A Risk-Based Approach to Managing Intentional Introduction of Non-Native Species

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Intentionally Introduced Species

- Introduced species have caused great harm
  - e.g., Mongoose, Game fish, Eucalyptus trees, Purple loosestrife
- Non-natives also provide benefits
  - Agricultural Crops & Livestock
  - Ornamental plants
  - Household pets
- Prohibition undesirable & unsuccessful
- Careful planning is essential

Approach

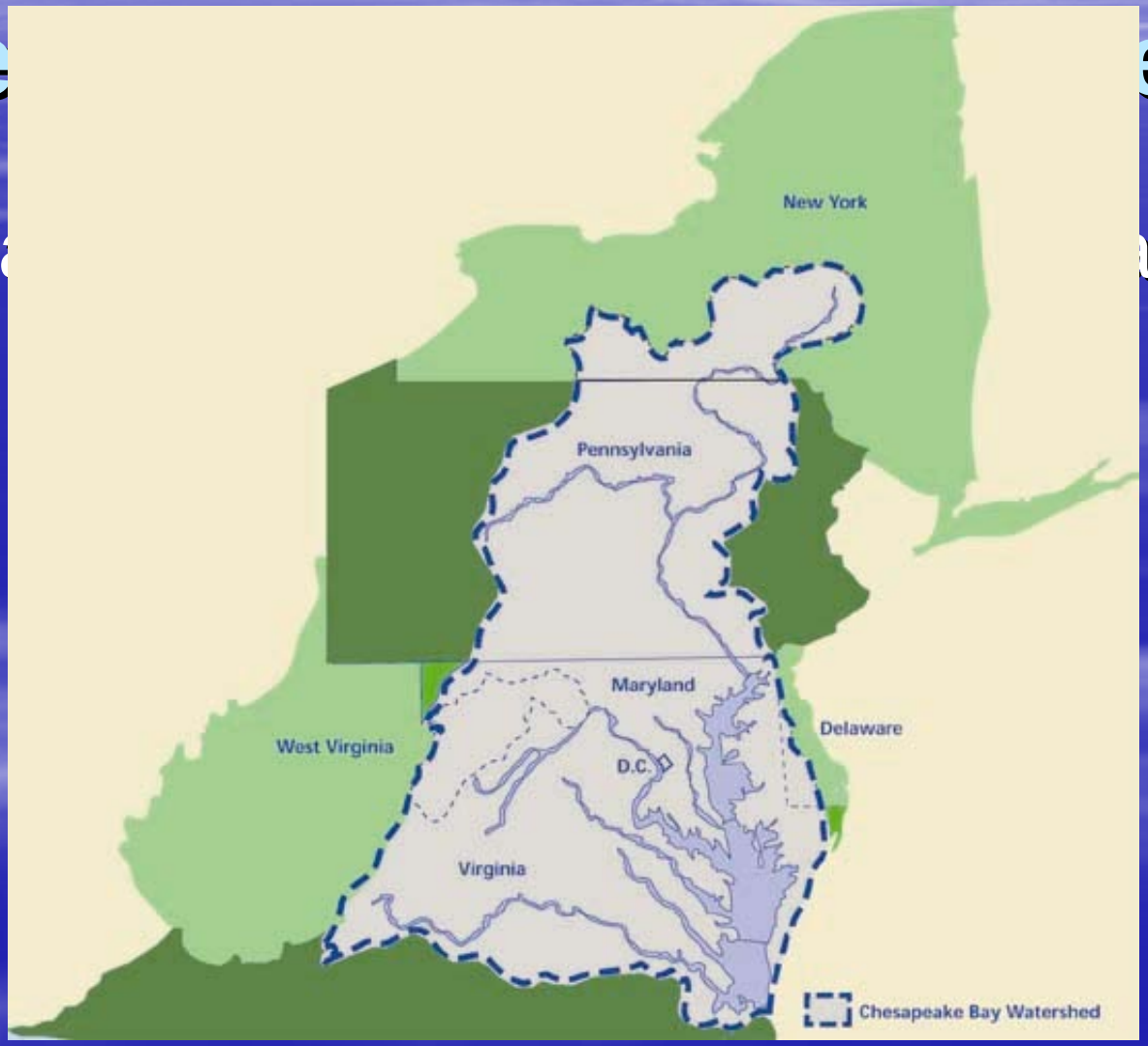
- Risk-based framework
- Balance benefits of intro vs risks of invasives
- Phased introduction w/intervention points

Multiple Tiers of Risk

- Introduced Species Becomes Invasive,
- Invasive “Hitchhiker” Species
- “Rogue” Introduction
- Financial Risks of Profitability

