Oysters – A Bit of History

- We developed the oyster model circa 2000 – 2005, on the 12,000-cell grid, to assess the impact of a ten-fold increase in oyster population.
- We moved the oyster model to the 50,000-cell grid in 2008.
- We ceased all activity shortly thereafter.
- The oyster model is operational in our current model but has not been calibrated or compared to data for biomass and distribution.

New Factors to Consider

- Estimates of the current natural population vs. estimates completed circa 2000.
- Designation of oyster sanctuaries.
- Development of aquaculture.

Three Oyster Populations

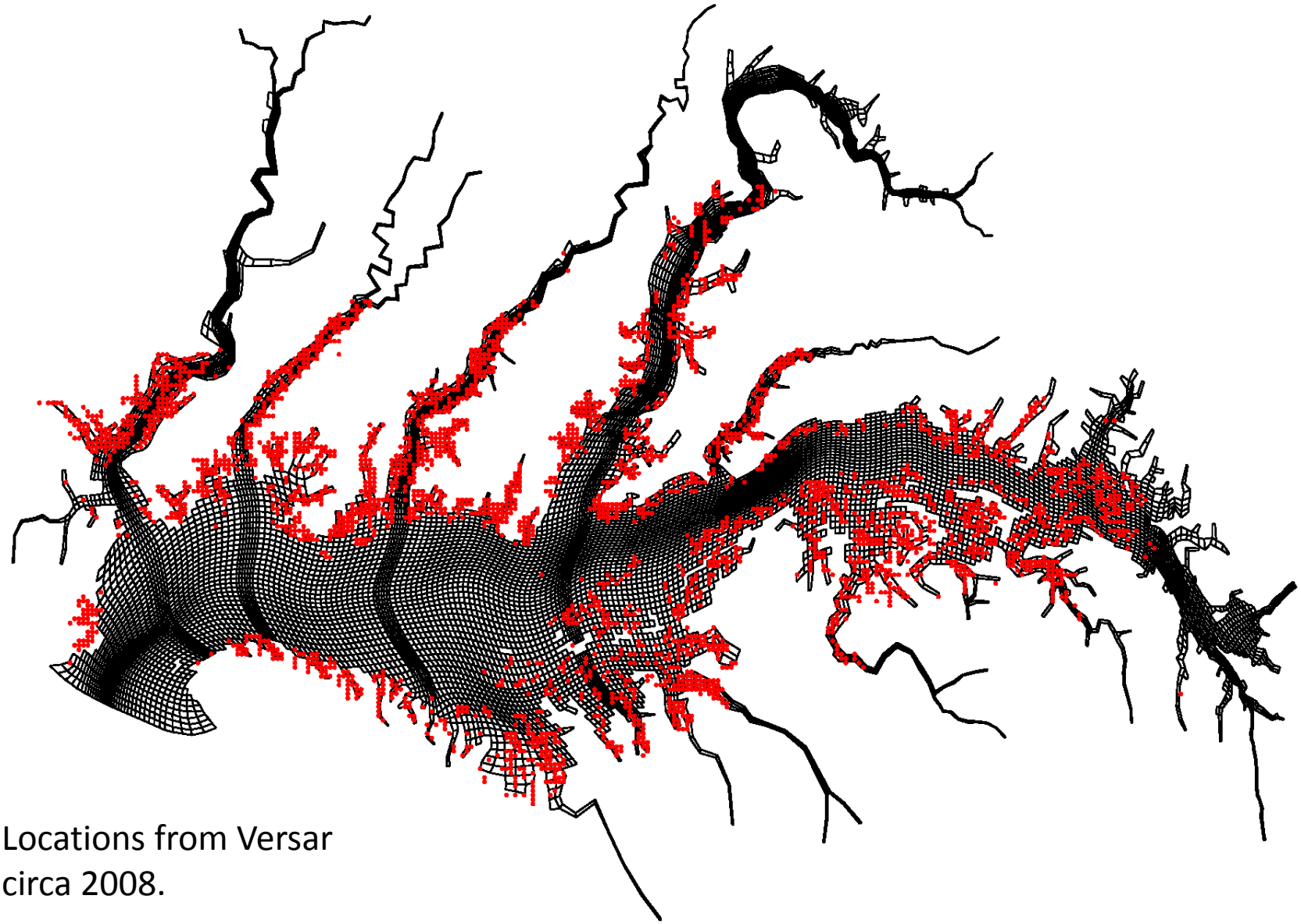
We're modeling three groups or populations of oysters:

1. Reefs subject to predation, disease, and harvest.
2. Sanctuaries subject to predation and disease but no harvest.
3. Aquaculture. Limited predation, 100% of the biomass is harvested each year.

What Do We Have to Do?

- Locate oysters on the present grid.
  - Oyster Bars
  - Sanctuaries
  - Aquaculture
- Obtain biomass estimates.
- Tune our model to represent current biomass in each group.
- Execute scenarios.

Oyster bars mapped to 50,000-cell grid.



Locations from Versar circa 2008.

