# Oyster Restoration in Maryland: Goals, objectives, monitoring and metrics of success

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# Ecological Restoration?

- To what condition does one restore any ecosystem?
- What does one use to measure the success of any restoration effort?
- What does one use to measure successful oyster restoration in Chesapeake Bay?

# Starting Definition

- *Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.*
  - Society for Ecological Restoration, 2002

# Current Status in Maryland

- Fishing mortality estimated at 50% annually (S. Jordan, MDNR)
- Disease mortality 10 to 95%
  - Depending on location/salinity
  - Two diseases - MSX, Dermo
- Density in MD - 2 oysters/$m^2$
- Recruitment irregular, infrequent
- 200,000 acres mapped in 1906; likely artificial
  - 100,000 productive
    - 50,000 currently “good”?

# Reproductive Capacity

% fertilization=0.49*OD$^{0.72}$*

| Oyster Density (/m$^2$) | % Fertilization efficiency |
|---:|---:|
| 1 | 0.49 |
| 2 | 0.81 |
| 5 | 1.56 |
| 10 | 2.57 |
| 25 | 4.97 |
| 50 | 8.19 |
| 100 | 13.50 |
| 200 | 22.23 |
| 500 | 43.00 |
| 1000 | 70.83 |

*From Mann and Evans (1998) adaptation of Levitan (1991)

# Maryland Objective

Maximize
the economic and ecologic
value of Maryland's
oyster population(s).

# Metrics of success?

- Increased harvest
- Increased spatset
- Clear water
- Higher benthic biodiversity
- Lower incidences of hypoxia
- 10x goal

# How do we measure success?

- Societal goals
  - Maintain industry
    - Processors, shuckers, etc
  - Maintain cultures
    - Watermen, skipjacks, independence, etc
  - Improve ecosystem health of Chesapeake

# How do we measure success?

- Systemic responses?
  - Plant broodstock→increase in local recruitment
  - Add millions→increase in harvest in a few years
  - Restore large reef →clear water

# How do we measure success?

- Local responses?
  - Increased benthic biodiversity?
  - Increased nitrogen cycling?
  - Increased local pelagic community?
  - Decreased ambient turbidity?
  - Decreased hypoxia?
  - Longevity?
  - Physical structure?

# Monitoring different levels of success

- Societal → harvest numbers, economy
- Systemic → recruitment rates, sustainability, turbidity
- Local → survival, growth, benthic faunal diversity/abundance

# Collecting relevant data

- Intensive monitoring of specific projects
  - Monitor for project-specific objectives and goals
    - Size, mortality, disease, faunal abundance, water qualities, etc
- Increased stock assessment quality
  - Need spatially specific data
    - Mortality, size, density, spat counts
- Combine stock assessment data with restoration data

# Sources of data in the Paynter Lab

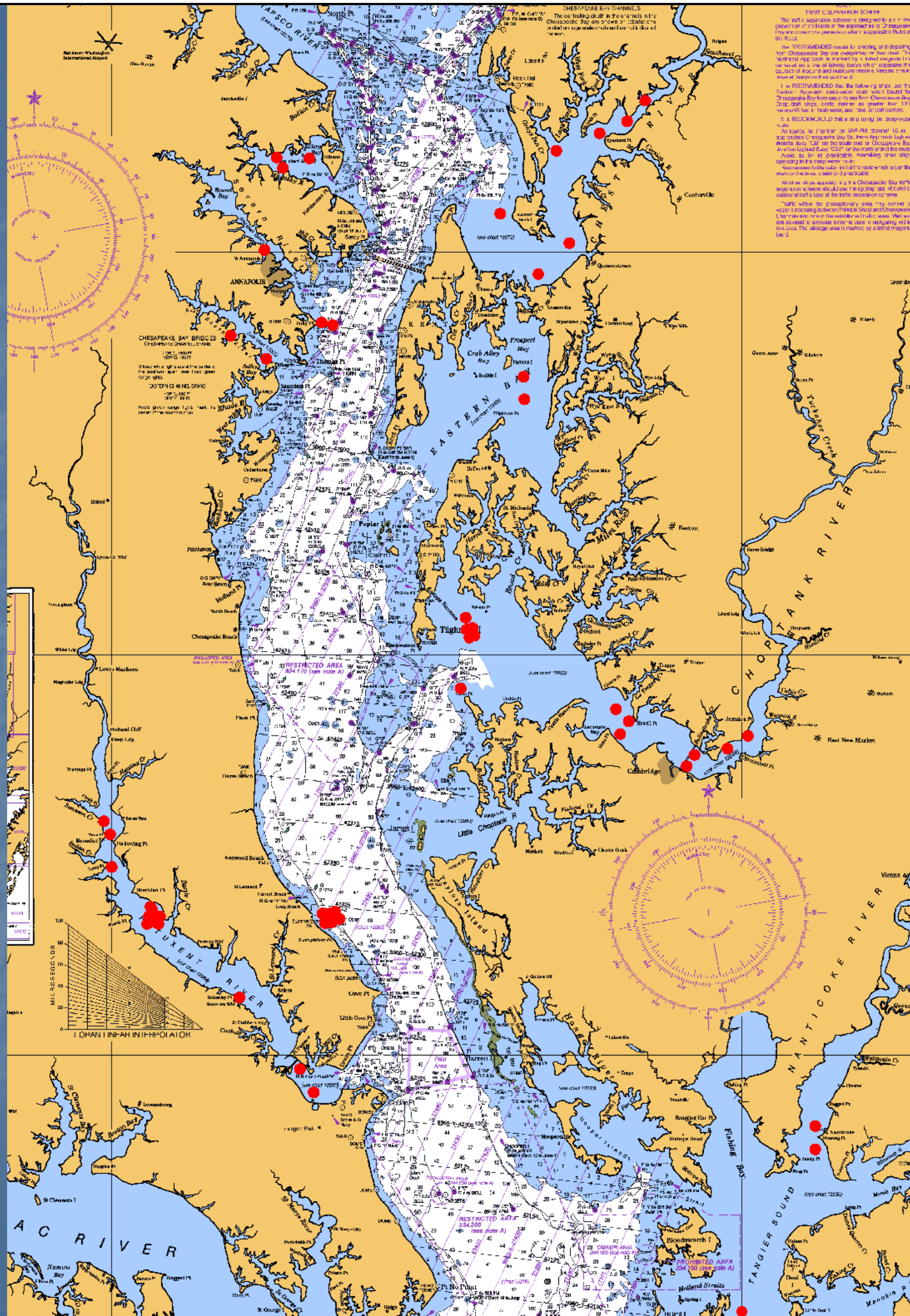
- Monitoring for Army Corps, Oyster Recovery Partnership, MDNR projects - too many to list
- NOAA/EPA Stock Assessment project w/Roger Mann, Steve Jordan
- ODRP/Sea Grant projects - disease transmission w/ Gene Burreson; larval transport/genetic structure - Matt Hare, Stan Allen, Mutt Meritt; ariakensis project

# Restoration Efforts in MD

- Largely experimental
  - Widely distributed geographically
  - Relatively small in size
  - Replicated in many cases
- Objectives
  - Understand oyster longevity/disease
  - Oyster productivity/growth
  - Ecological value
  - Techniques

# Current Restoration Effort in Maryland

- Watermen, DNR, NGOs, academics involved
- Agree on objective
- Agree on location - sanctuary or reserve
- Place shell
- Plant seed
- Monitor for survival, growth, disease


ANNAPOLIS
CHESAPEAKE BAY BRIDGES
EASTERN BAY
Crab Alley Bay
Prospect Bay
Tilghman
CHOPTANK RIVER
Cambridge
Little Choptank R
NANTICOKE RIVER
TANGIER SOUND
Fishing Bay
RESTRICTED AREA
Tilghman Pt
Poplar I.
Cove Pt
Kenwood Beach
Chesapeake Beach
Easton
East New Market
Vienna
Bloodsworth I
Holland Straits
Pt No Point

# Experimental Restoration Efforts in MD

- Initial Disease/Growth project - 3 rivers
- Density project
- Strain trials
- Reserves/bar cleaning
- Alternative substrates
- Faunal differences/Fish utilization
- Underwater video/education effort

# Monitoring protocols

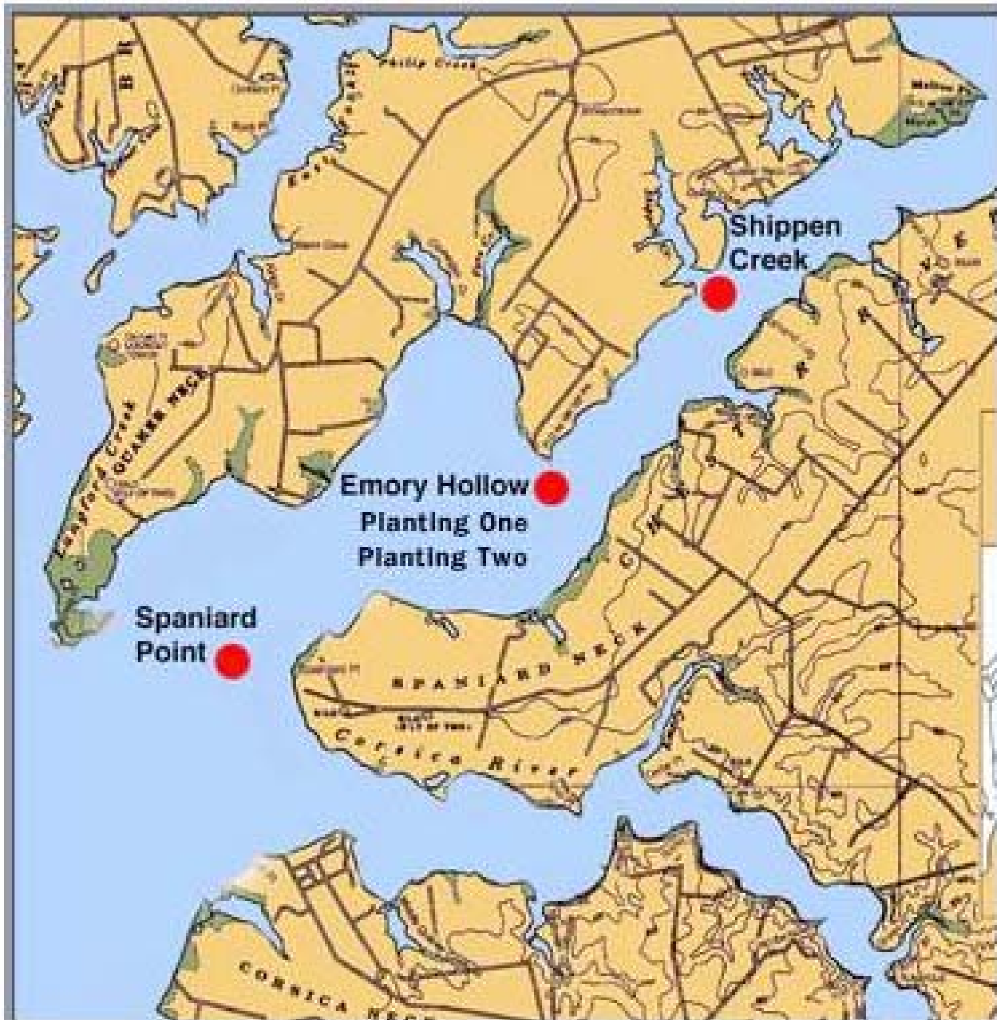
- SCUBA Diver retrieved samples and observation
- Differential GPS
  - precision sampling - 4 corner waypoints/plot
- Shell height, density, condition index, other measures
- RFTM for *Perkinsus* diagnoses
  - Whole/half for spat
  - Rectal tissue for larger oysters
  - Tissue samples archived for

  *H. nelsoni*/other pathogens

QuickTime™ and a
Motion JPEG OpenDML decompressor
are needed to see this picture.

