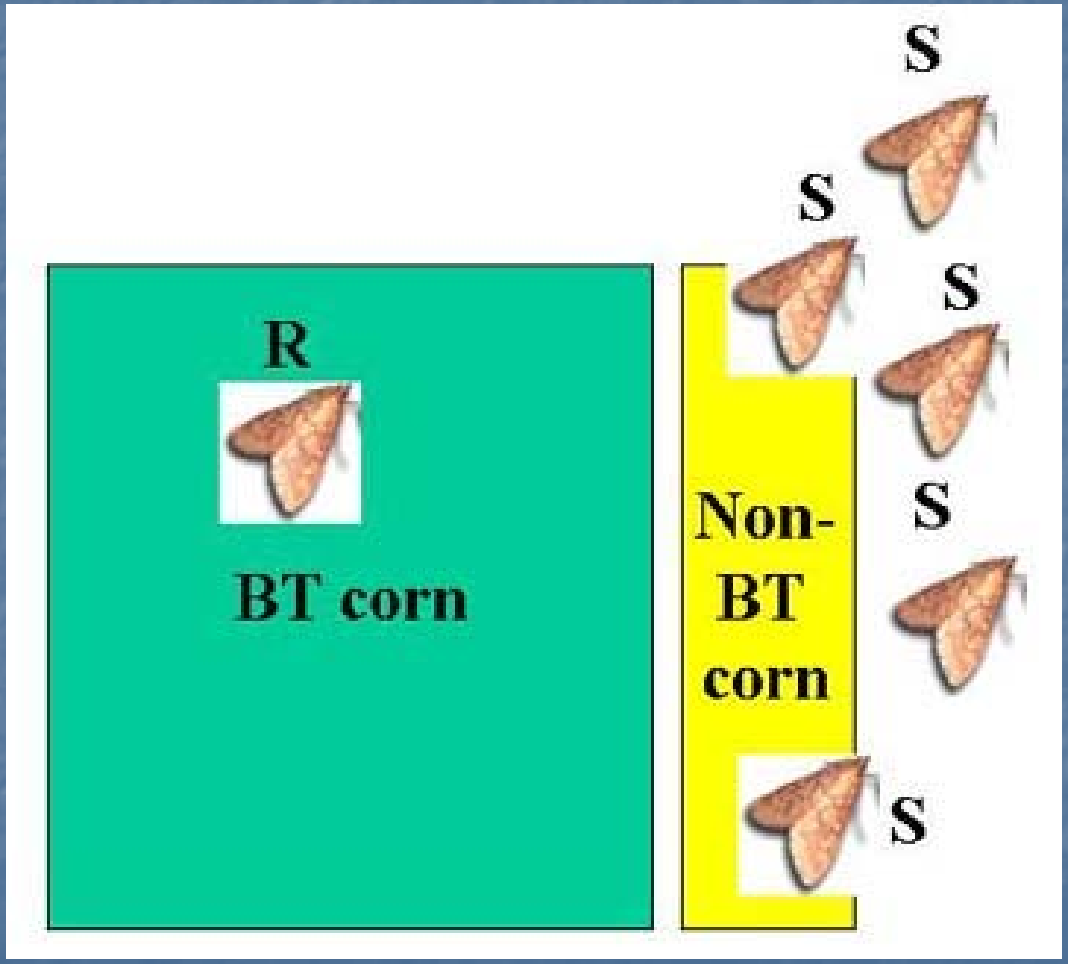
Potential impacts to aquatic organisms

- Impacts of Bt pollen and detritus on aquatic systems
- Shredding/scraping caddisflies
- 90% of watershed in crops
- B = .055 g/m^2
  - (ambient)
- C = 2.75 g/m^2
  - (2-3X the observed max.)