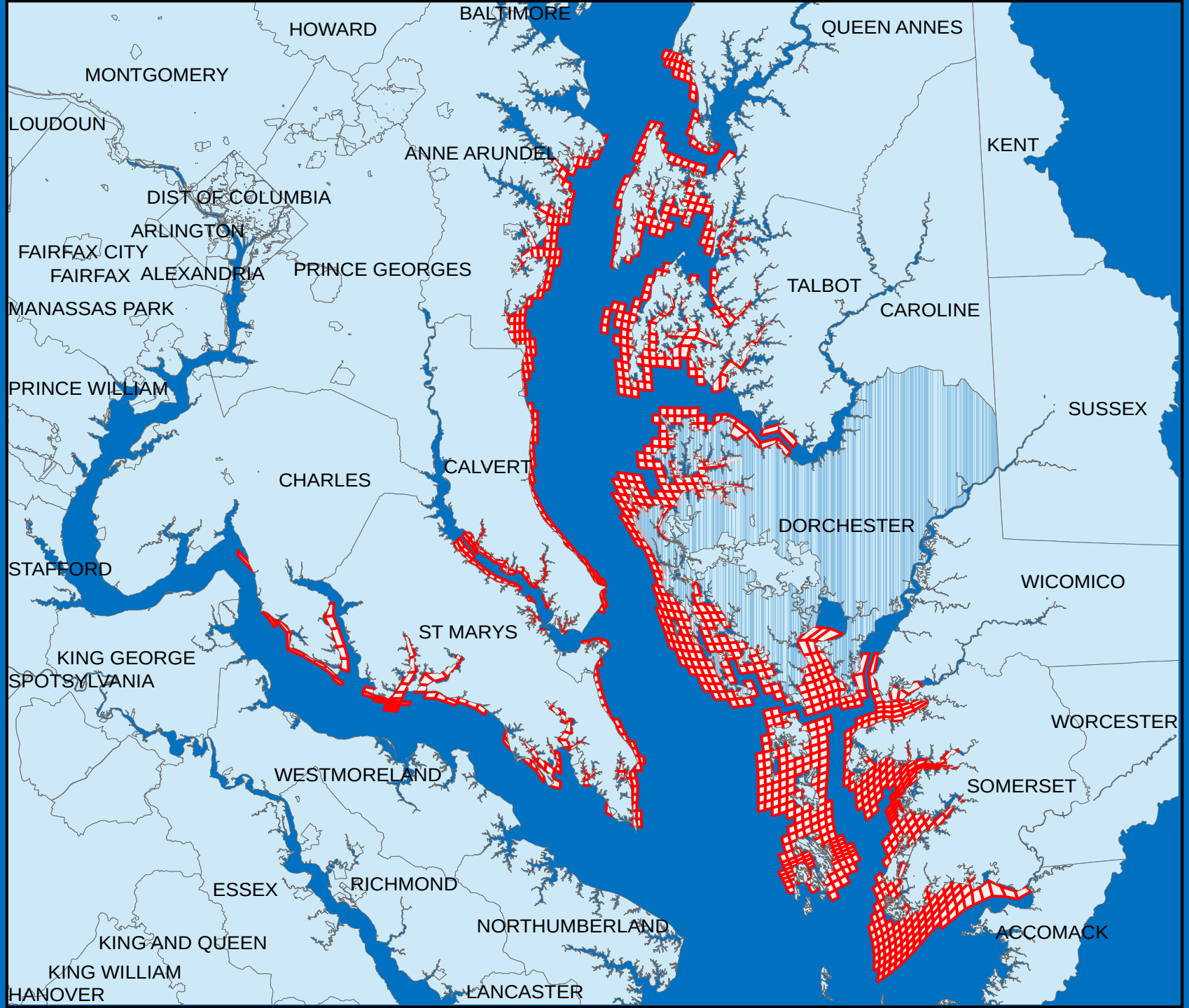
Maryland oyster leases by county, October 2015

Lease type	Anne Arundel	Calvert	Charles	Dorchester	Kent	Queen Anne	St. Mary's	Somerset	Talbot	Wicomico	Worcester	Total
Submerged land (SL)	24	11	1	57	1	5	64	24	52	40	10	289
Water column (WC)	2	2	0	19	1	2	22	6	1	0	8	63
Total	26	13	1	76	2	7	86	30	53	40	18	352

Oyster farmers are trying a variety of high-tech and low-tech *approaches to growing this bivalve in Maryland waters, but the state Department of Natural Resources classifies them in only two categories: Submerged Land Leases (SL) and Water Column Leases (WC). The first category primarily covers on-bottom techniques that feature loose shell to catch natural spat set or plantings of spat-on-shell. The second category covers cages, bags, floats, and any other device that holds oysters off the bottom. As the map shows, the busiest centers for both styles of aquaculture are Dorchester County on the Eastern Shore and St. Mary's County on the western side of the Bay.* TABLE SOURCE: KARL ROSCHER; MAP, CREATED BY SANDY RODGERS ON A BASE MAP FROM VECTORSTOCK.COM

Aquaculture

- We have Maryland harvest by county.
- We do not have location of aquaculture facilities.
- As a start, we are assigning aquaculture activity to Maryland waters with salinity > 7 and depth < 12 feet.