# Choptank & Chester Rivers

- Take home lessons
  - Very low dermo acquisition at most sites
  - Oysters on mounds didn’t grow faster than those on flat bars
  - Growth rates ≈25-30mm/yr




BACK TO MAIN MAP

THE PAYNTER LABS

MONITORING DATA

PLEASE SELECT A SITE TO THE LEFT

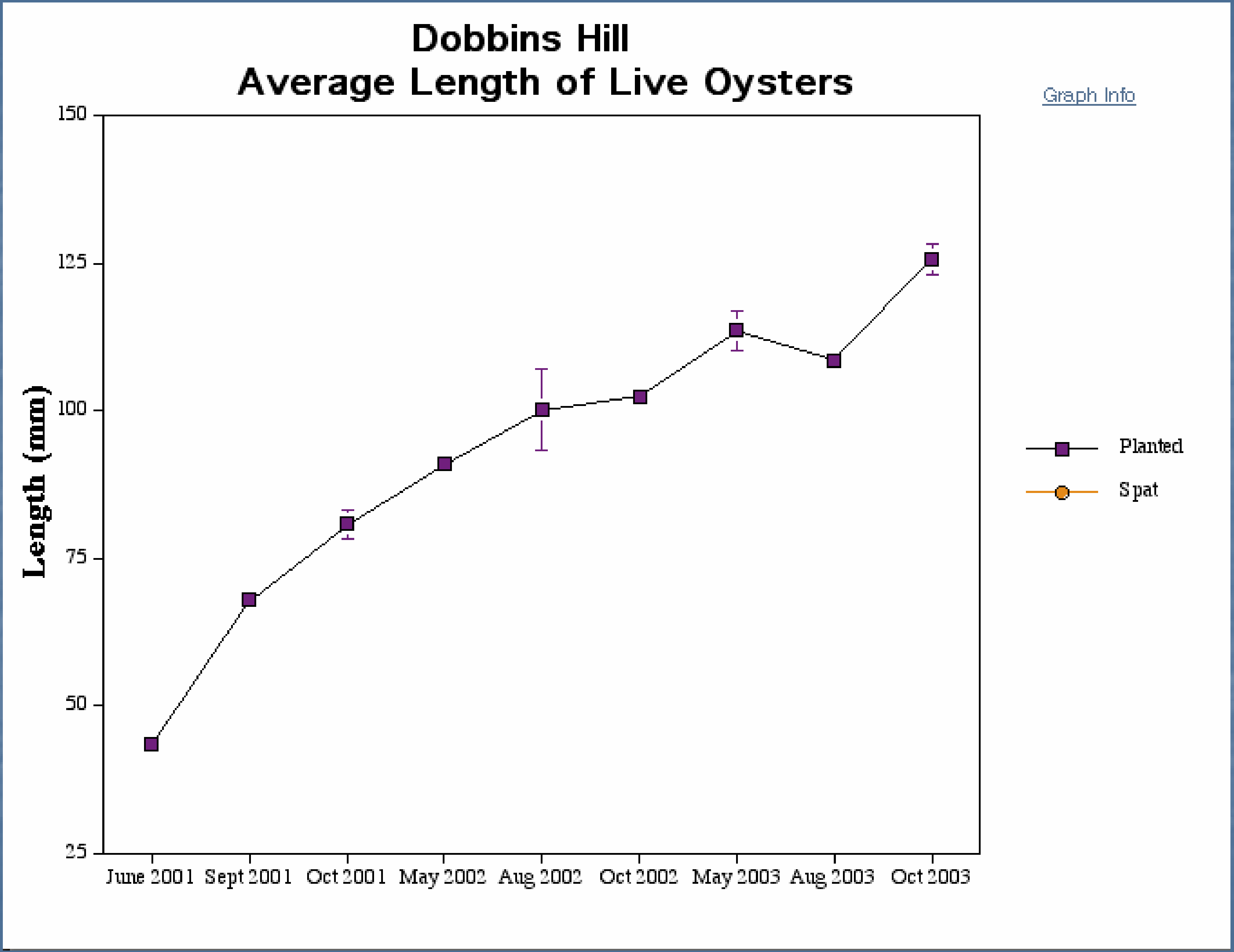
## Chester River | Shippen Creek

**DATE OF LAST SAMPLING: 8/22/2003**

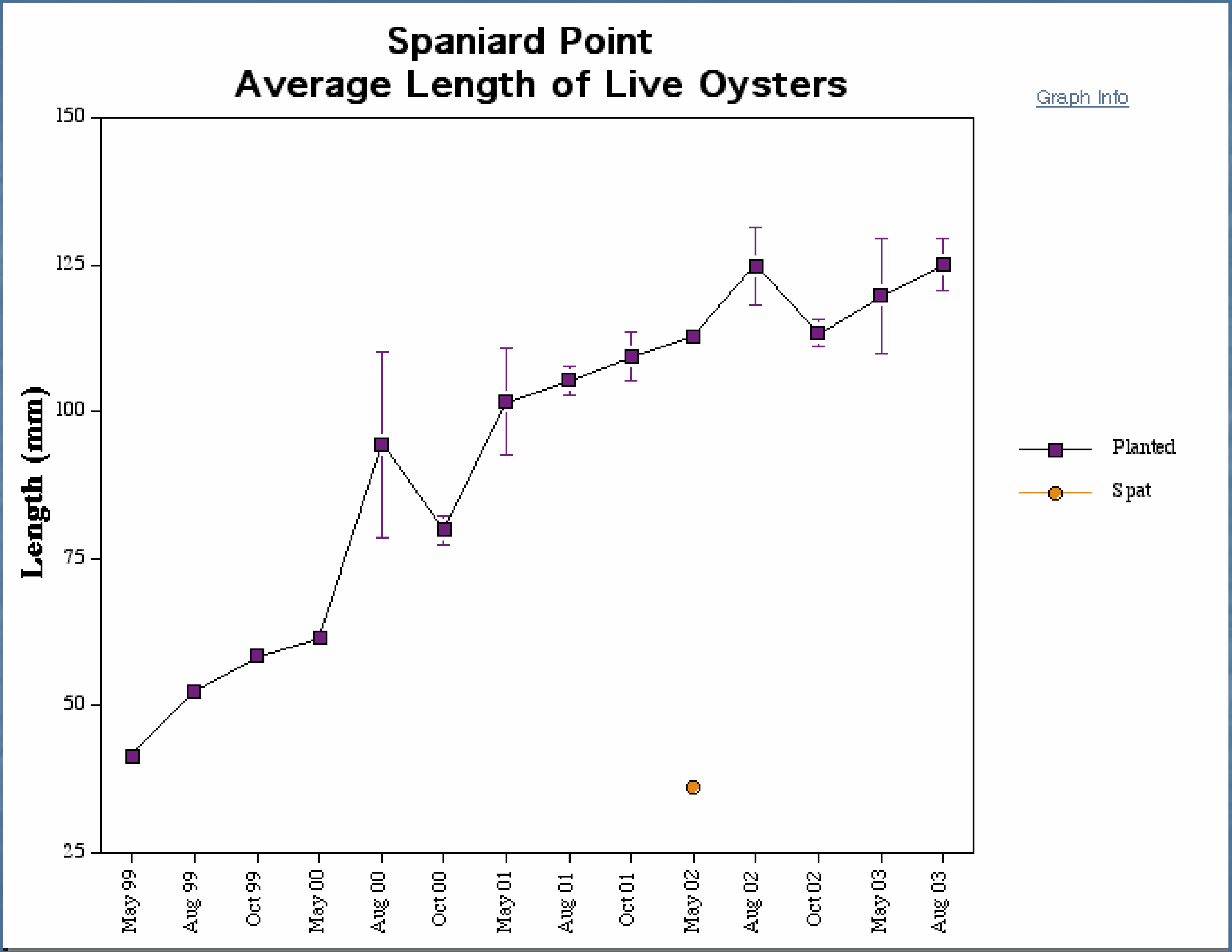
to print this page, right-click(pc), or click in frame, then select print (mac)

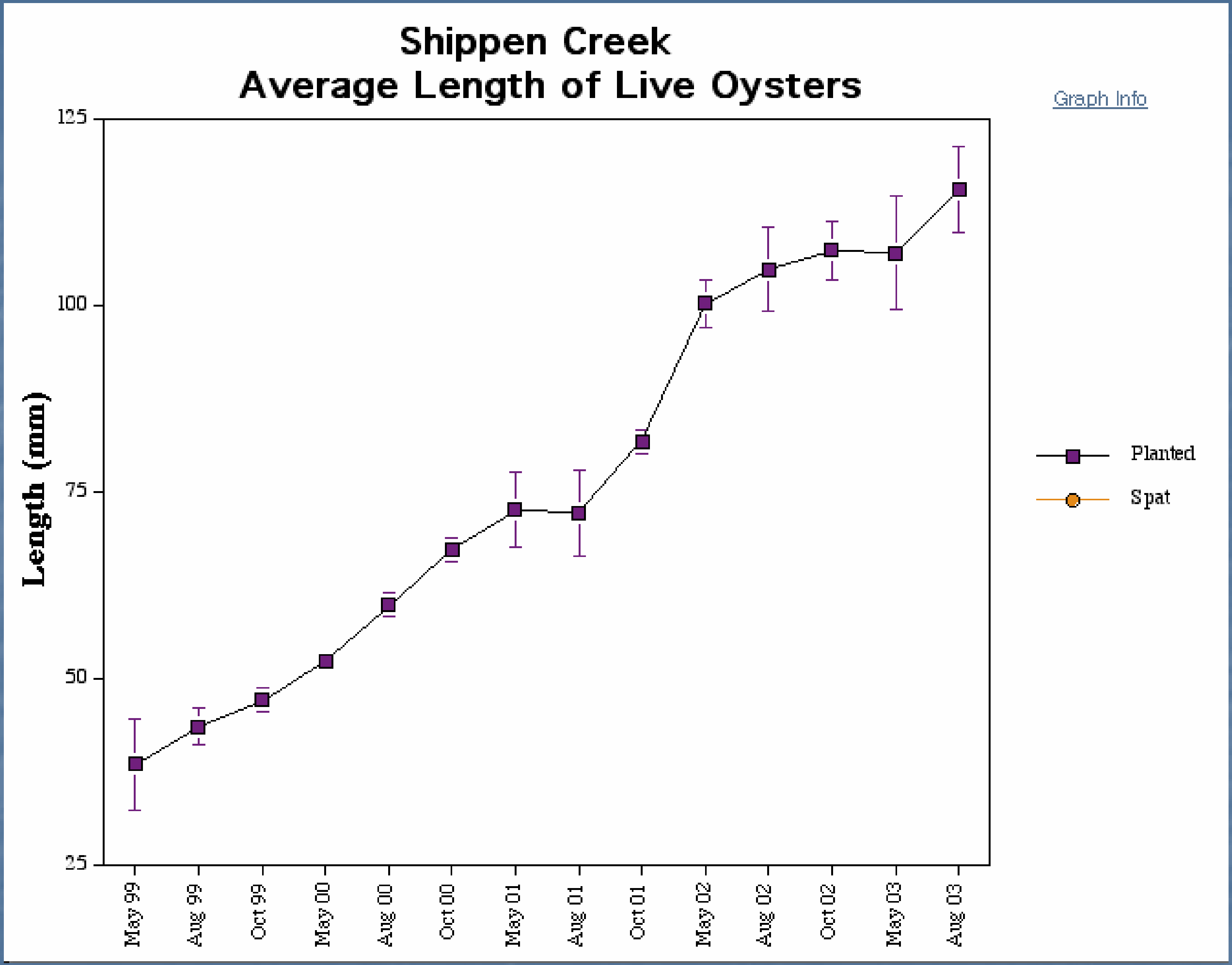
| Imagery | |
|---|---|
| Video Clip | Images |

| Bottom Water Quality | |
|---|---|
| Temperature (°F) | 83.3 °F |
| Temperature (°C) | 28.5 °C |
| Salinity (ppt) | 4.4 |
| Dissolved Oxygen (mg/l) | 5.5 |



Dobbins Hill
Average Length of Live Oysters
Graph Info
Length (mm)
150
125
100
75
50
25
June 2001
Sept 2001
Oct 2001
May 2002
Aug 2002
Oct 2002
May 2003
Aug 2003
Oct 2003
Planted
Spat