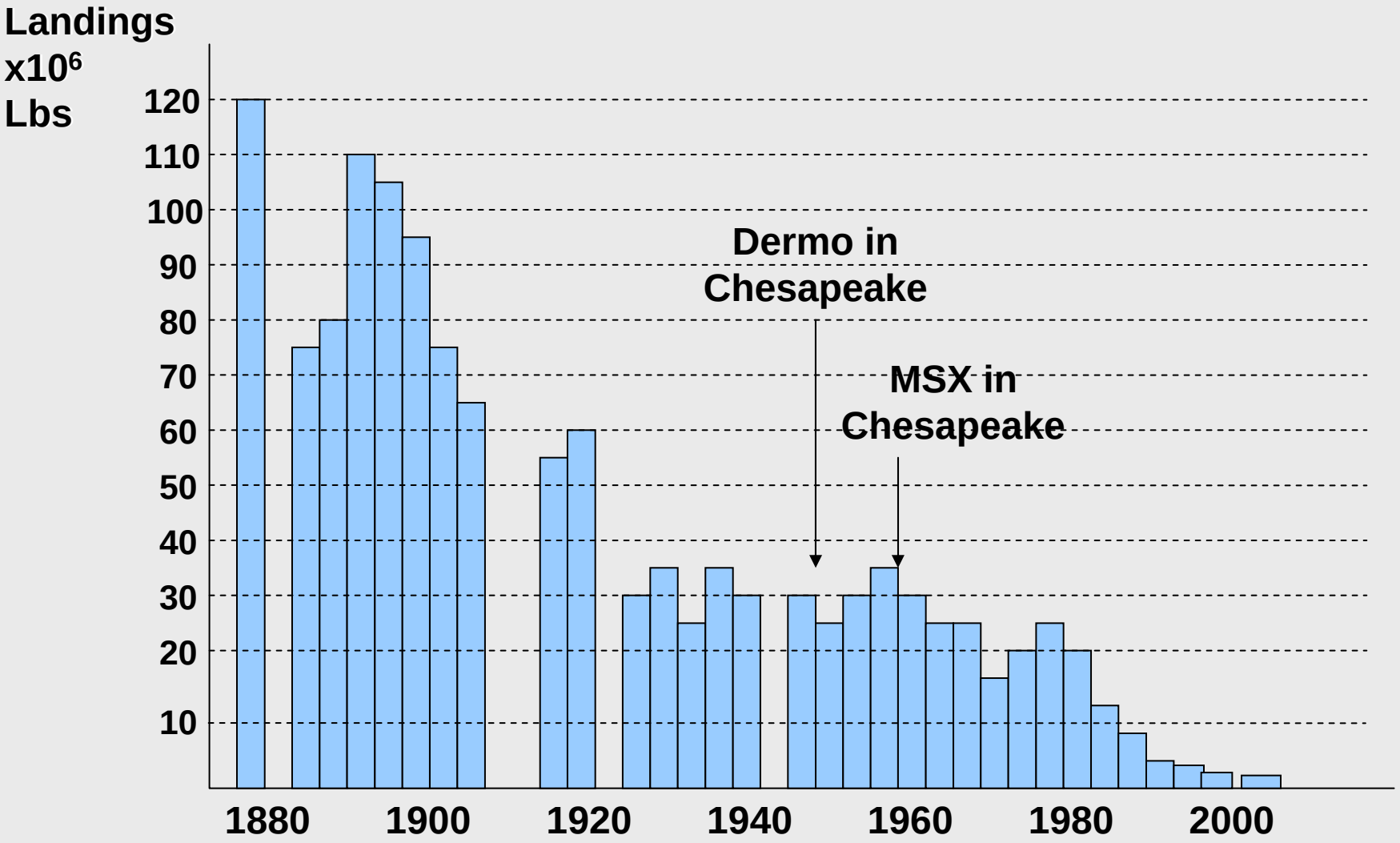
Application: Introducing Non-native e Bay

- Chesa ary



Application: Introducing Non-native Oysters in Chesapeake Bay

- Chesapeake is nation's largest estuary
- Dramatic decline in native oysters (C.Virginica) in Chesapeake
- Disease responsible for recent declines



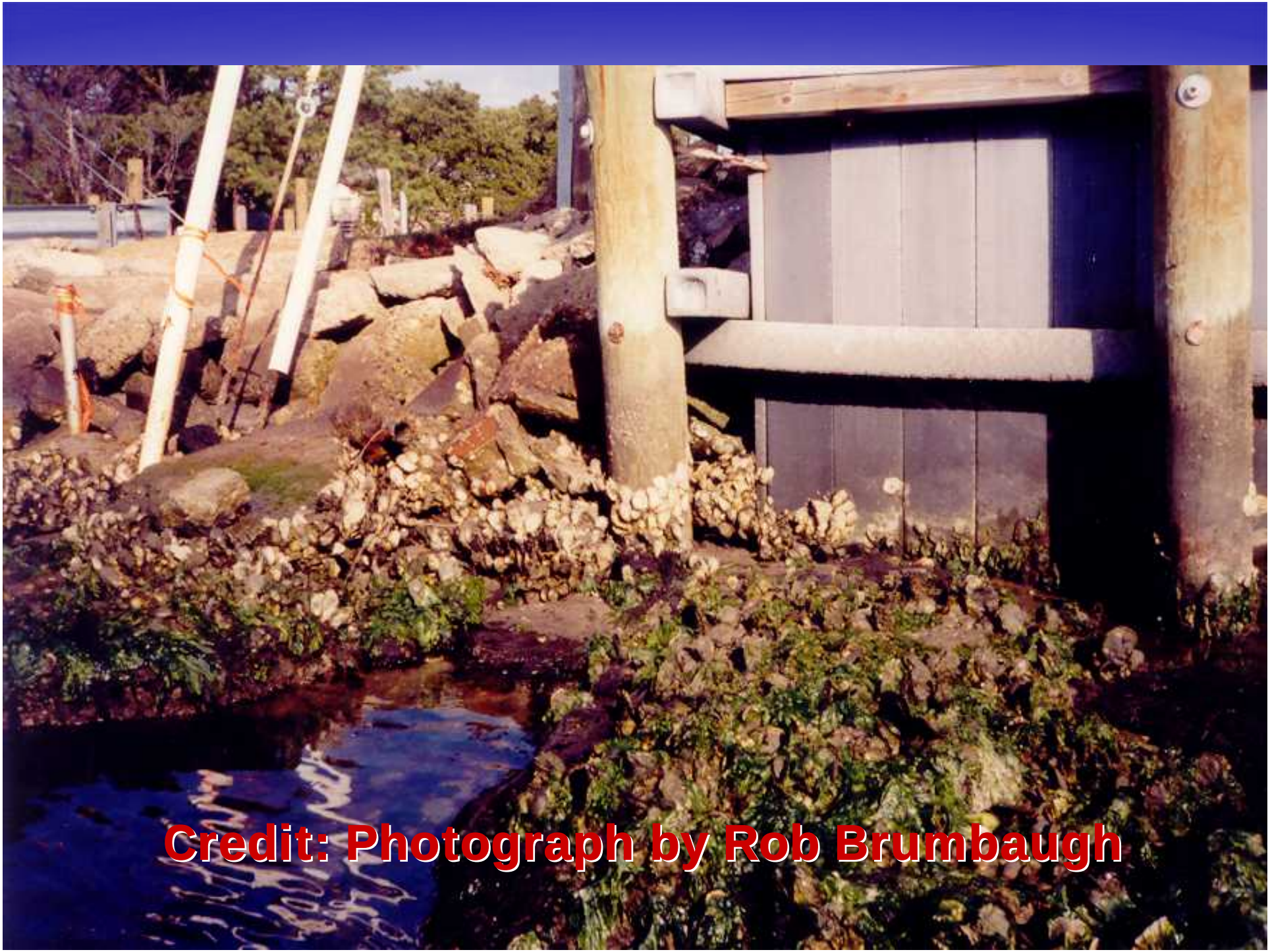
Time Series of Oyster Landings in Chesapeake Bay