BALTIMORE
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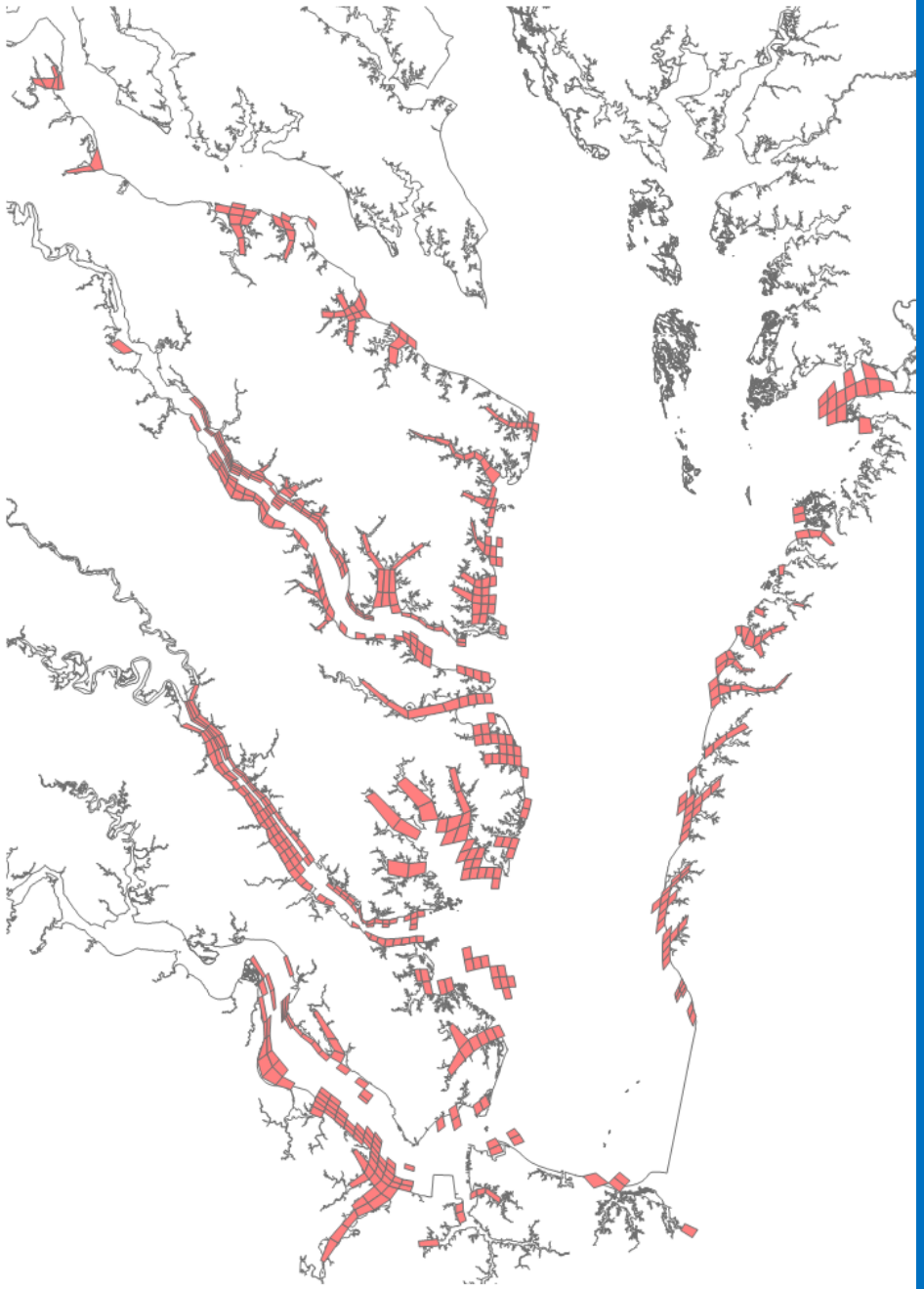
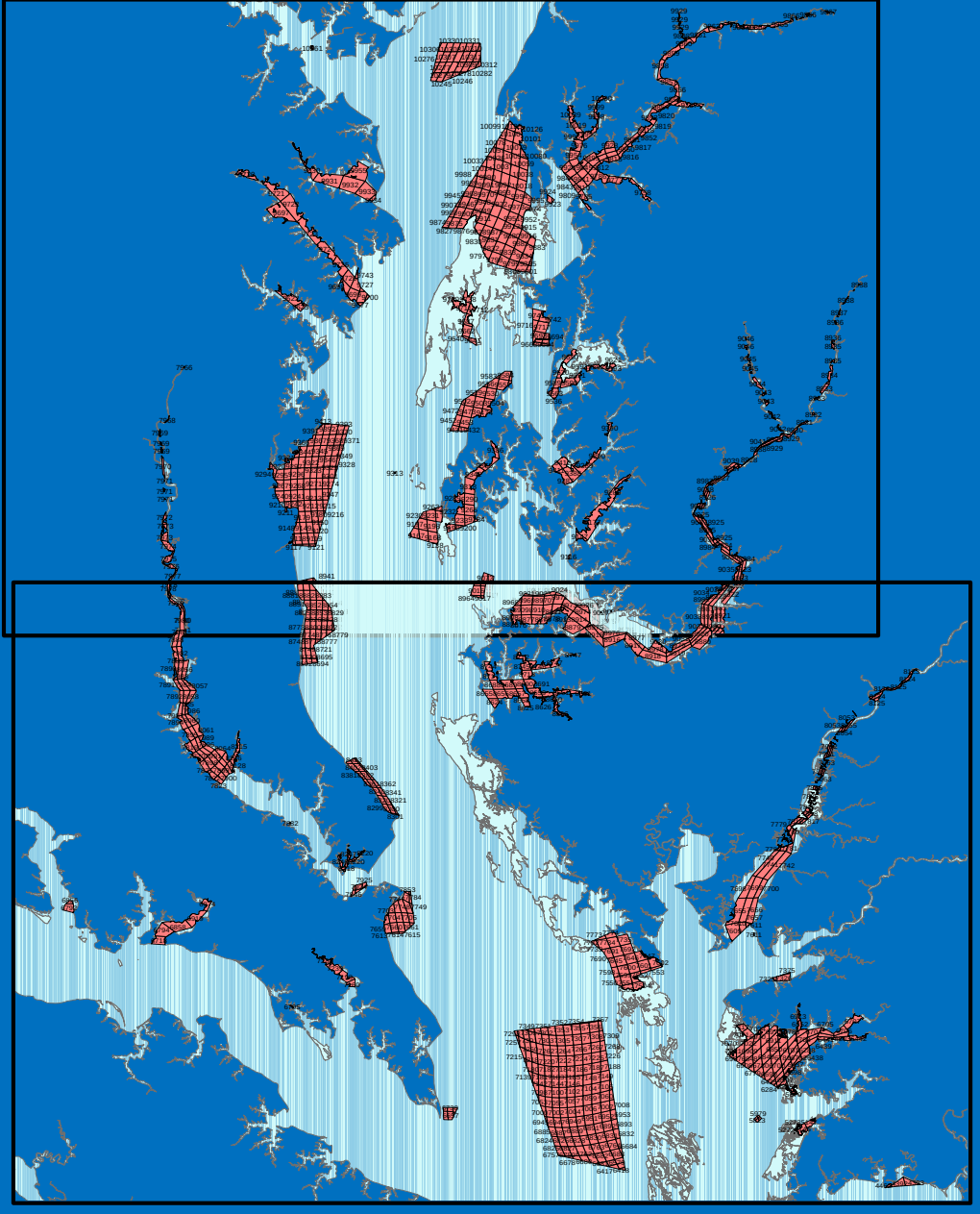
QUEEN ANNES
MONTGOMERY
LOUDOUN
ANNE ARUNDEL
KENT
DIST OF COLUMBIA
ARLINGTON
FAIRFAX CITY
FAIRFAX
ALEXANDRIA
PRINCE GEORGES
TALBOT
CAROLINE
MANASSAS PARK
PRINCE WILLIAM
SUSSEX
CALVERT
CHARLES
DORCHESTER
STAFFORD
WICOMICO
ST MARYS
KING GEORGE
SPOTSYLVANIA
WORCESTER
WESTMORELAND
SOMERSET
ESSEX
RICHMOND
NORTHUMBERLAND
ACCOMACK
KING AND QUEEN
KING WILLIAM
HANOVER
LANCASTER



Aquaculture

- We have a GIS file of Virginia lease areas.
- We do not have specific location of aquaculture facilities.
- As a start, we are assigning aquaculture activity to lease areas with salinity > 7 and depth < 12 feet.