Spaniard Point
Average Length of Live Oysters
Graph Info
Length (mm)
150
125
100
75
50
25
May 99
Aug 99
Oct 99
May 00
Aug 00
Oct 00
May 01
Aug 01
Oct 01
May 02
Aug 02
Oct 02
May 03
Aug 03
Planted
Spat



Shippen Creek
Average Length of Live Oysters
Graph Info
Length (mm)
125
100
75
50
25
May 99
Aug 99
Oct 99
May 00
Aug 00
Oct 00
May 01
Aug 01
Oct 01
May 02
Aug 02
Oct 02
May 03
Aug 03
Planted
Spat

QuickTime™ and a
DV/DVCPRO - NTSC decompressor
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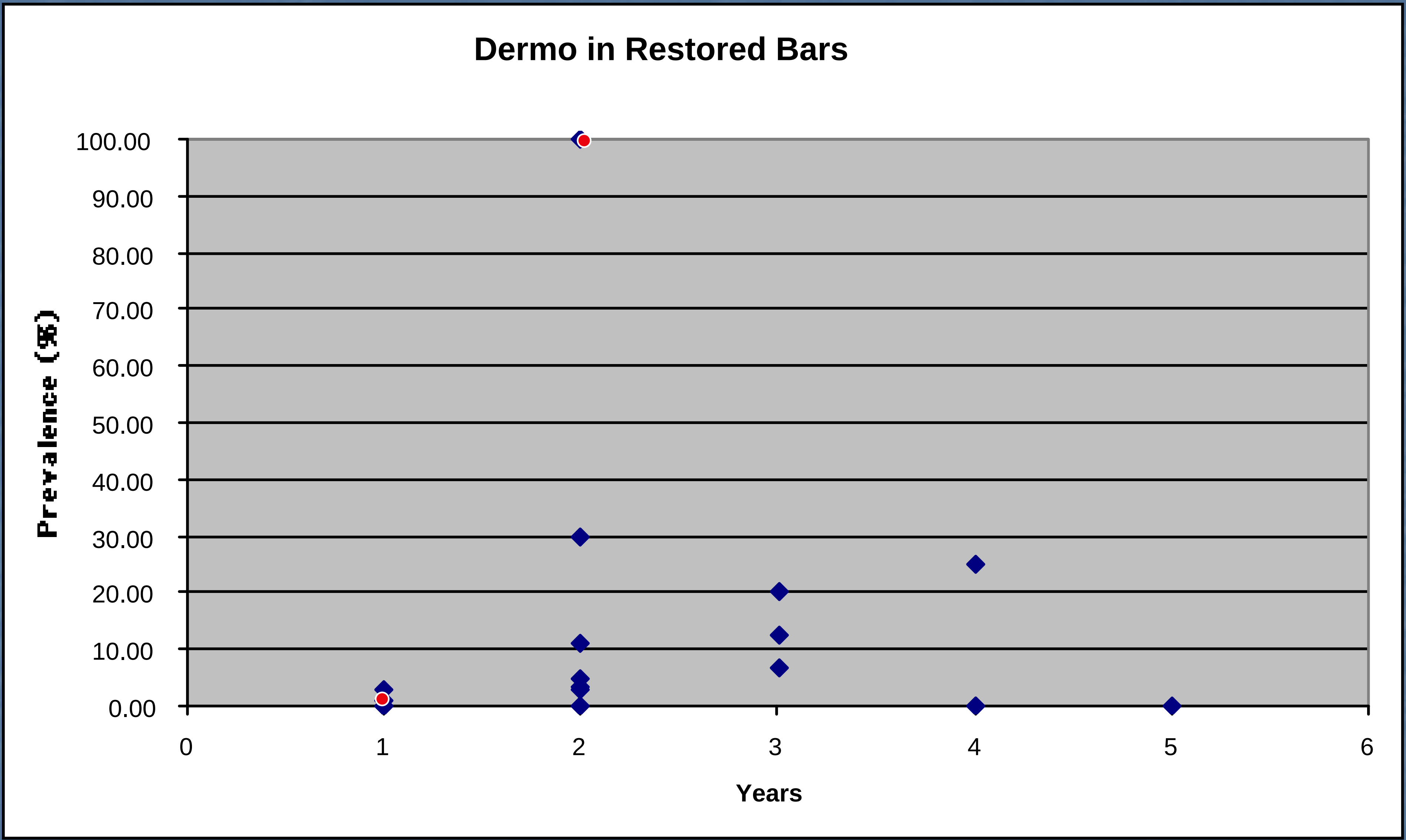
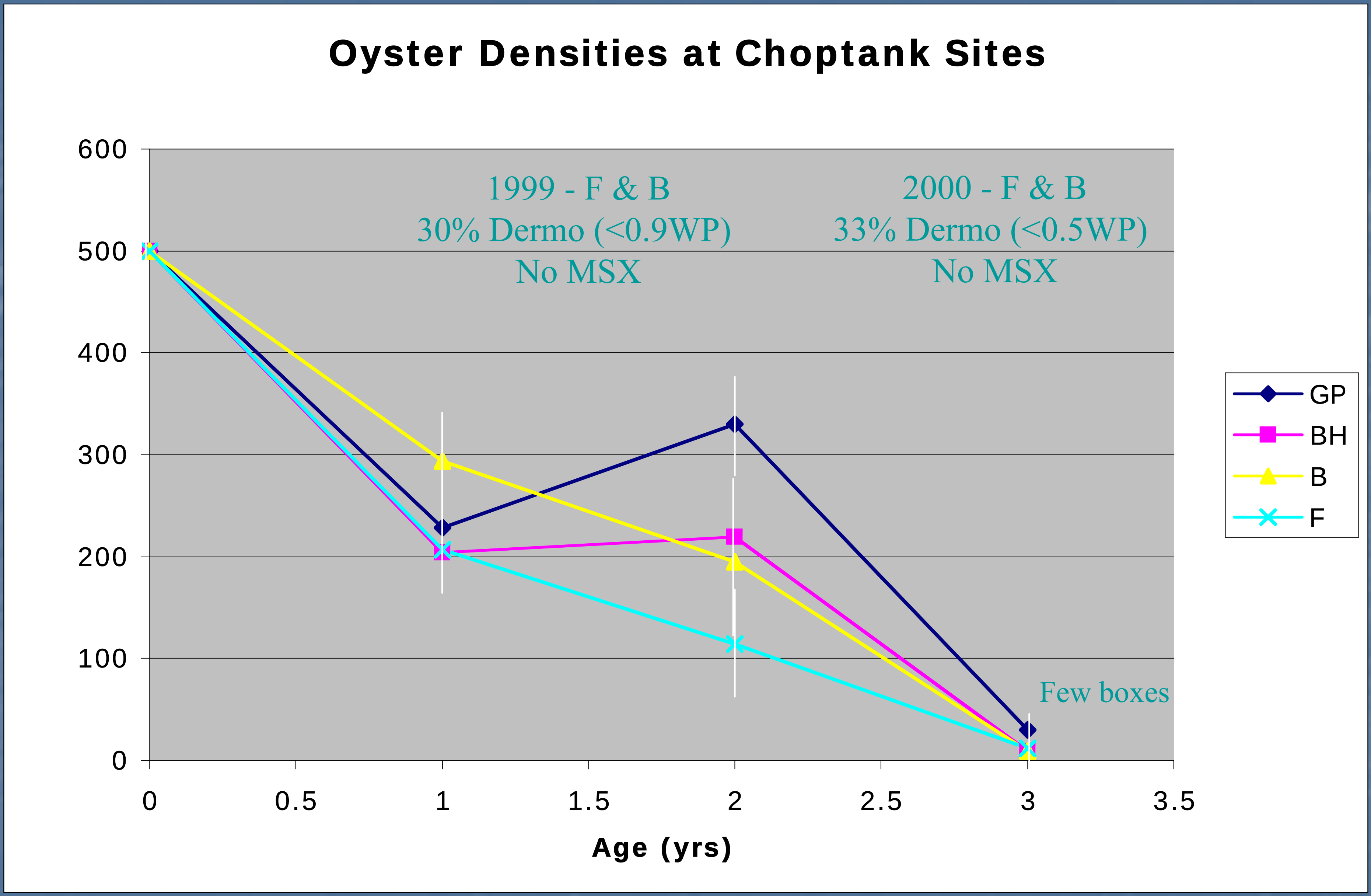

Dermo in Restored Bars
Prevalence (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
1
2
3
4
5
6
Years

# Dermo transmission in low (<14ppt) salinity

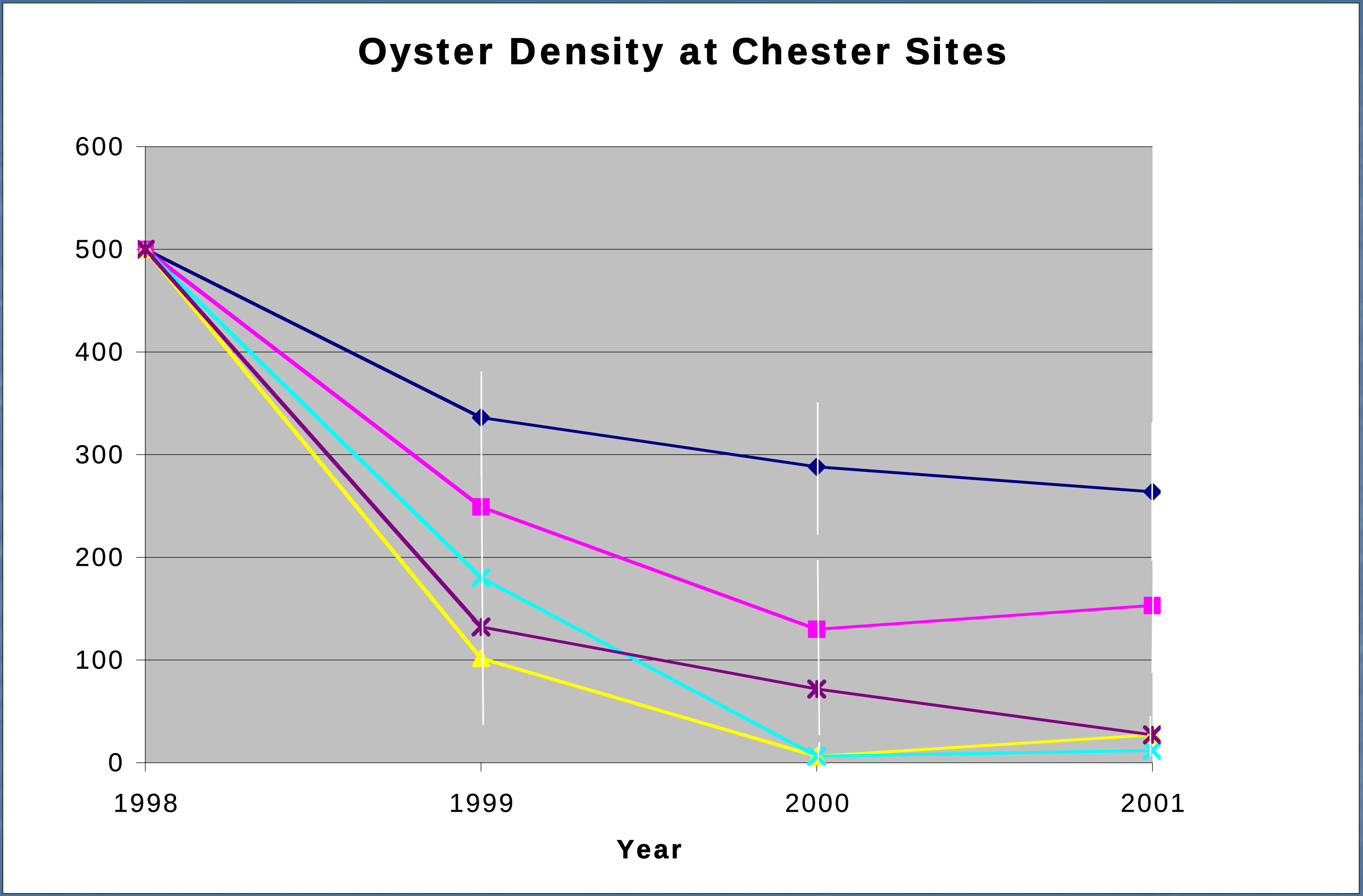
- **Rarely related to salinity gradient**
- **In Chester infections geographically clustered**
  - all plots at Spaniard Pt□ infected
- **Mean time to infection**
  - on restored bars - years
  - on infected bars - weeks
- **Some infections abated**
  - Dobbin Hill in Magothy River