Sources: Data from Chesapeake Bay Program & National Marine Fisheries Service

Application: Introducing Non-native Oysters in Chesapeake Bay

- Chesapeake is nation's largest estuary
- Dramatic decline in native oysters (C.virginica) in Chesapeake
- Disease Responsible for Recent Declines
- Non-native Suminoe oyster (c.Ariakensis) may be solution
- Very Controversial


Credit: Photographs by Rob Brumbaugh
Chesapeake Bay Foundation


Credit: Photograph by Rob Brumbaugh

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Chesapeake Bay Foundation

Interesting Application

- Important and controversial issue
- Illustrates problems common to other introductions
- Extensive Data Available

Attributes of Ariakensis

- Faster growing than native oysters,
- Tolerated MSX and Dermo disease;
- Indistinguishable taste from native oysters

Invasive Risk Management

- Biological Controls

Biological Controls

- Triploids unable to reproduce
- But probability of reverting to diploids (mosaics), capable of reproducing
- Fear of becoming invasive

Invasive Risk Management

- Biological Controls
- Technology-based standards

Technology Based Standard

High Harvest Certainty

Source: Dew, Berkson, Hallerman and Allen, "Demographic Simulation Model for Assessing and Managing Risks Posed by Proposed Deployment of Triploid Suminoe Oysters in the Chesapeake Bay"

Invasive Risk Management

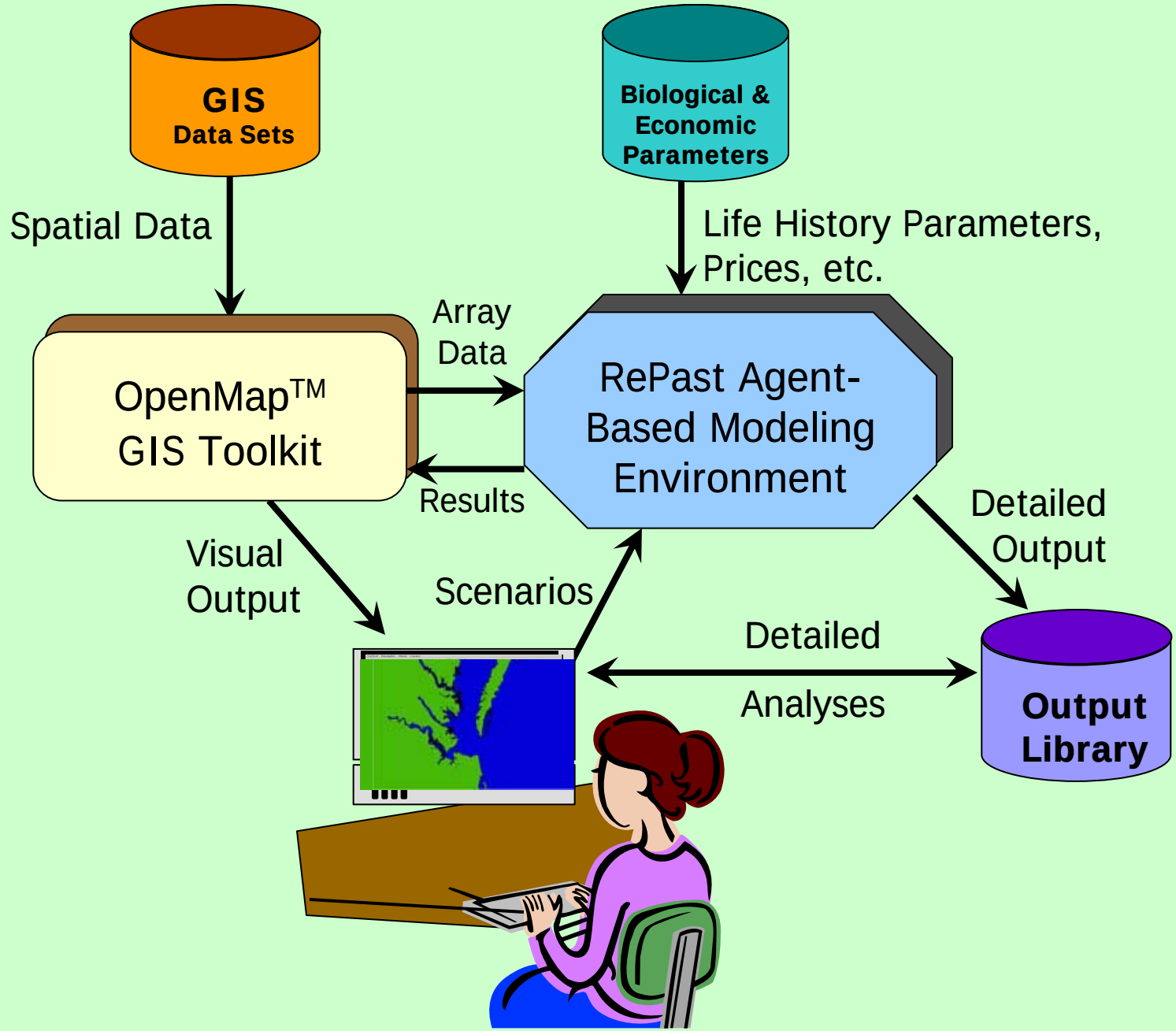
- Biological Controls
- Technology-based standards
- Best management practices
  - e.g., Locations where oysters are planted
- Performance standards
  - e.g., Maximum escapement rates
- Incentives
  - e.g., Liability for response costs & damages