Sanctuaries

- We have Maryland oyster sanctuaries mapped to the grid.
- We have overlap with the oyster bar data from 2008.
- If a sanctuary and a bar coincide, we assume that bar is now a sanctuary.
- We lack information on location of Virginia sanctuaries.

CBOPE

Chesapeake Bay Oyster Population Estimate

- A web site maintained by VIMS originally intended to measure progress towards the planned ten-fold population increase.
- Extends from 1994 to 2002 (MD), 2008 (VA).
- Contains “fishery-independent data” (standing stock) for two states. Little locational information.
- Contains “fishery dependent” data, separated into “public” and “private” effort, by state.

Aquaculture Biomass

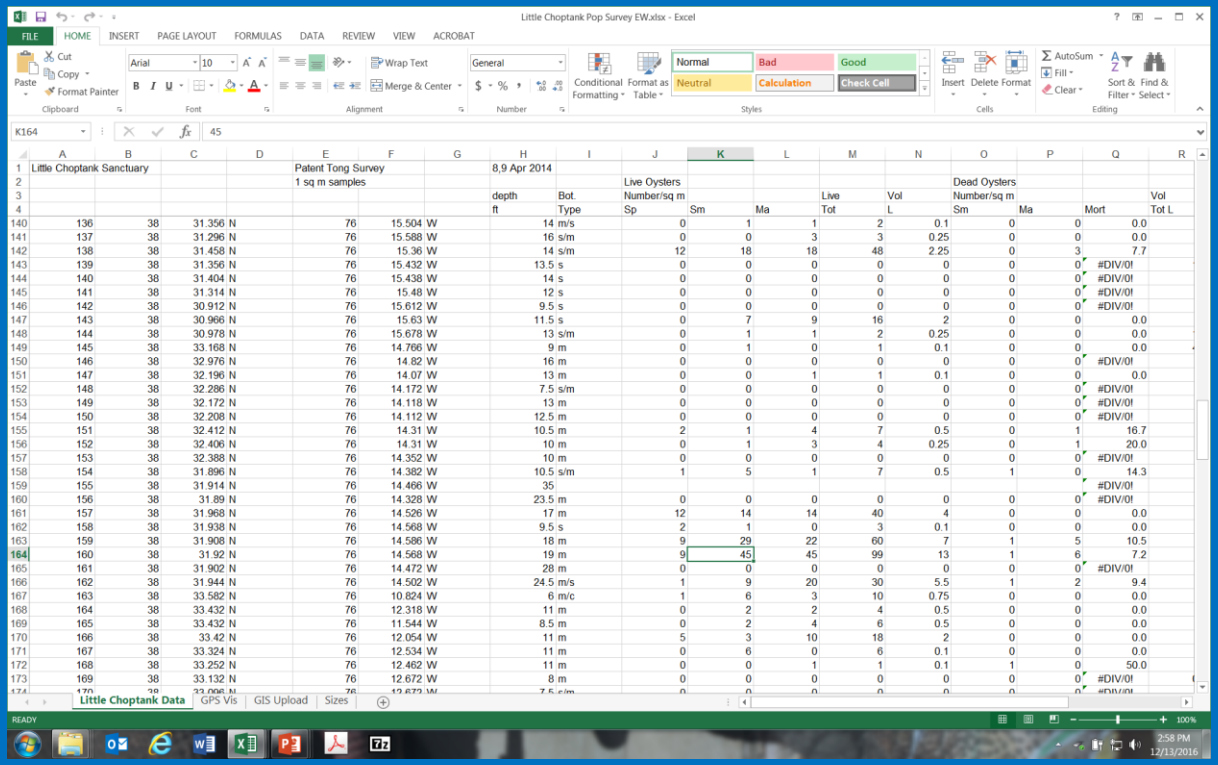
Assume the biomass is equivalent to the harvest. The farmer plants the seeds and harvests the crop. This activity is continuous year-round.

Maryland – We have 2014-2016 data from Julie Riechert.

Virginia – We have results from VIMS “Crop Reporting” surveys.

Sanctuaries

- We have the area of each Maryland sanctuary and some measure of density (quantity per unit area) for each sanctuary.
- It's going to be extraordinarily difficult to work up this data for each sanctuary and impossible to individually represent each sanctuary in the model.
- Modeled reef and sanctuary populations will be combined and compared with fishery-independent population estimates.