# Then what's the major cause of mortality in low salinity?

- MSX not present below 10 ppt
- Dermo present in most bars but not virulent except in old oysters



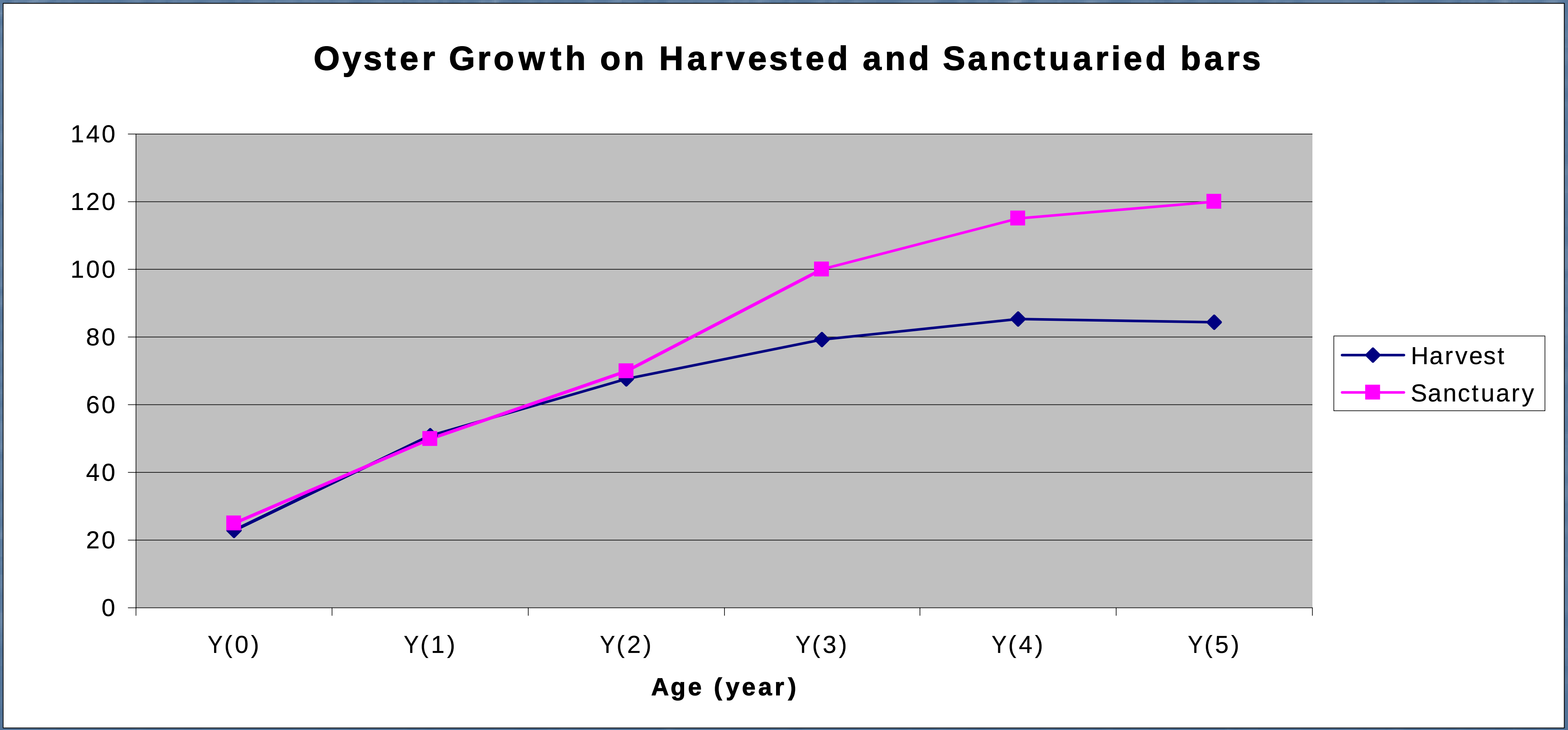
Oyster Densities at Choptank Sites
1999 - F & B
30% Dermo (<0.9WP)
No MSX
2000 - F & B
33% Dermo (<0.5WP)
No MSX
Few boxes
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
Age (yrs)
GP
BH
B
F


Oyster Density at Chester Sites
600
500
400
300
200
100
0
1998
1999
2000
2001
Year

# Dermo in low (<14ppt) salinity

- **Transmission rarely related to salinity gradient**
- **Some infections geographically clustered; some infections abated**
- **Mean time to infection**
  - on restored bars - years
  - on infected bars - weeks
- **Fishing caused higher mortality than disease on planted reserves! (Bars with repletion seed are predisposed to have high disease mortality).**

# Effects of Fishing




Harvest data from Jessica (Vanisko) Coakley

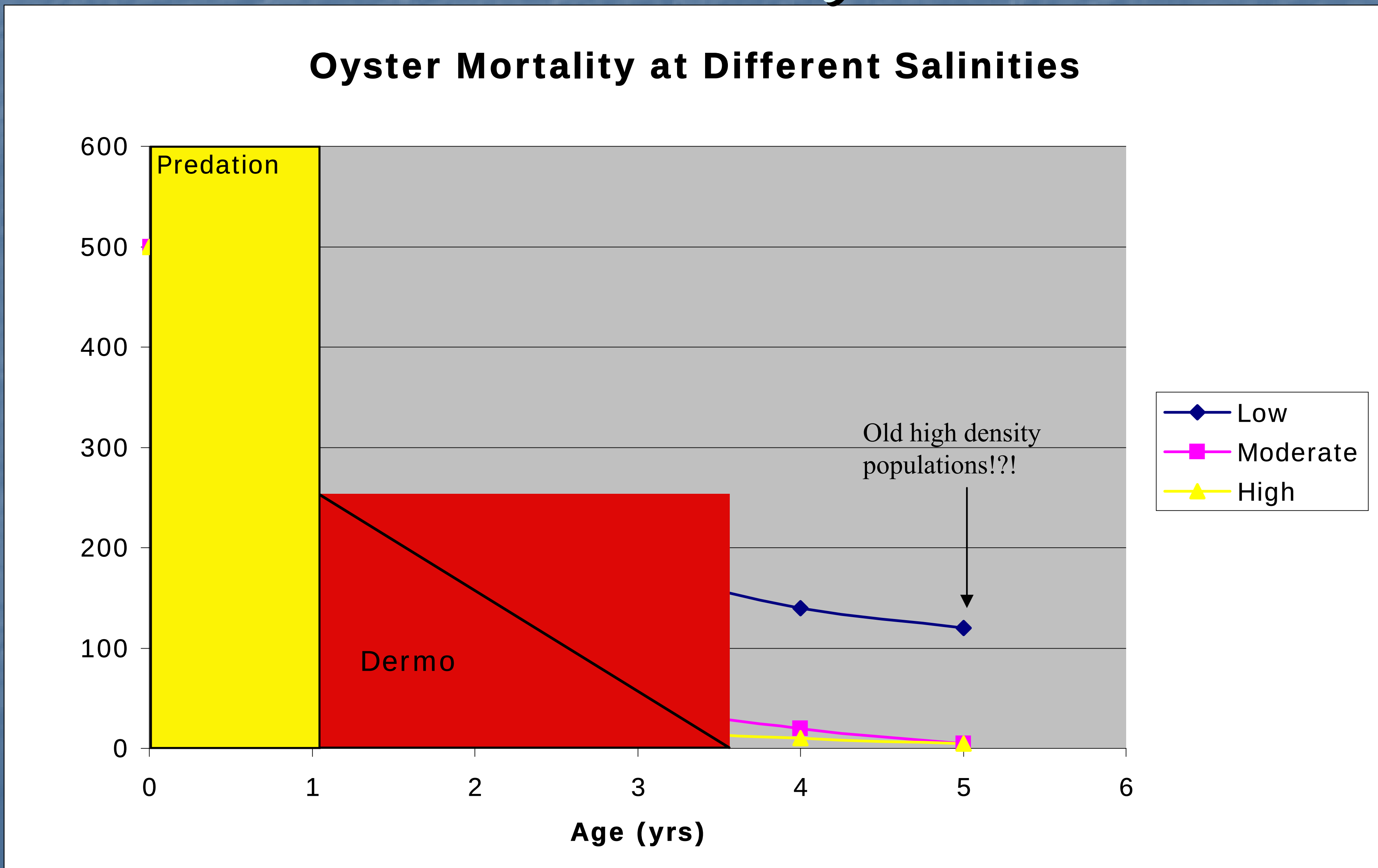
# Effects of fishing?

- Reduction in large animals
- Growth rate of population essentially stops after three years
- Remnant population composed of low-density, slower growing oysters
- Remnant population highly infected with contagious parasite (*P. marinus*)

# Strain study-will resistance develop in naturalized populations?

- Choptank River; Tangier Sound
- 4 strains - planted in 2000
  - Local susceptible, local tolerant, Louisiana strain, CROSBreed
- 2002 - mean size: 65 mm; Dermo low in all strains
- Heavy MSX-induced mortality
  - Local susceptible and Louisiana strains - 90%
  - CROSBreed and local tolerant - 60%
- Open to harvest in Fall 2002

# Natural Mortality of Planted Oysters



# Density Project

- 12 1/4 acre plots
- 3 replicate treatments of 4 densities
  - 0, 100, 250, 500 oysters/$m^2$
- Actual densities ranged from 0 to 800 oysters/$m^2$
- **Growth, mortality rates, dermo infection rates and condition indices were NOT different among densities for first two years (mean SH = 70mm)**
- MSX impacted in 2002 - 80 to 90% mortality
  - Density independent infection
- Benthic community more abundant at higher densities

# Alternative substrates

- MDNR project
- Stone, concrete (memorial stadium), slag, shell

- Stone worst substrate (fewest recruits); slag, concrete, shell equal.

# Ecological Assessments

- Fouling community
- Benthic populations
- Pelagic populations
- Filtration rates
- Nutrient cycling
- More…

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

QuickTime™ and a
DV/DVCPRO - NTSC decompressor
are needed to see this picture.

There is a paucity of information on macrofaunal communities on Maryland’s subtidal mesohaline oyster habitats. We sampled restored and unrestored plots on 4 subtidal mesohaline oyster bars in Maryland.