Institutions

- States play major role
- Md. plants beds, and licenses harvesters
- Va. leases oyster beds to private parties

Project Framework

- Spatially Explicit
- Limited Access, Shared Resource (Md. Model)
  - Multi-agent Simulation Modeling
- Principal-Agent Model (Va Model)
  - Gov. Agency is Principal
  - Introducing Firms are Agents
  - Sole Owner



Depiction of the Modeling System Architecture

Oyster Population Dynamics

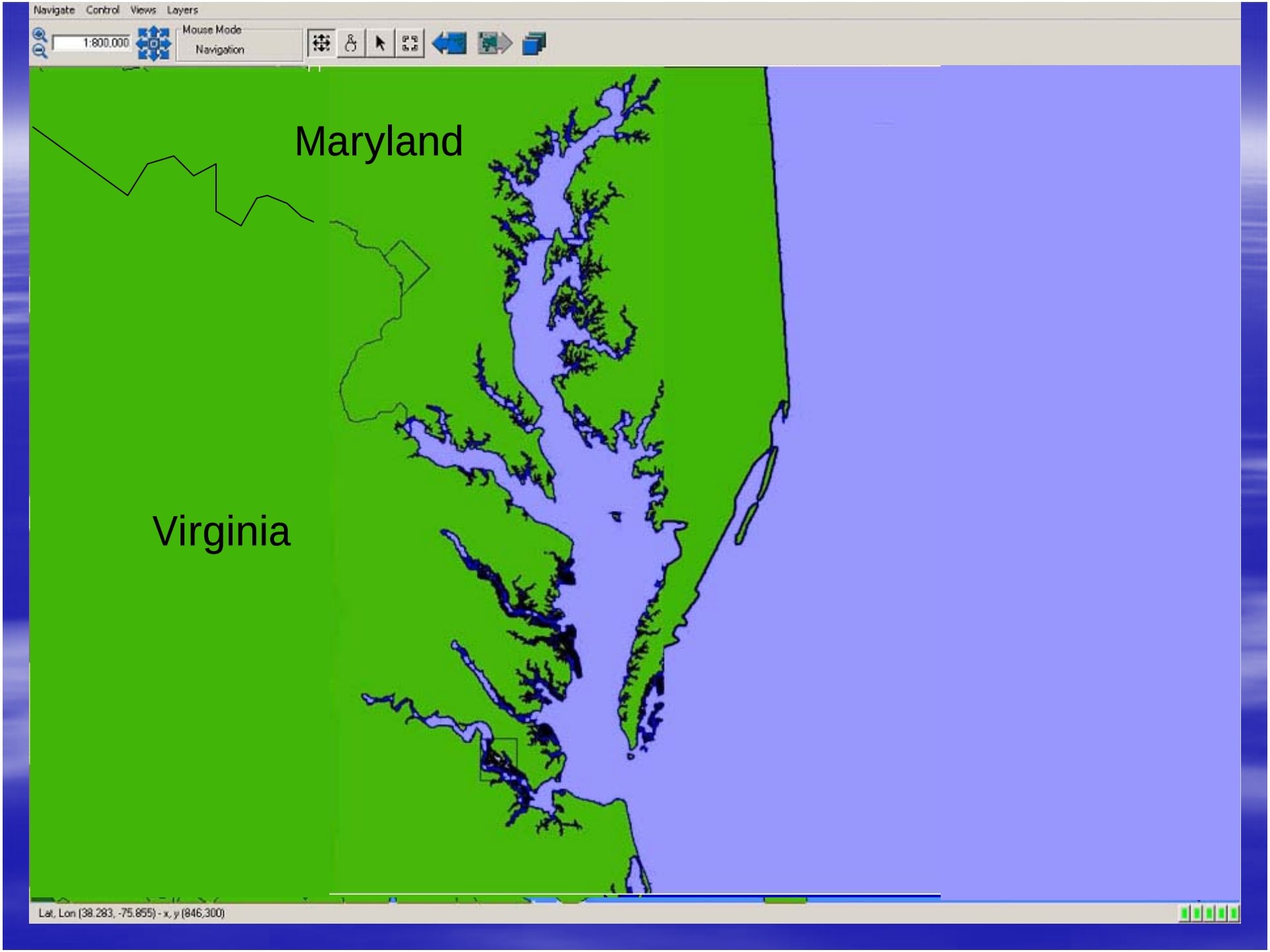
- Cohort-Based Model (Dew et al. 2005)
- Spatially Explicit Agent-Based Model
- Adult Oysters Sedentary
- Transport Only During Reproduction
- Detailed Modeling of Early Life Stages