Source: Marshall et al. 2006

Managing GMO Bt Resistance using Insect Resistance Management (IRM) plans



BT Corn Refuge:
- 80% planted in BT Corn
- 20% planted in non-BT corn

50% planted in BT cotton in certain areas of the south

R = Resistant
S = Susceptible

Source: Colorado State University

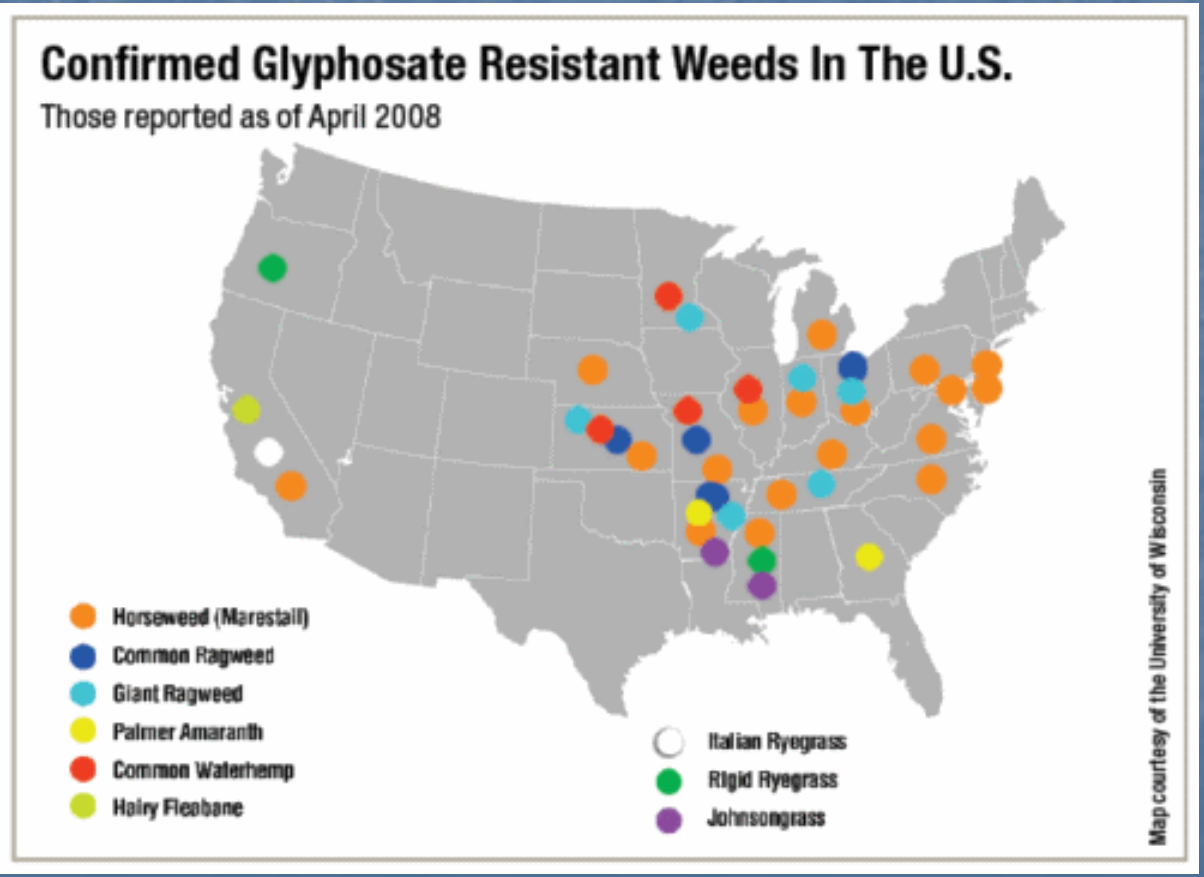
Assumptions in Bt Refuge Systems

- Resistant genes to Bt are rare
- Resistant genes are recessive
- Susceptible and resistant moths will mate
- Farmers will comply with refuge requirements
  - 13-29% initial non-compliance rate
  - Compliance improving
    - >90% corn IRM compliance (2006)