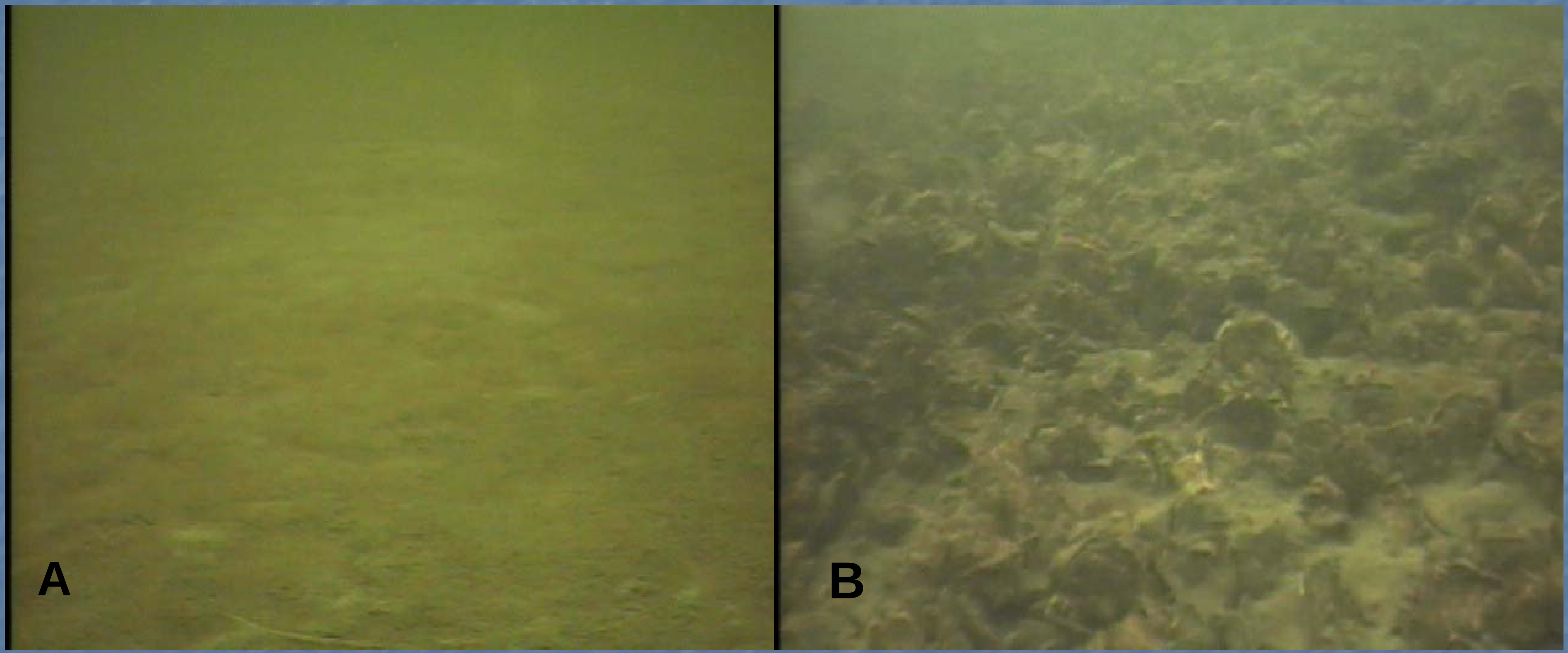
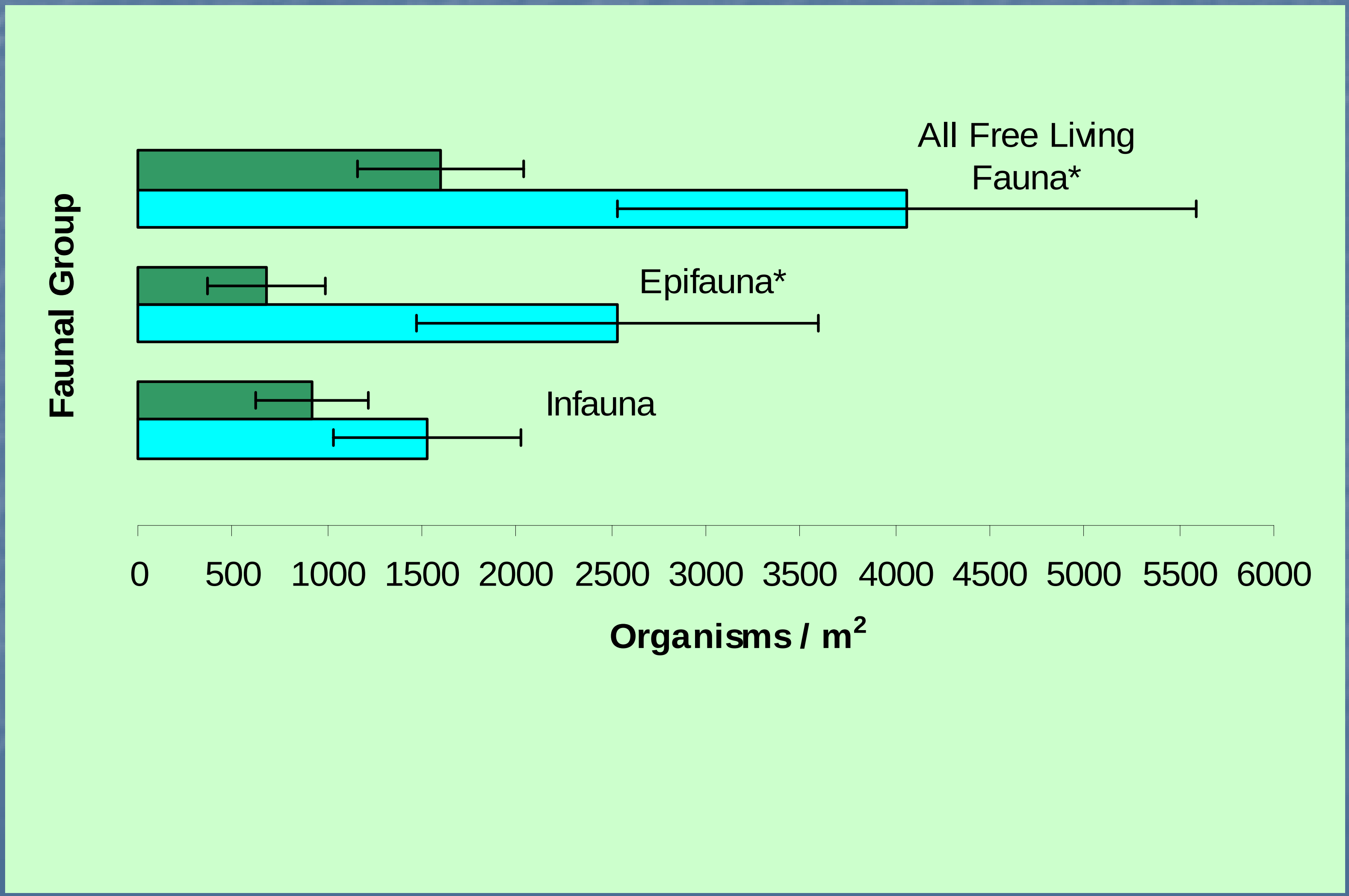


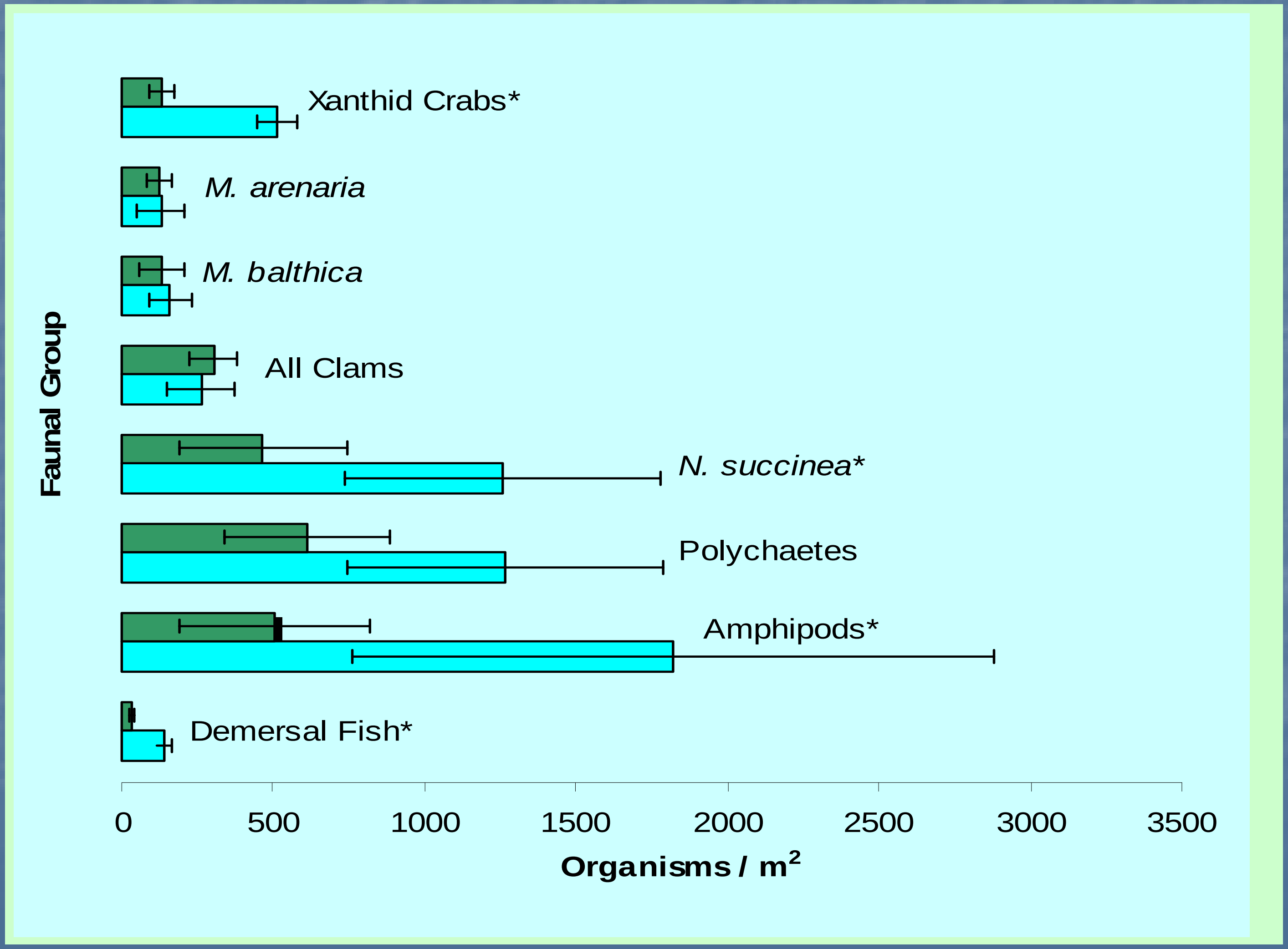

**Figure 1. These pictures show an unrestored oyster reef (A) as compared to a typical restored oyster reef (B).**

**Some representative macrofaunal organisms from 2003 sampling. All were more abundant on restored reefs except *P. gouldii* (bottom right, shown next to its tube), and the two clams *M. batlthica* (bottom center) and *M. Arenaria* (far right).**

Comparisons of mean faunal densities in restored (blue bars) and unrestored (green bars) plots for 3 broadly inclusive functional groups. Error bars represent +/- 1 SEM. Asterisks following group titles indicate statistically significant differences.



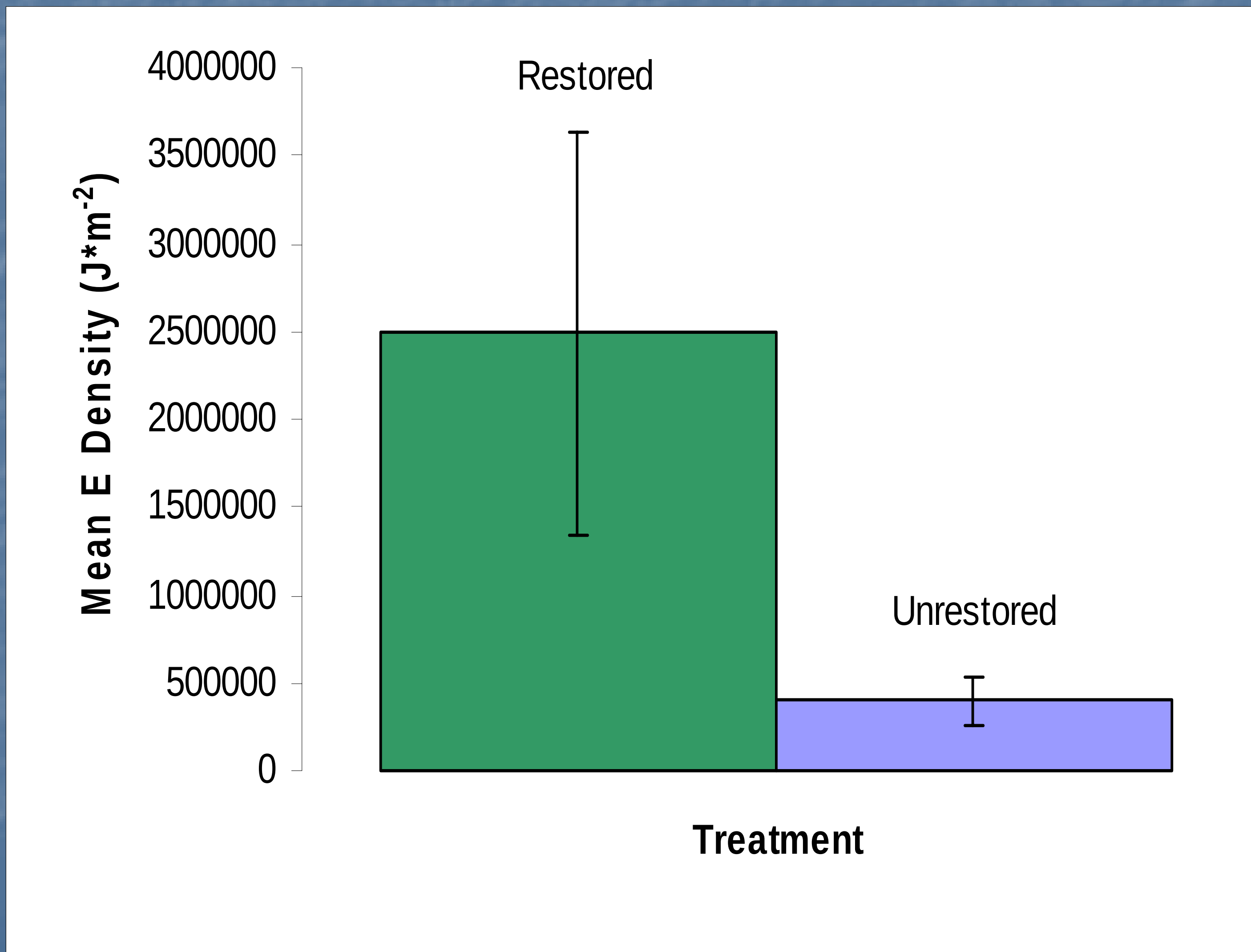
Comparisons of mean faunal densities in restored (blue bars) and unrestored (green bars) plots for 8 taxonomic groups. Error bars represent +/- 1 SEM. Asterisks following group titles indicate statistically significant differences.