Larval Modeling

- Gamete Production
- Fertilization
  - Density Dependent
  - Gamete Sink
- Survival
  - Depends up environmental conditions (e.g., Salinity)
- Transport and Setting on Habitat

Transport Mechanism

- Transport Occurs During Reproduction
- Broadcast Spawners
- Multi-Agent Simulation Model
- Calibrated to North et al. (2007)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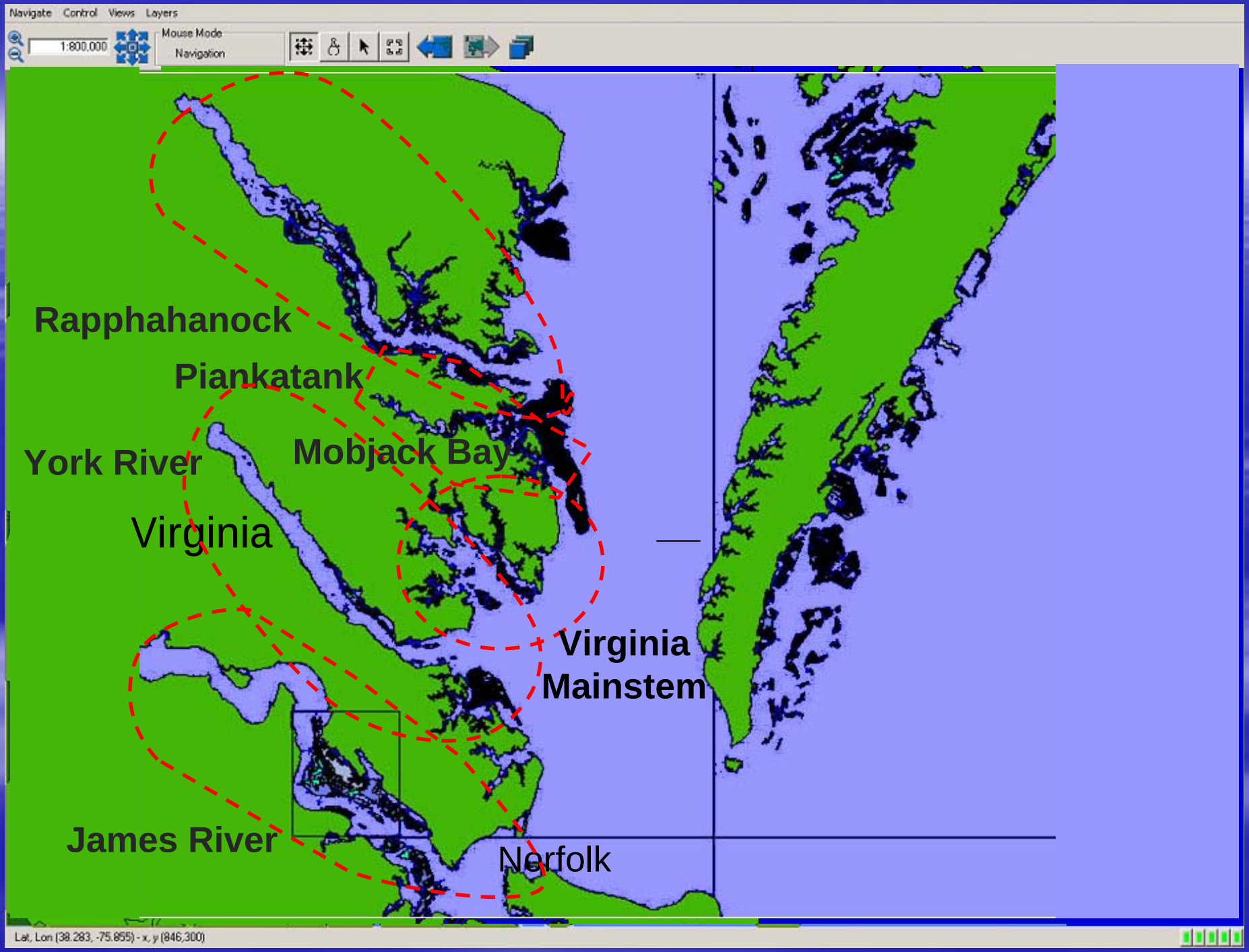
Mouse Mode
Navigation
Maryland
Virginia
Lat, Lon (38.283, -75.855) - x, y (846,300)


Navigate Control Views Layers
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Mouse Mode
Navigation
Rapphahanock
Piankatank
York River
Mobjack Bay
Virginia
Virginia
Mainstem
James River
Norfolk
Lat, Lon (38.283, -75.855) - x, y (846,300)

Mean Distance Traveled by Year: Introduced Species (km)