Glyphosate Resistance

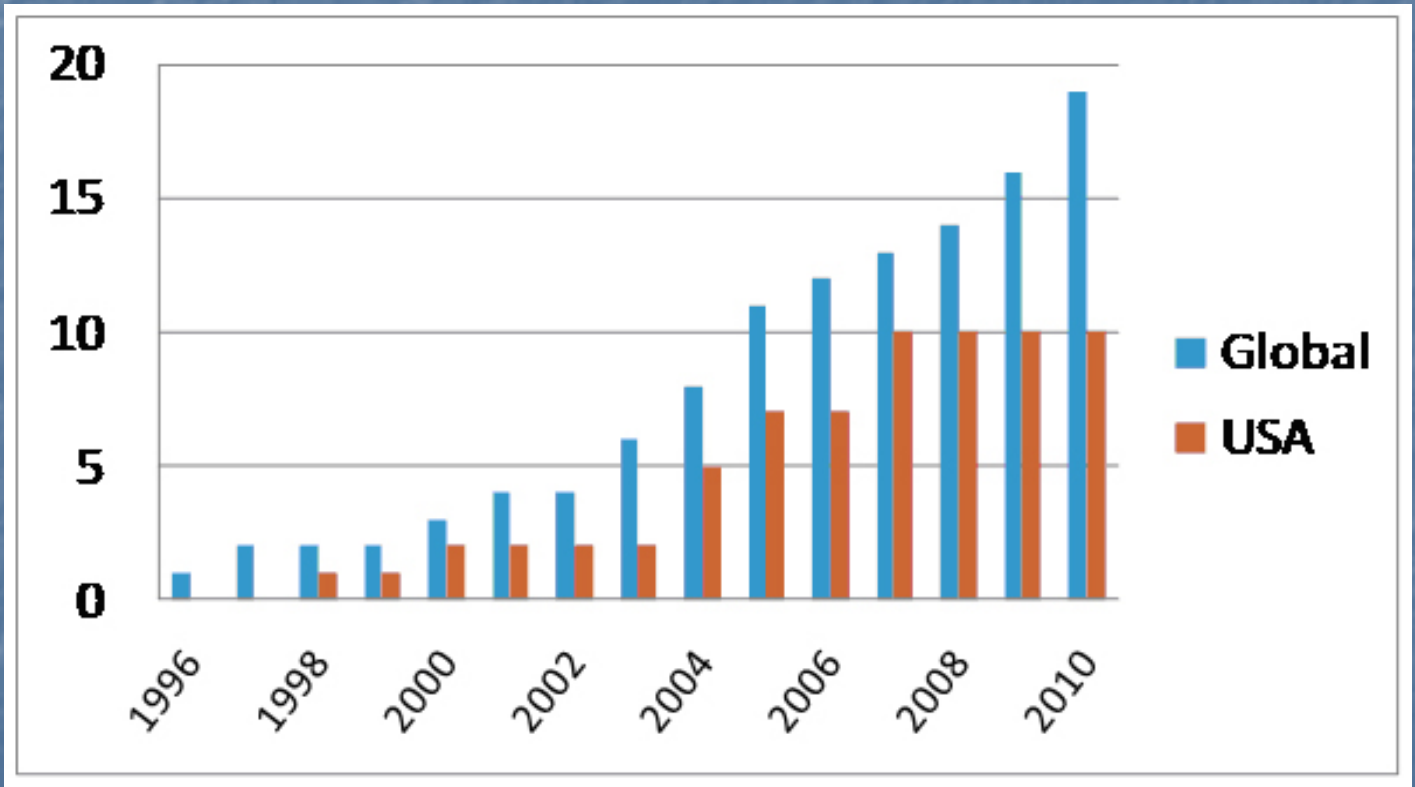
- First identified in DE fields in 2000
- HT Soybean and cotton
- Multiple weed species identified
  - Common and giant ragweed, horseweed, common lambsquarters, pigweed, cocklebur, black nightshade, waterhemp, buckhorn plantain, etc.
- Glyphosate Stewardship Forum

Glyphosate resistant weeds in the US



Source: www.croplife.com

Number of glyphosate resistant weed species



Glyphosate Stewardship Practices

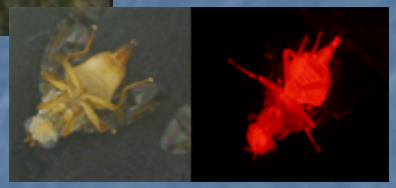
- Rotation of RR crops w/ conventional or other HTC's
- Rotating glyphosate with herbicides that have different modes of action
- Tank mixing during burndown treatments
- Scout fields regularly to identify weeds
- Apply glyphosate at labeled rates at the correct stage of growth.

Biodiversity

- Potential for reduction in weed seed banks
  - Corn, oilseed rape, sugar beets production
- Potential for indirect impacts to non-target organisms?

Future Use of GMOs

- Agriculture
  - Corn, alfalfa, tomato, rice, grapes, sunflower
- Silviculture/Turf
  - HTC, insect resistance, reduced lignin and volatiles
- Biofuels
- Insects
  - Mosquitoes, PBW, Fruit Flies, honeybees
- Plant Based Vaccines/Pharma
- Bioremediation
  - Hazardous waste and oil spills



Source: Oxitec