# So, macrofauna are more abundant on restored reefs, but will striped bass come looking for them?

QuickTime™ and a
DV/DVCPRO - NTSC decompressor
are needed to see this picture.

# Macrofaunal Energy Density -
## evidence of increased benthic-pelagic coupling?



# Predicting productivity and disease avoidance

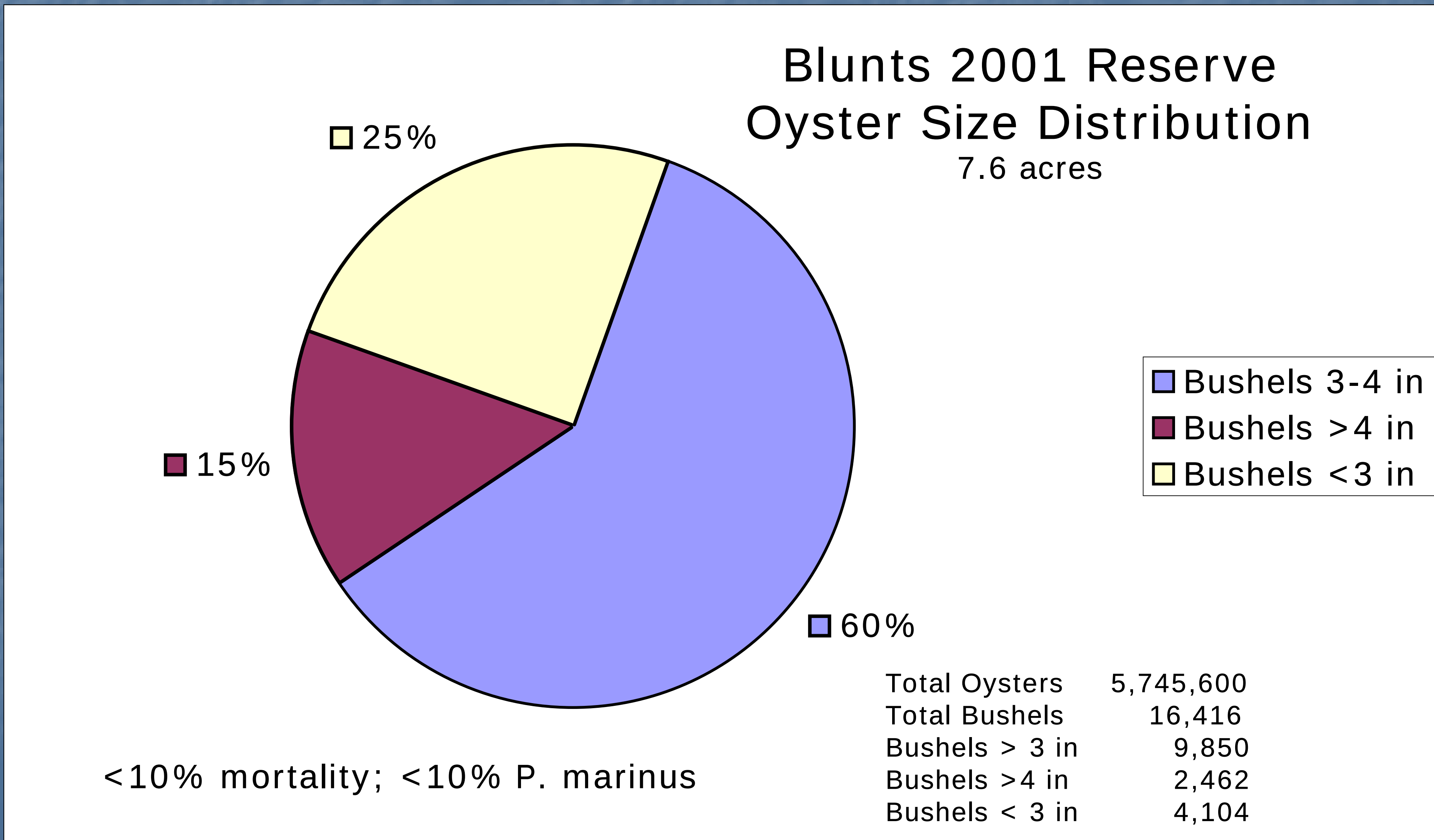
- Reserve experiments

# Reserve Studies - just started

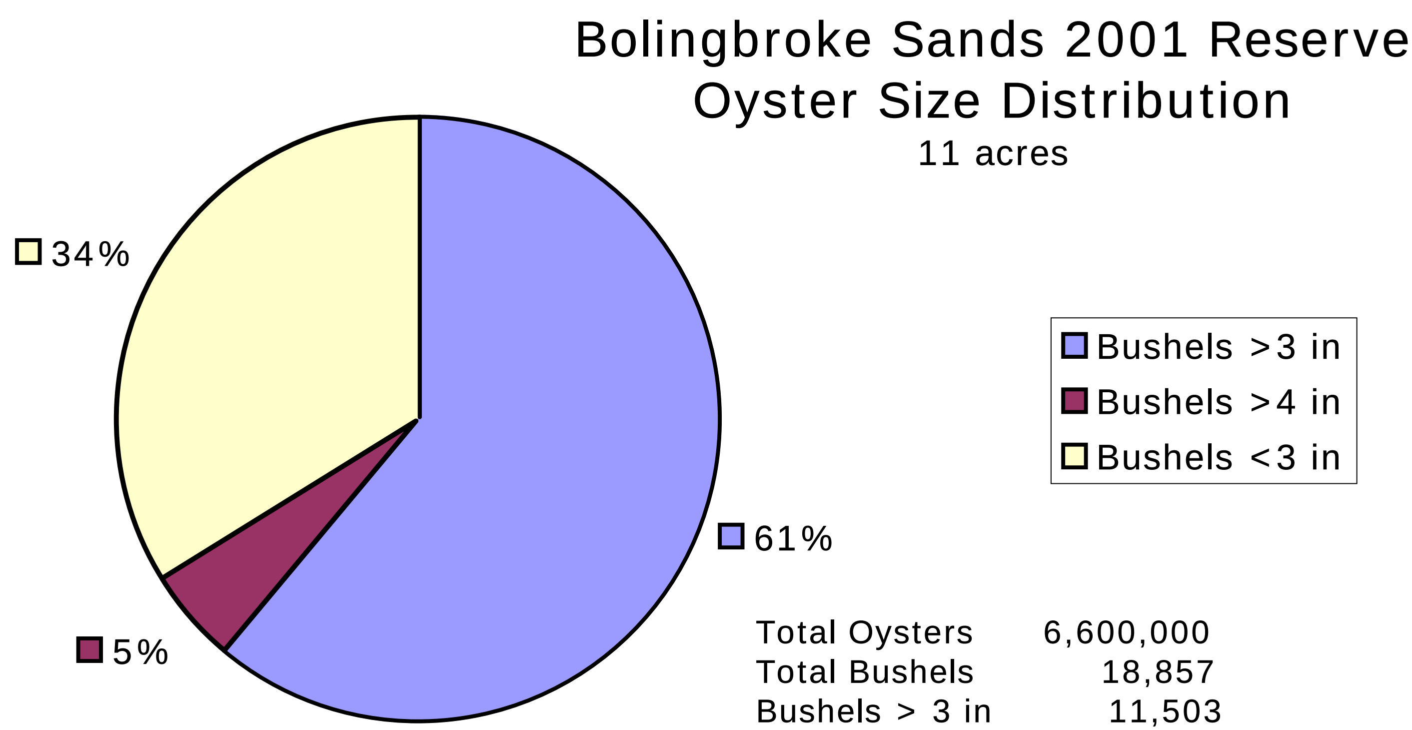
- Cooperative effort with watermen
- Exhaustively harvest bar w/dredges
- Plant w/SPF seed
- Follow growth and disease acquisition
- Harvest at 100mm mean size

- Understand how to maximize productivity of rotational approach using SPF seed
- Maximize ecological value

# Reserve Production- Chester River - 2 yrs old



# Reserve Production - Choptank River- 2 yrs old




| | |
|---|---|
| Total Oysters | 6,600,000 |
| Total Bushels | 18,857 |
| Bushels > 3 in | 11,503 |
| Bushels >4 in | 943 |
| Bushels < 3 in | 6,411 |

<10% mortality; <10% P. marinus

# Nearby oyster bar

- Oyster Shell Pt
  - Mortality
    - 2001- 28%; 2002 - 55%
  - Dermo
    - 2001- 100%; 2002 - 100%

# Restoration Success?

These two reserves will likely produce more oysters in the 2004/2005 season than were produced in the entire state last year.

# Strategies for restoring and managing the Eastern oysters in Chesapeake Bay: quantitative biological analysis of management options

**Maryland Department of Natural Resources**
Steve Jordan, Kelly Greenhawk and Jessica Coakley
Sarbanes Cooperative Oxford Laboratory, 904 S. Morris St., Oxford, MD 21654

**Virginia Institute of Marine Science**,
Roger Mann, David A. Evans, Juliana M. Harding and Melissa Southworth
School of Marine Science, College of William and Mary, Gloucester Point, VA 23062

**University of Maryland**
Mary Christman
Dept. Animal and Avian Sciences, University of Maryland, College Park, MD 20742
Kennedy Paynter and Michael Liddel
Chesapeake Biological Laboratory, P.O. Box 38, Solomons, MD 20688 and
Department of Biology, University of Maryland, College Park, MD 20742

# Chesapeake Bay Oyster Population Estimation (CBOPE)

Project Overview and Objectives
Basin Estimates
Maryland
Virginia
Sentinel Sites
Maryland
Virginia
Project Partners
Project Sponsors

CBOPE Home
VIMS Molluscan Ecology Home

## Project Overview and Objectives

One of the principal goals of the Chesapeake 2000 Agreement was a 10-fold increase in the Bay oyster population by 2010. The baseline for this goal is the oyster population biomass that existed at the beginning of 1994, as assessed by surveys in fall 1993. In 2000, the NOAA Chesapeake Bay Stock Assessment Committee and the US EPA Chesapeake Bay Program jointly funded an interstate research project for the purposes of (1) quantifying the baseline oyster population, and (2) establishing the monitoring, data management and data analysis frameworks for measuring progress toward the oyster restoration goal, Chesapeake Bay Oyster Population Estimation or CBOPE. This collaborative project between Maryland and Virginia partners has produced to date annual estimates of Chesapeake Bay oyster populations for the period 1994-2002 (MD) and 1998-2002 (VA). Using the formats established by the CBOPE project, annual tracking of progress towards the 2010 goal will continue.