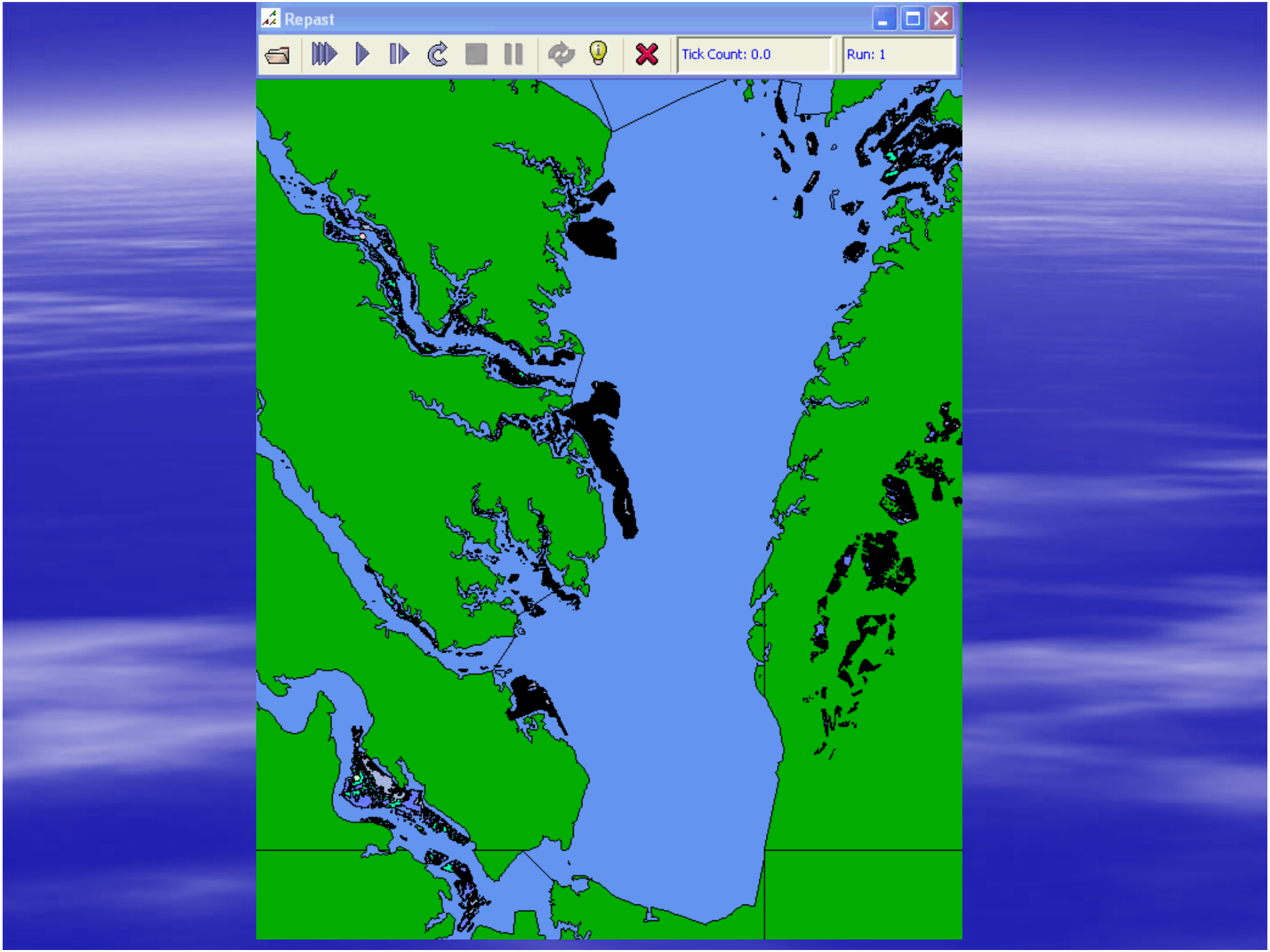
Basin	All Years	1995	1996	1997	1998	1999
Mobjack Bay	5.9	6.3	6.5	5.8	5.3	5.7
Piankatank	3.9	5	4.9	3.4	3.2	3.2
Rappahannock	7.2	8.7	7.5	7	6.4	6.3
VA Mainstem	16.7	19.4	17.2	15.8	15.9	14.8
York River	7.1	7.9	7.2	6.9	6.4	7.1
Std Dev	9.9					
Maximum	121.4					

Source: North et al, 2007

Connectivity Across Tributaries: Native Species

	Rappha-hannock	Piankatank	York River	Virginia Mainstem	Mobjck Bay	James River
Rapphahannock	**92.1%**	2.0%	0.4%	5.3%	0.3%	
Planatank	3.4%	**69.4%**	0.5%	26.3%	0.4%	
York			**93.7%**	0.7%	5.5%	0.05%
Virginia Mainstem	8.8%	4.0%	6.1%	**72.7%**	6.2%	1.6%
Mobjck Bay			5.9%	1.8%	**92.3%**	0.03%
James				1.6%		**98.4%**