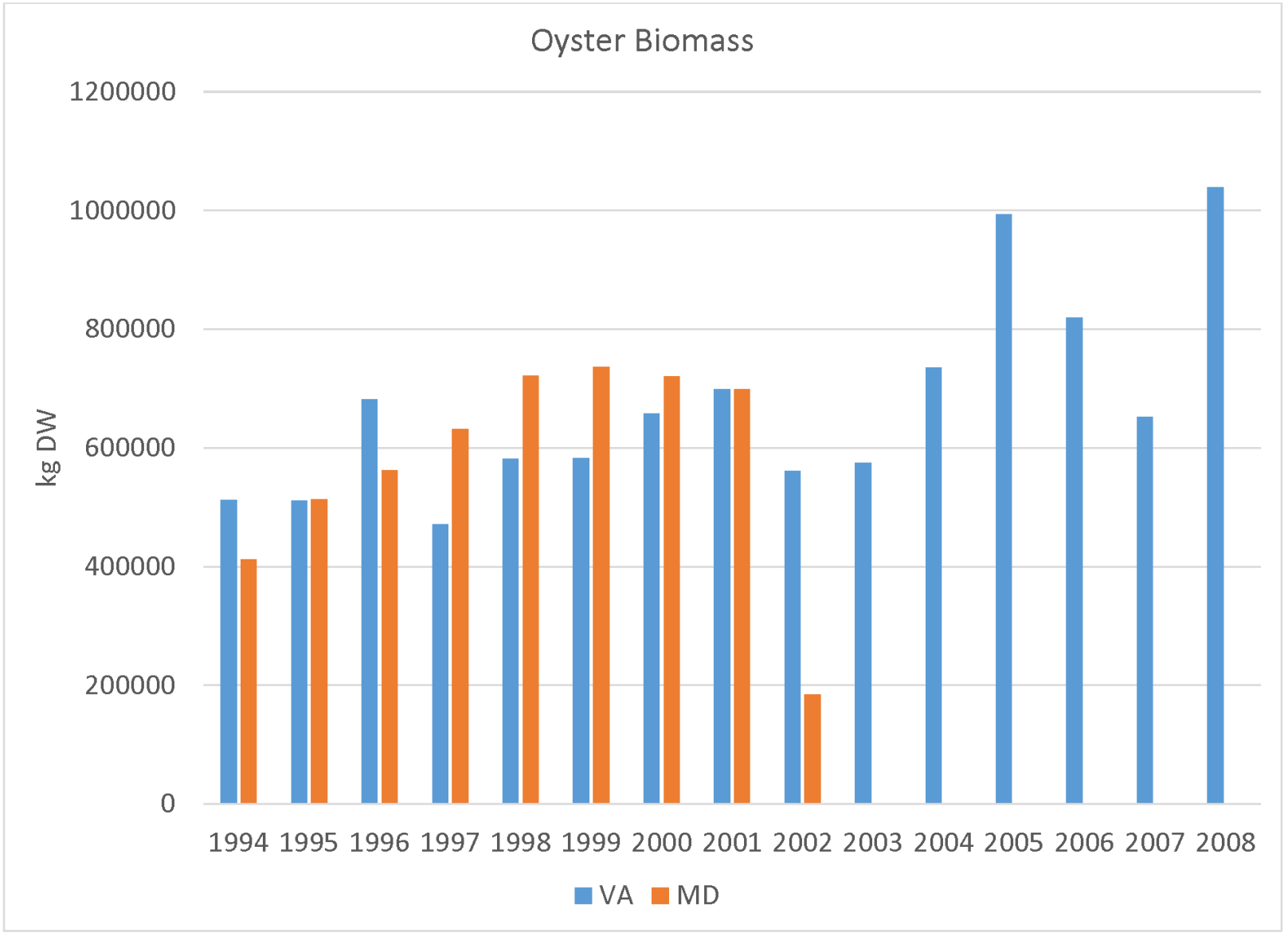
Little Choptank Pop Survey EW.xlsx - Excel