Each state has identified distinct basins or water bodies as well as sentinel sites within the Chesapeake Bay that will be used to estimate abundance and biomass of Chesapeake oyster populations. Annual oyster population estimates for basins provide evidence of geographic trends within watersheds. The term "sentinel site" is applied to individual sites where oyster populations have been, or henceforth will be, monitored annually. Data from these sites may provide an index of restoration or replenishment success in relation to both basin and technique.

Document last modified
07.05.2003

A collaboration between:
Maryland Department of Natural Resources Sarbanes Cooperative Oxford Laboratory
University of Maryland Marine Estuarine and Environmental Studies Program
Virginia Institute of Marine Science Department of Fisheries Science Molluscan Ecology Program
Virginia Marine Resources Commission Conservation and Replenishment Division

This web site is maintained at the Virginia Institute of Marine Science

CBOPE Contacts
Disclaimer

www.vims.edu/mollusc/cbope/overview.htm

# Conclusions from last year

- Abundances ranged from 1.6 (MD, 2002) to $6.30 \times 10^8$ oysters from 1993-2002
- Small oysters constitute 79% of the population from 1993-2001 in VA
- Mean density in Maryland is approximately 1 oyster/$m^2$

# Collecting relevant data

- Intensive monitoring of specific projects
  - Monitor for project-specific objectives and goals
    - Size, mortality, disease, faunal abundance, water qualities, etc
- Increased stock assessment quality
  - Need spatially specific data
    - Mortality, size, density, spat counts
- Combine stock assessment data with restoration data

# Important stuff

- Collect spatially explicit data
- Work on multiple scales
- Collect data relevant to both science and public interest (education/outreach)
- Photography/videography - pictures speak a thousand words

STOP HERE

# Reproductive Capacity

- % fertilization=0.49*OD$^{0.72}$*

| Oyster Density (/m$^2$) | % Fertilization efficiency |
|---:|---:|
| 1 | 0.49 |
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| 200 | 22.23 |
| 500 | 43.00 |
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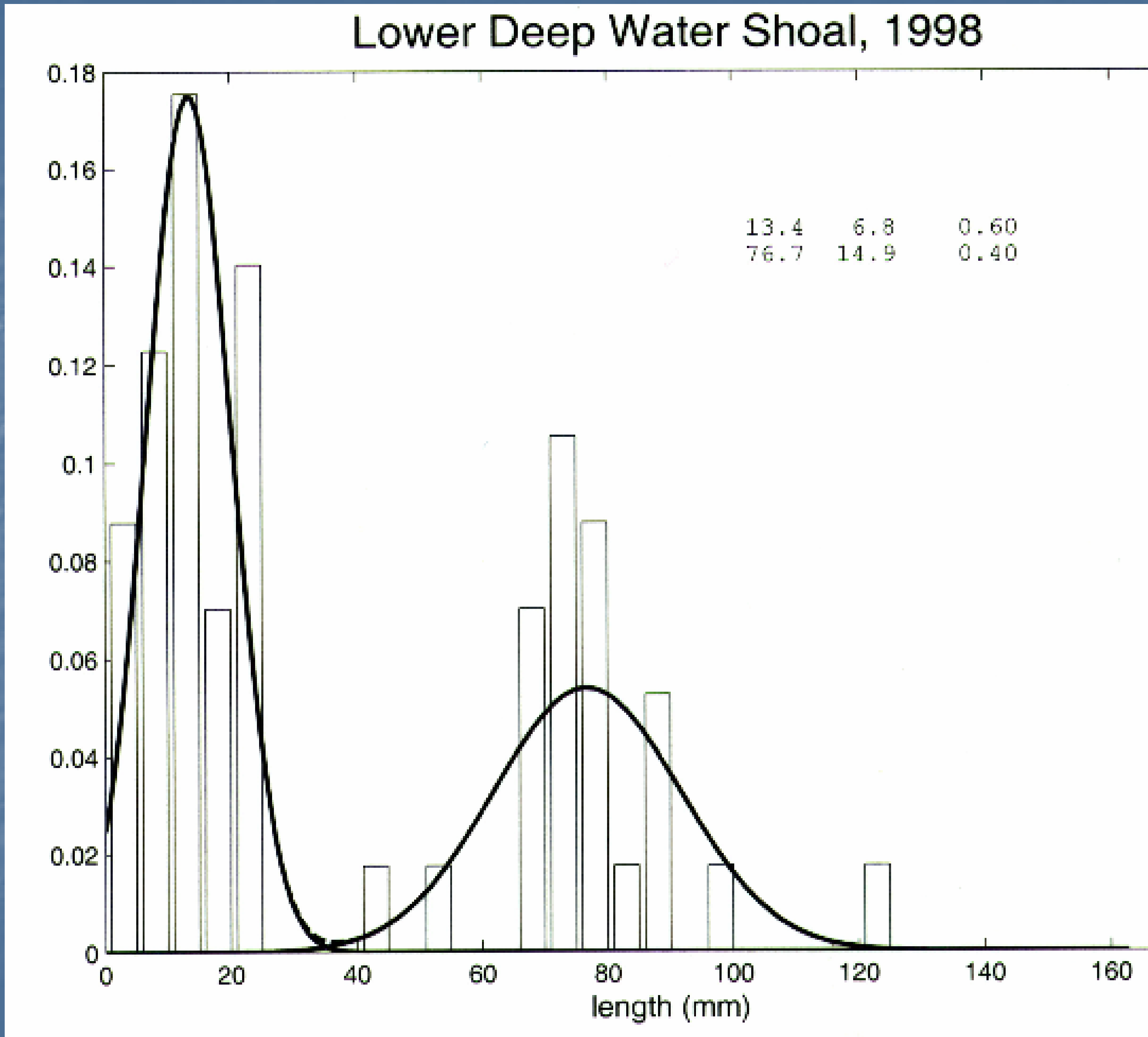
*From Mann and Evans (1998) adaptation of Levitan (1991)

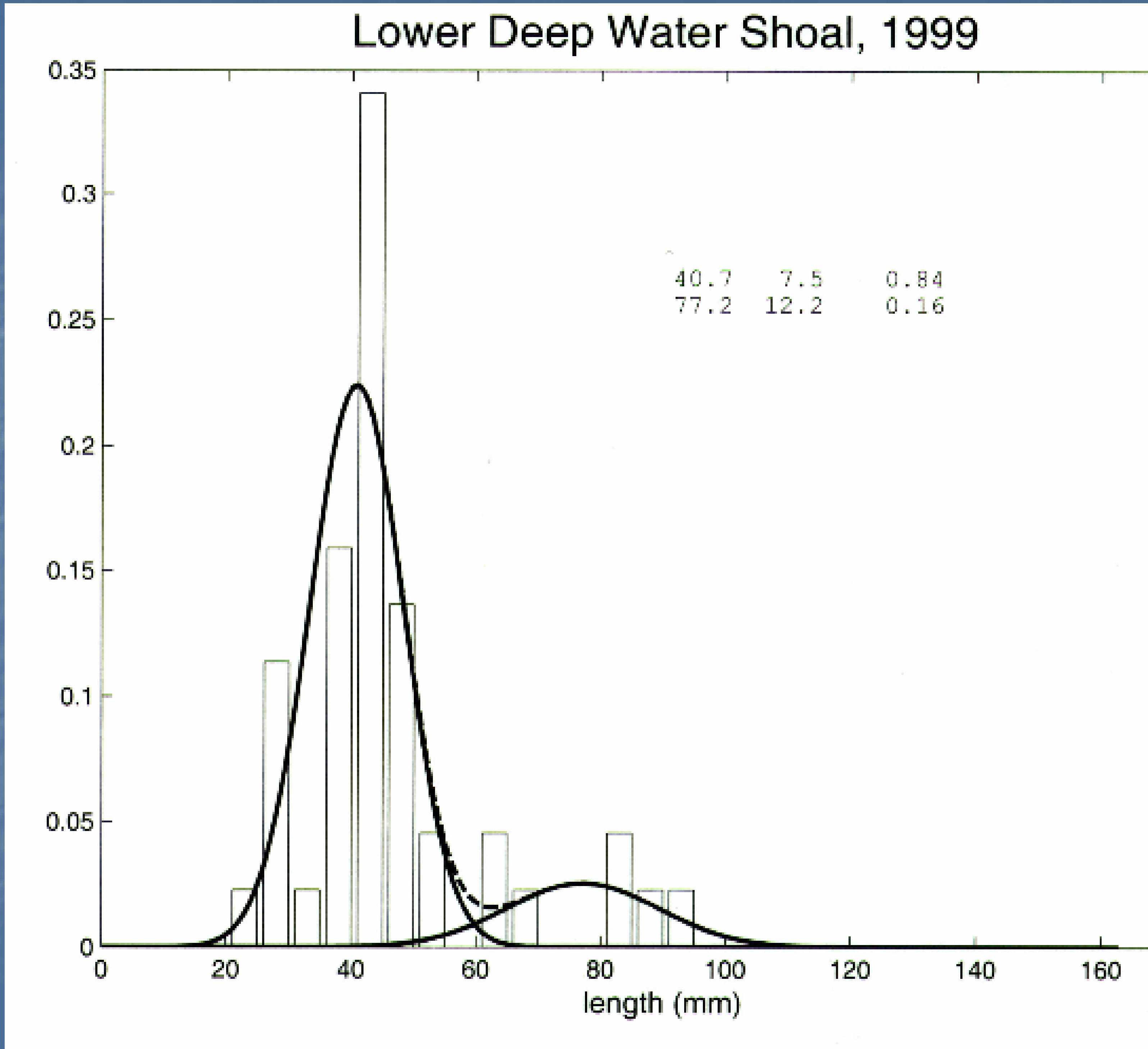
# Extracting data from the field

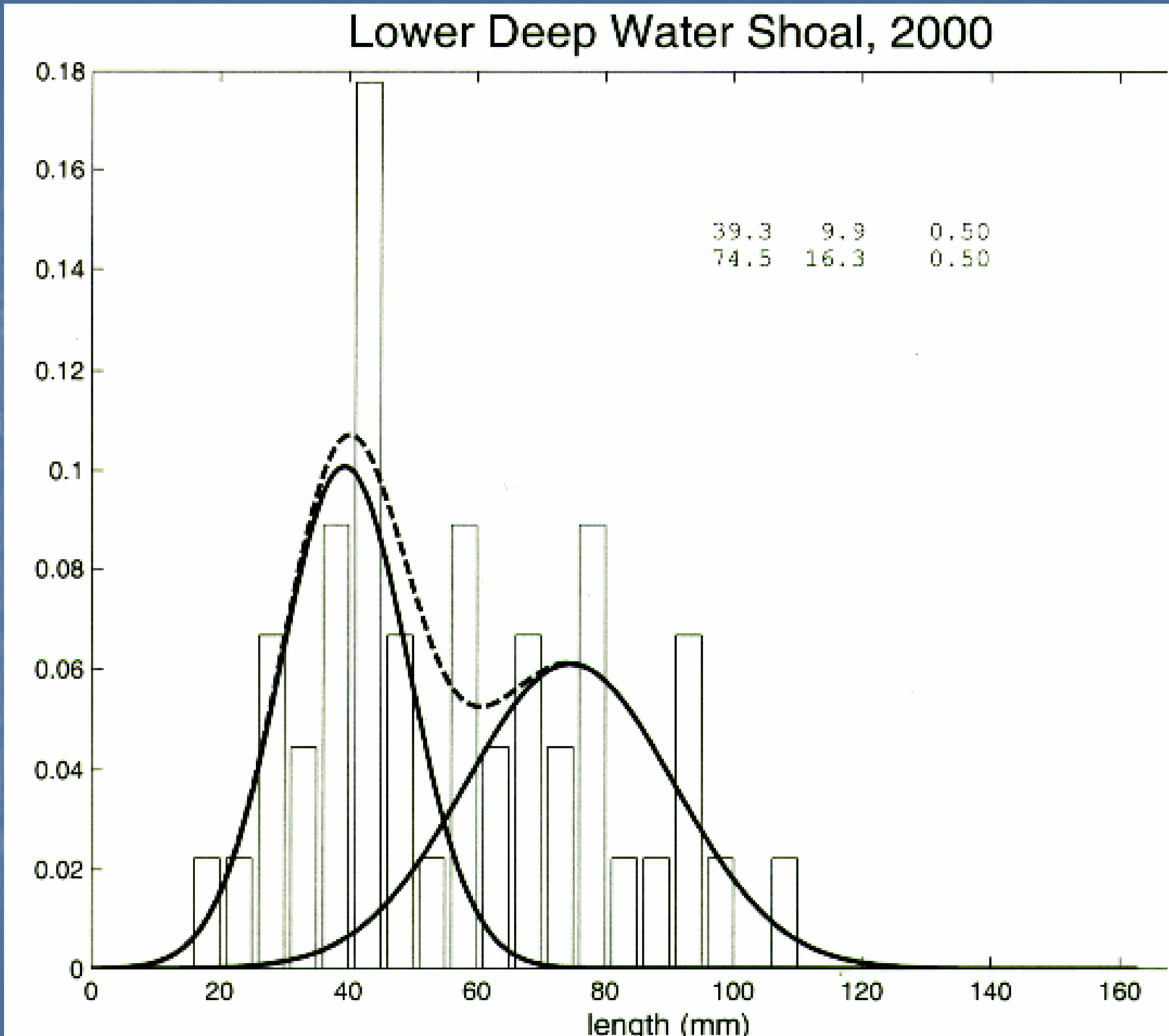
- Estimating age, growth and mortality rates from natural/exploited populations
  - Size frequency analysis over time
    - Changes in density?
- Measuring growth & mortality of hatchery reared seed planted for restoration projects
  - Intensive monitoring over time