Source: North et al, 2007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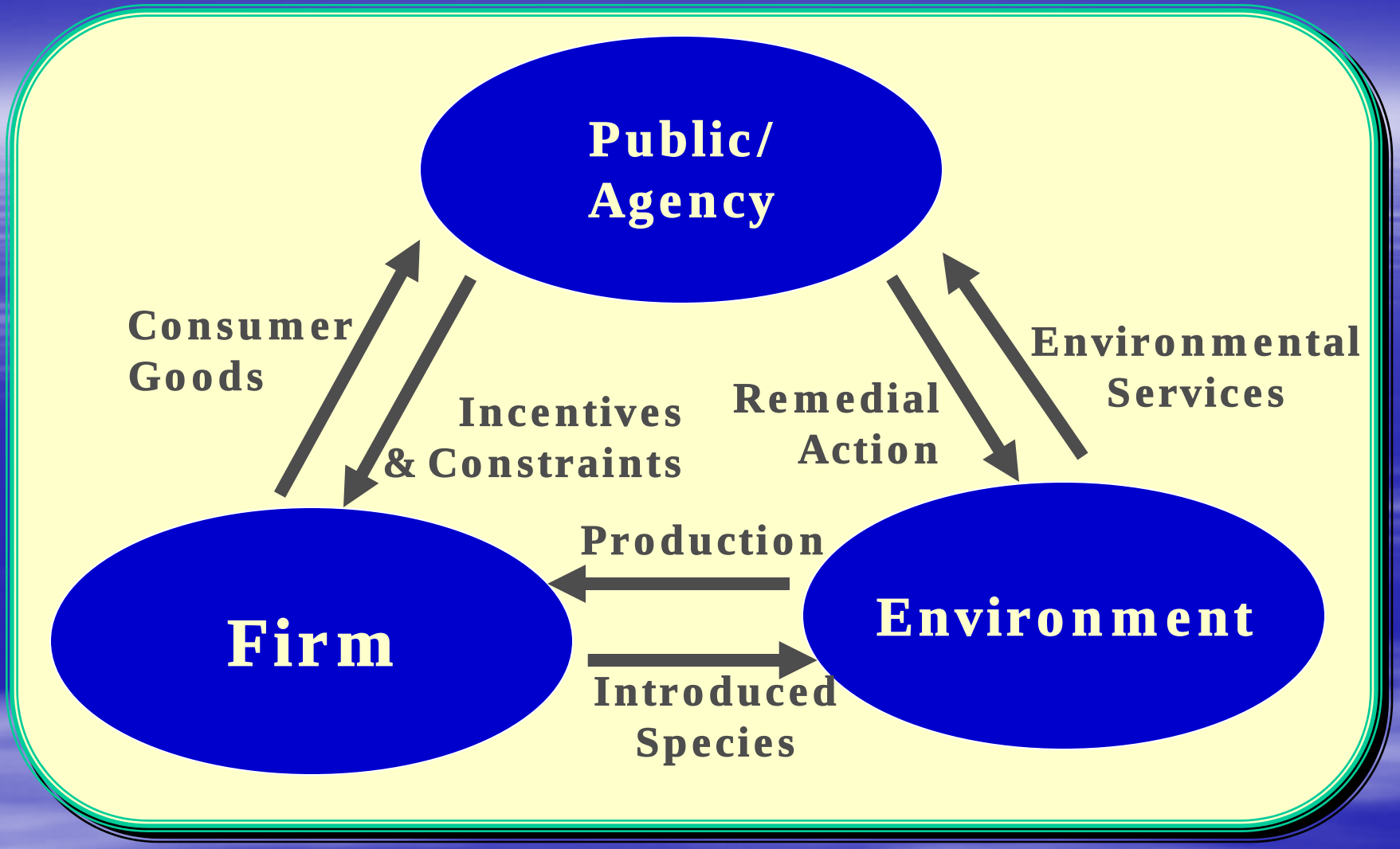
Principal Agent Model

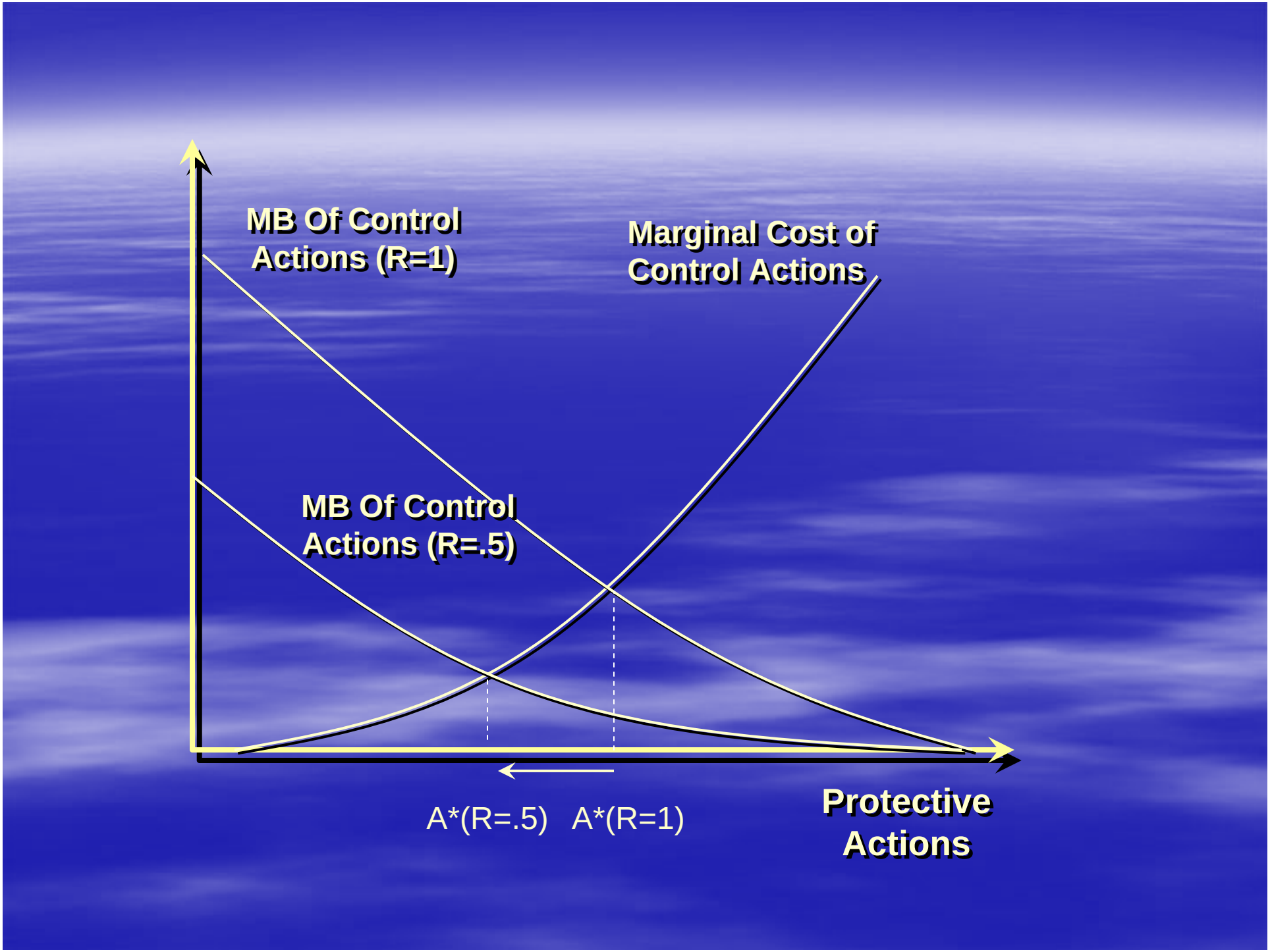
- Firm Proposes to Introduce Oysters
- Governments Sets Constraints On Actions by Firms
- Firms Range in Reliability (0 to 1)
  - 'Unreliable' Firms Discount Costs of Invasion
    - Underestimate Probability of Invasion
    - &/or Believe They Won't be Held Accountable