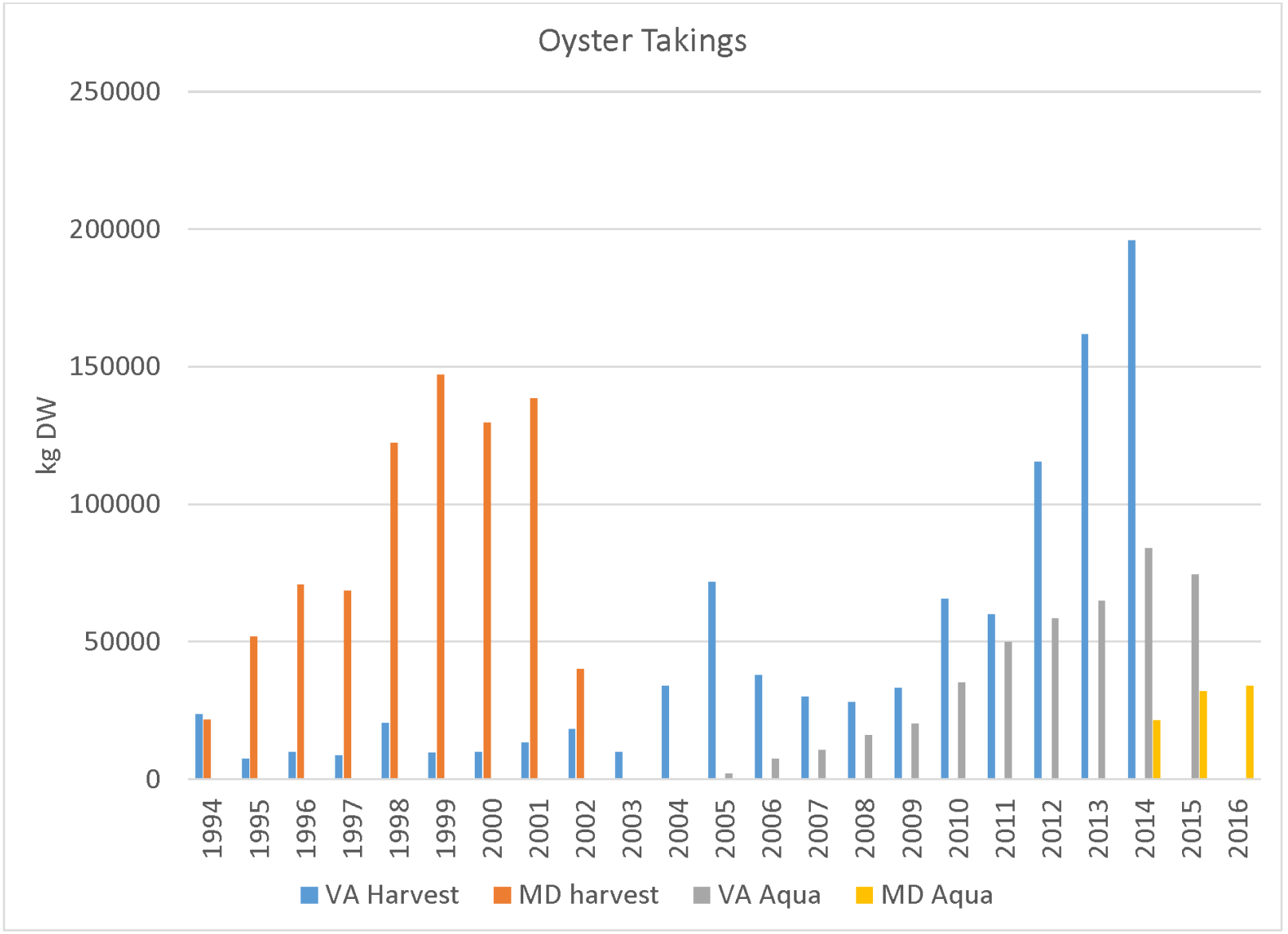
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Little Choptank Sanctuary				Patent Tong Survey			8,9 Apr 2014										
2					1 sq m samples					Live Oysters					Dead Oysters			
3								depth	Bot.	Number/sq m			Live	Vol	Number/sq m			Vol
4								ft	Type	Sp	Sm	Ma	Tot	L	Sm	Ma	Mort	Tot L
140	136	38	31.356 N		76	15.504 W		14	m/s	0	1	1	2	0.1	0	0	0.0	
141	137	38	31.296 N		76	15.588 W		16	s/m	0	0	3	3	0.25	0	0	0.0	
142	138	38	31.458 N		76	15.36 W		14	s/m	12	18	18	48	2.25	0	3	7.7	
143	139	38	31.356 N		76	15.432 W		13.5	s	0	0	0	0	0	0	0	#DIV/0!	
144	140	38	31.404 N		76	15.438 W		14	s	0	0	0	0	0	0	0	#DIV/0!	
145	141	38	31.314 N		76	15.48 W		12	s	0	0	0	0	0	0	0	#DIV/0!	
146	142	38	30.912 N		76	15.612 W		9.5	s	0	0	0	0	0	0	0	#DIV/0!	
147	143	38	30.966 N		76	15.63 W		11.5	s	0	7	9	16	2	0	0	0.0	
148	144	38	30.978 N		76	15.678 W		13	s/m	0	1	1	2	0.25	0	0	0.0	
149	145	38	33.168 N		76	14.766 W		9	m	0	1	0	1	0.1	0	0	0.0	
150	146	38	32.976 N		76	14.82 W		16	m	0	0	0	0	0	0	0	#DIV/0!	
151	147	38	32.196 N		76	14.07 W		13	m	0	0	1	1	0.1	0	0	0.0	
152	148	38	32.286 N		76	14.172 W		7.5	s/m	0	0	0	0	0	0	0	#DIV/0!	
153	149	38	32.172 N		76	14.118 W		13	m	0	0	0	0	0	0	0	#DIV/0!	
154	150	38	32.208 N		76	14.112 W		12.5	m	0	0	0	0	0	0	0	#DIV/0!	
155	151	38	32.412 N		76	14.31 W		10.5	m	2	1	4	7	0.5	0	1	16.7	
156	152	38	32.406 N		76	14.31 W		10	m	0	1	3	4	0.25	0	1	20.0	
157	153	38	32.388 N		76	14.352 W		10	m	0	0	0	0	0	0	0	#DIV/0!	
158	154	38	31.896 N		76	14.382 W		10.5	s/m	1	5	1	7	0.5	1	0	14.3	
159	155	38	31.914 N		76	14.466 W		35									#DIV/0!	
160	156	38	31.89 N		76	14.328 W		23.5	m	0	0	0	0	0	0	0	#DIV/0!	
161	157	38	31.968 N		76	14.526 W		17	m	12	14	14	40	4	0	0	0.0	
162	158	38	31.938 N		76	14.568 W		9.5	s	2	1	0	3	0.1	0	0	0.0	
163	159	38	31.908 N		76	14.586 W		18	m	9	29	22	60	7	1	5	10.5	
164	160	38	31.92 N		76	14.568 W		19	m	9	45	45	99	13	1	6	7.2	
165	161	38	31.902 N		76	14.472 W		28	m	0	0	0	0	0	0	0	#DIV/0!	
166	162	38	31.944 N		76	14.502 W		24.5	m/s	1	9	20	30	5.5	1	2	9.4	
167	163	38	33.582 N		76	10.824 W		6	m/c	1	6	3	10	0.75	0	0	0.0	
168	164	38	33.432 N		76	12.318 W		11	m	0	2	2	4	0.5	0	0	0.0	
169	165	38	33.432 N		76	11.544 W		8.5	m	0	2	4	6	0.5	0	0	0.0	
170	166	38	33.42 N		76	12.054 W		11	m	5	3	10	18	2	0	0	0.0	
171	167	38	33.324 N		76	12.534 W		11	m	0	6	0	6	0.1	0	0	0.0	
172	168	38	33.252 N		76	12.462 W		11	m	0	0	1	1	0.1	1	0	50.0	
173	169	38	33.132 N		76	12.672 W		8	m	0	0	0	0	0	0	0	#DIV/0!	
174	170	38	33.096 N		76	12.672 W		7.5	s/m	0	0	0	0	0	0	0	#DIV/0!	

Little Choptank Data | GPS Vis | GIS Upload | Sizes

READY

2:58 PM 12/13/2016


Oyster Biomass
1200000
1000000
800000
600000
400000
200000
0
kg DW
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
VA
MD