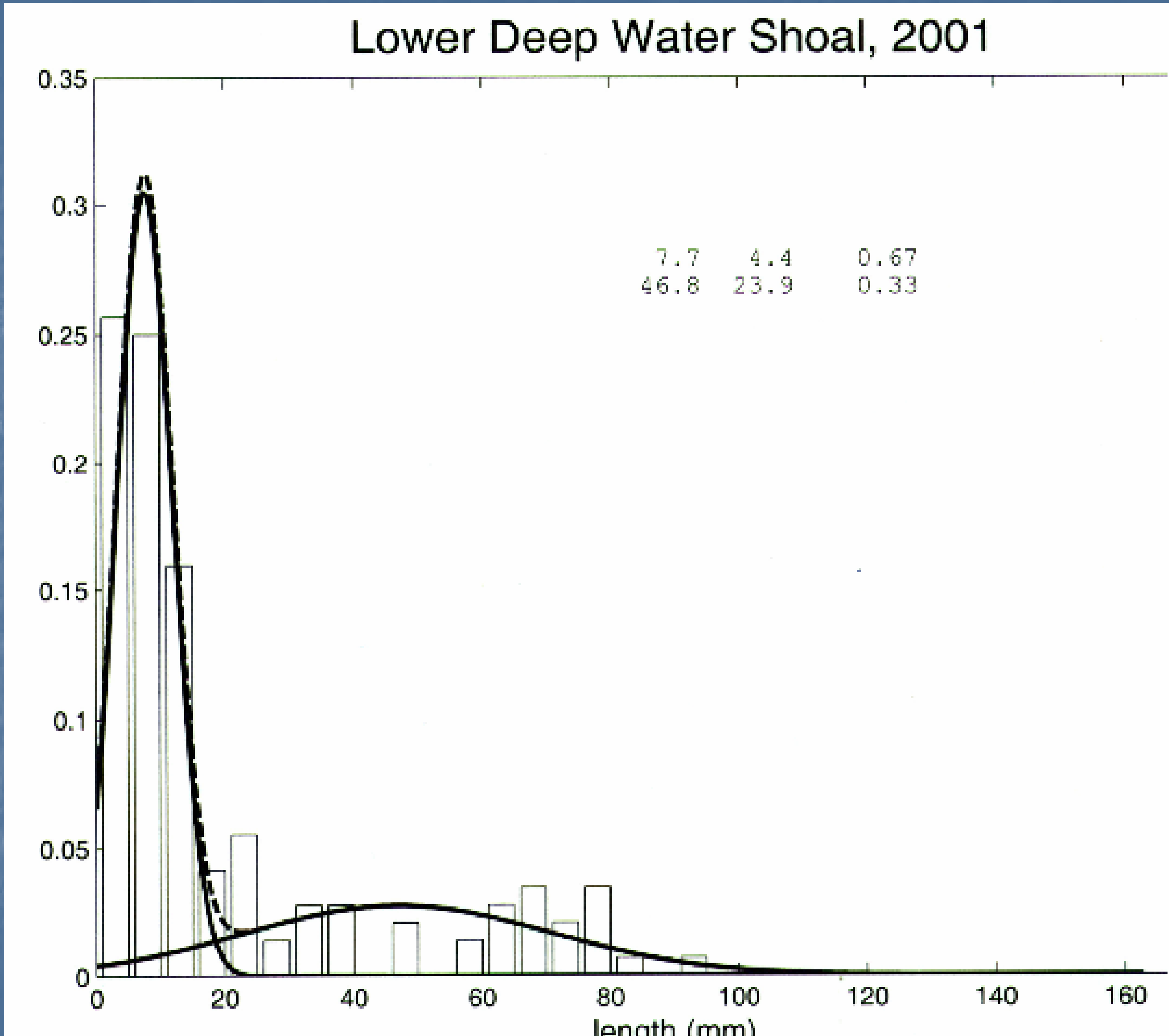
# Natural and/or exploited population data

Taking what you can get


Lower Deep Water Shoal, 1998
13.4 6.8 0.60
76.7 14.9 0.40
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0
20
40
60
80
100
120
140
160
length (mm)


Lower Deep Water Shoal, 1999
40.7 7.5 0.84
77.2 12.2 0.16
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 20 40 60 80 100 120 140 160
length (mm)

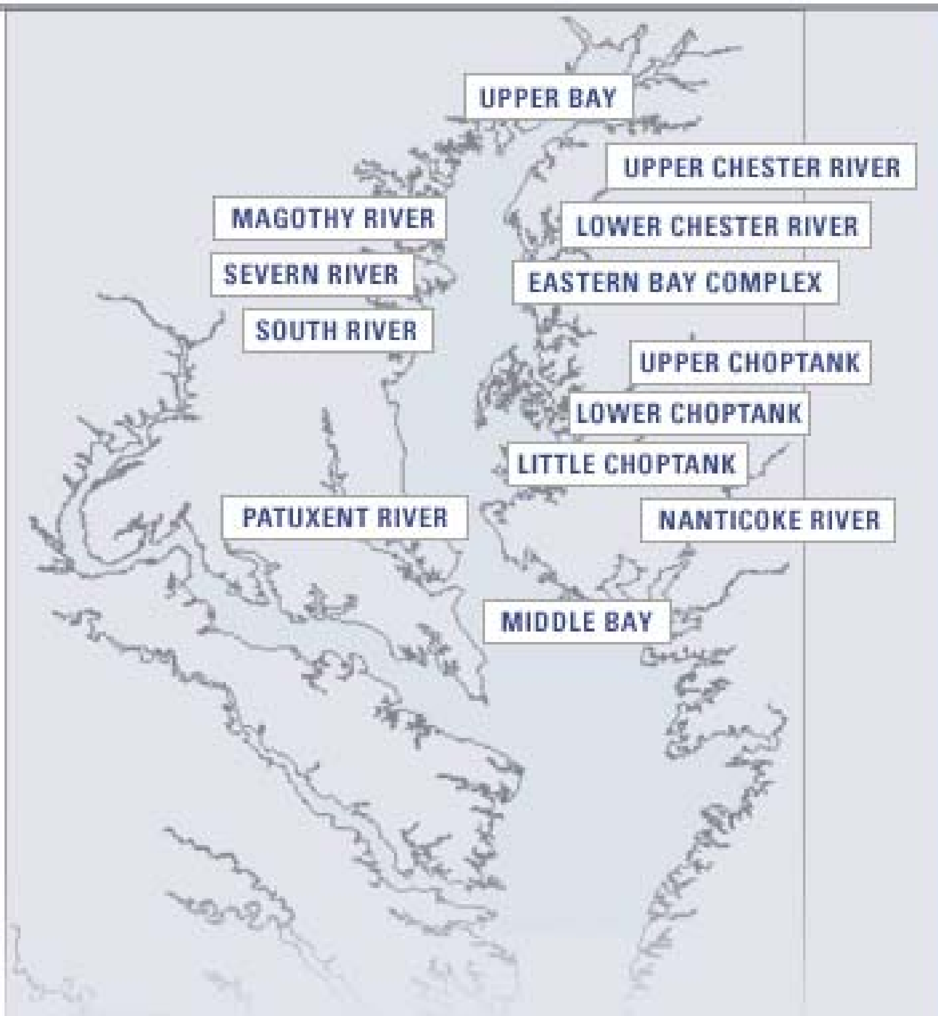

Lower Deep Water Shoal, 2000
39.3 9.9 0.50
74.5 16.3 0.50
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 20 40 60 80 100 120 140 160
length (mm)



Lower Deep Water Shoal, 2001
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7.7 4.4 0.67
46.8 23.9 0.33
0 20 40 60 80 100 120 140 160
length (mm)

# Data from planted, protected populations

Pretty close to controlled experiments




BACK TO MAIN MAP

THE PAYNTER LABS

## MONITORING DATA

PLEASE SELECT A SITE TO THE LEFT

- Upper Bay
- Magothy River
- Severn River
- South River
- Patuxent River
- Middle Bay
- Nanticoke River
- Upper Choptank
- Little Choptank
- Lower Choptank
- Eastern Bay Complex
- Lower Chester River
- Upper Chester River


www.oyster.umd.edu

# What we have learned

- How to restore
  - Location - avoid diseases
  - Prepare - clean shell base
  - Precision - GPS to mark shell and seed placement
  - Plant high densities - 2 million/acre - maximize ecological value
  - Monitor - collect relevant data - use in adaptive management
  - Protect - mark areas

# What have we learned

- SPF oysters planted on clean shell grow well and will survive >4 years in low salinity (<12ppt) waters with minimal dermo impacts
- From 1997-2002 - Very little evidence of spatset at any location except in Tangier Sound
- High density planting does not reduce growth rate and enhances benthic community development - effects with dermo untested
- MSX - unpredictable and devastating

# Is restoration working in Maryland?

- It depends on objectives
  - **Locally** - yes, in low salinity - good growth, longevity, excellent community responses; not yet, in moderate or high salinity - diseases
  - **Systemically**, not yet; no responses in local spatset, water clarity
  - **Societally** - yes/not yet; watermen/mangers/ academics are working together in unprecedented ways; no increases in harvest/industry

# But,

nothing about recruitment

except that it has only occurred in high densities at one site during 2 of the 5 yrs we were sampling.  And we were sampling at least 10 sites throughout MD each year.

# So what do we need?

For ecologically fully functional oysters reefs

1. Oyster longevity - 5 to 10 years

2. Recruitment
    1. Enough to replace the natural mortality established by 1 above.
    2. At densities high enough to create valuable habitat ($>50/m^2$?, $>100/m^2$?)

# What do we have?

- Longevity at low salinities (<12 ppt) - MD
  - But little to no recruitment
- Recruitment at high salinities - VA
  - But overwhelming disease-induced mortality within 2 to 3 years
- Little in between
  - Low life expectancy, infrequent and low density recruitment

# Will disease resistance/ tolerance develop?

## Strain experiments

- Choptank River; Tangier Sound
- 4 strains - planted in 2000
  - Local susceptible, Local tolerant, Louisiana strain, CROSBreed
- 2002 - mean size: 65 mm; Dermo low in all strains
- Heavy MSX-induced mortality
  - Local susceptible and Louisiana strains - **90%**
  - CROSBreed and local tolerant - **50-60%**

# Mixed messages

- Large-scale oyster reef restoration can be accomplished and appears to offer substantial ecological benefits.

- *C. virginica* still dies from disease, even after decades of selective breeding.