Depiction of Key Relationships of Principal Agent Model

Model I:
No Monitoring of Control Actions

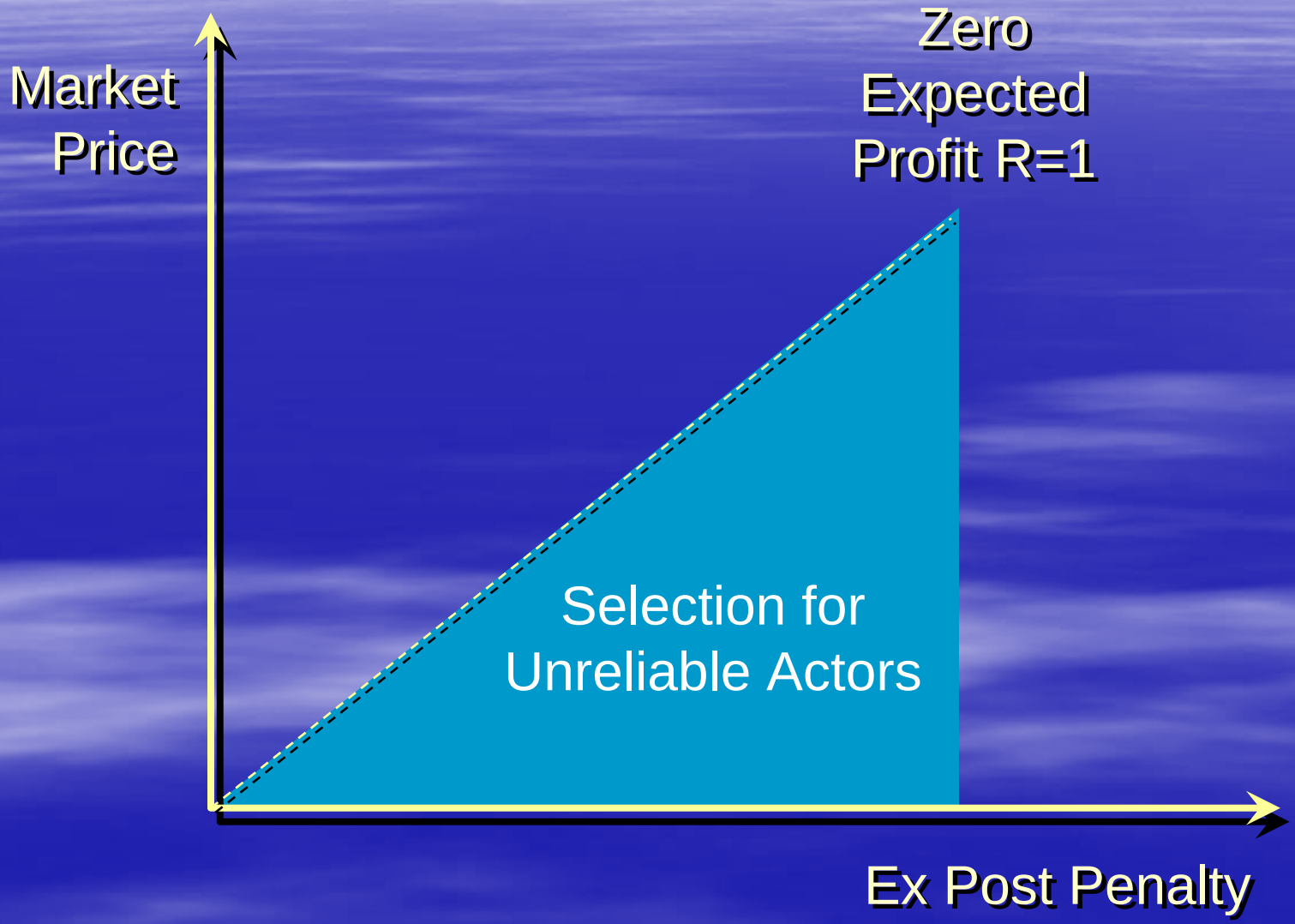
- Government Allocates Fixed Number of Permits to Firms for Introduction
- Control Actions by Firms Not Observable
- Government Observes Invasion After the Fact
- Firm is Penalized if Invasion Occurs


MB Of Control Actions (R=1)
Marginal Cost of Control Actions
MB Of Control Actions (R=.5)
A*(R=.5)
A*(R=1)
Protective Actions

Ex Ante Expected Profit

Returns – P_{Inv}* Penalty

Adverse Selection



General Results

- ‘Unreliable’ Firms Discount *ex post* Penalties
  - Understate Expected Costs of Invasion
  - Less Likely to Take Protective Actions
  - Overstate *Ex Ante* Profitability
  - More Likely to Participate
- Conclusions: Market Forces Select for ‘Unreliable’ Firms