Oyster Takings
250000
200000
150000
100000
50000
0
kg DW
1994
1995
1996
1997
1998
1999
2000
2001
2002
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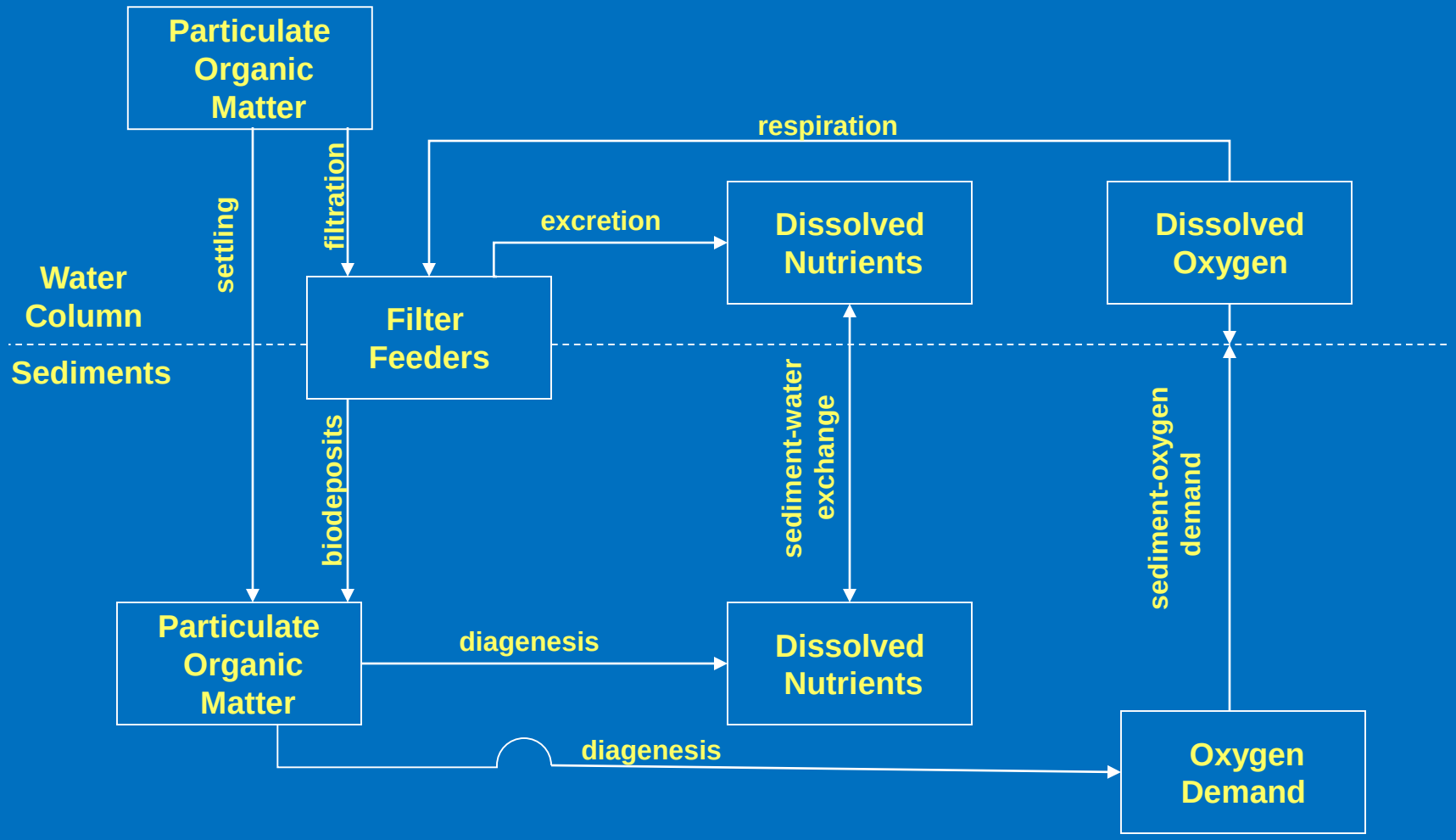
2014
2015
2016
VA Harvest
MD harvest
VA Aqua
MD Aqua



Diagenesis Model with Benthos

Basic Equation

$$\frac{dO}{dt} = \propto \cdot Fr \cdot POC \cdot IF \cdot (1 - RF) \cdot O - BM \cdot O - \beta \cdot O$$

In which:

O = oyster biomass (g C m^{-2})

α = assimilation efficiency ($0 < \alpha < 1$)

Fr = filtration rate (m^3 g^{-1} C d^{-1})

POC = particulate organic carbon (g m^{-3})

IF = ingestion fraction ($0 < IF < 1$)

RF = respiration fraction ($0 < RF < 1$)

BM = basal metabolism (d^{-1})

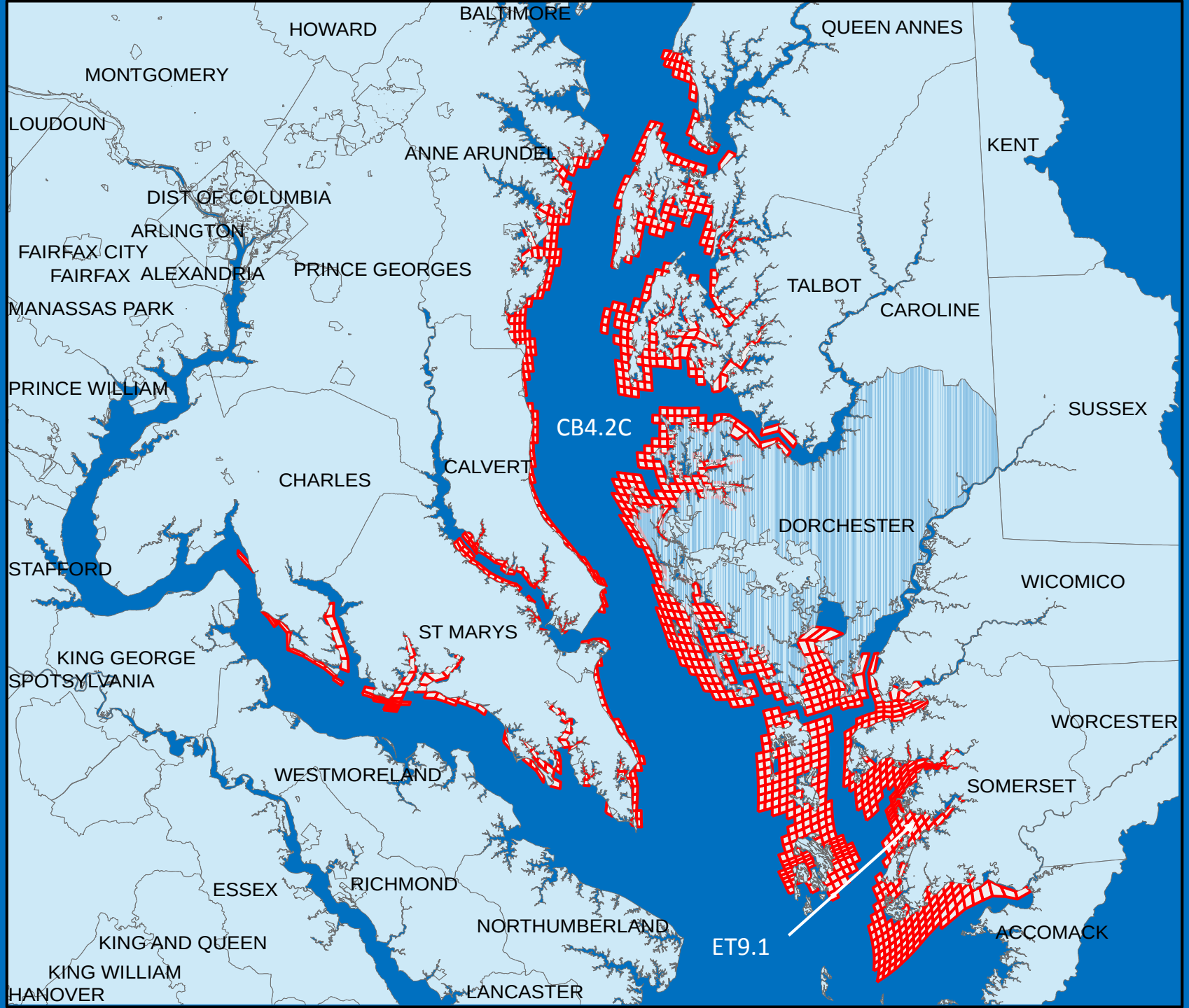
β = mortality (d^{-1})

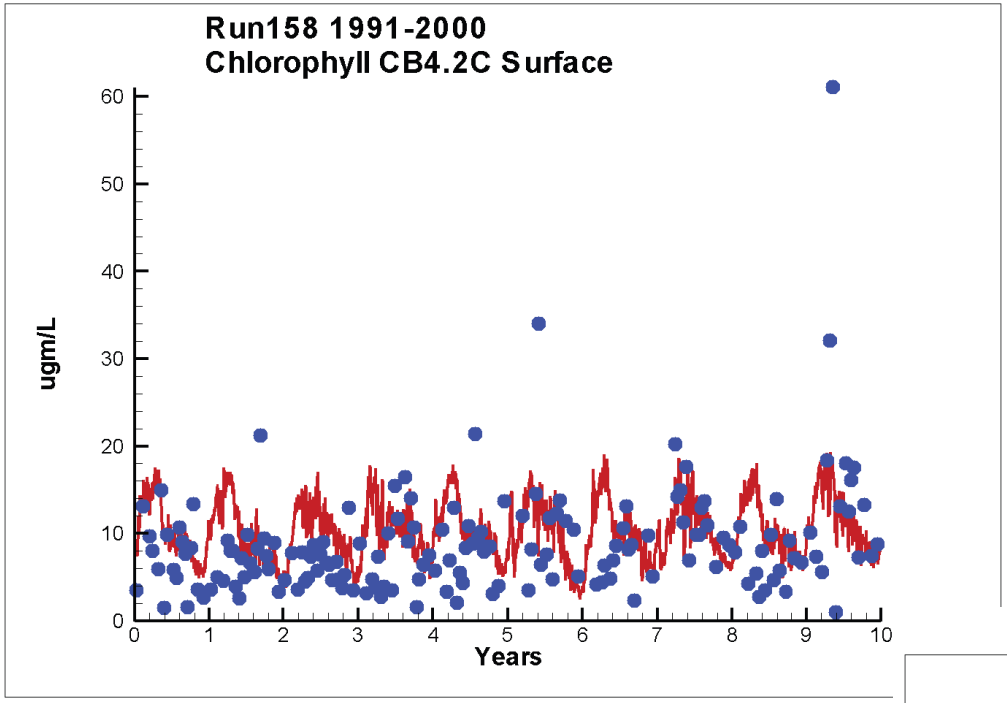
The Approach

- Adapt most parameters from 2005 oyster model.
- The mortality term includes predation, disease, and harvest. Tune the mortality term until computed biomass is consistent with observations.
- We can implement a “fix” for aquaculture. Set dO/dt to zero and impose reported biomass.
- To an extent, we let the oysters locate themselves in regions with appropriate conditions.

MD Aquaculture

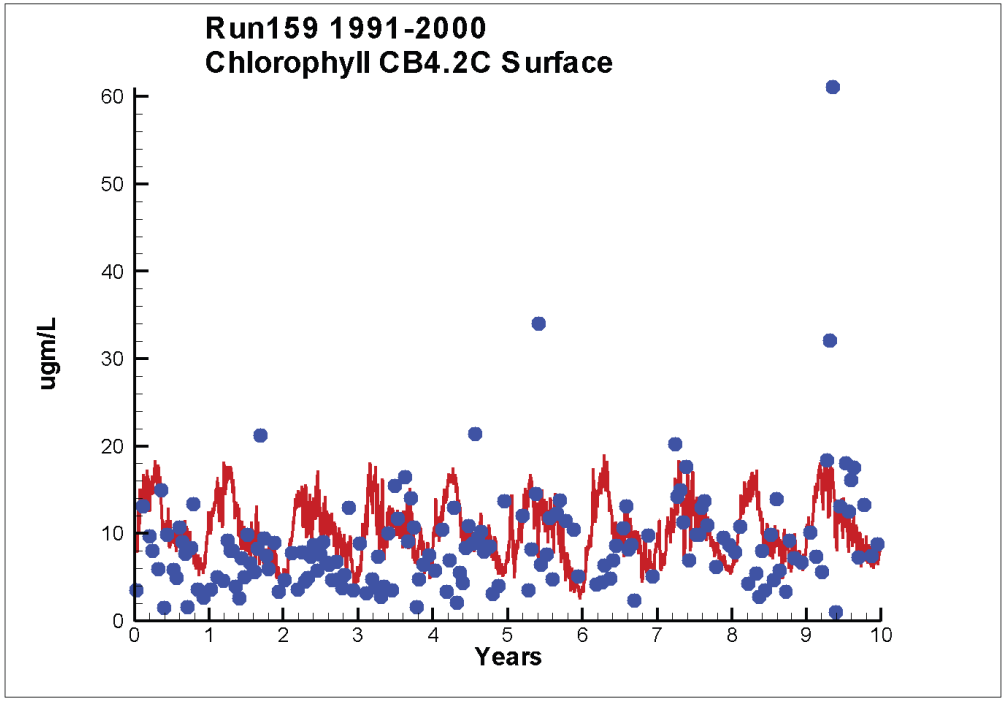
- Let's take the 2014 – 2016 MD aquaculture biomass and distribute it uniformly across cells.
- We have records by county so we can distribute across cells by county.
- Install this biomass in the 1991-2000 calibration.

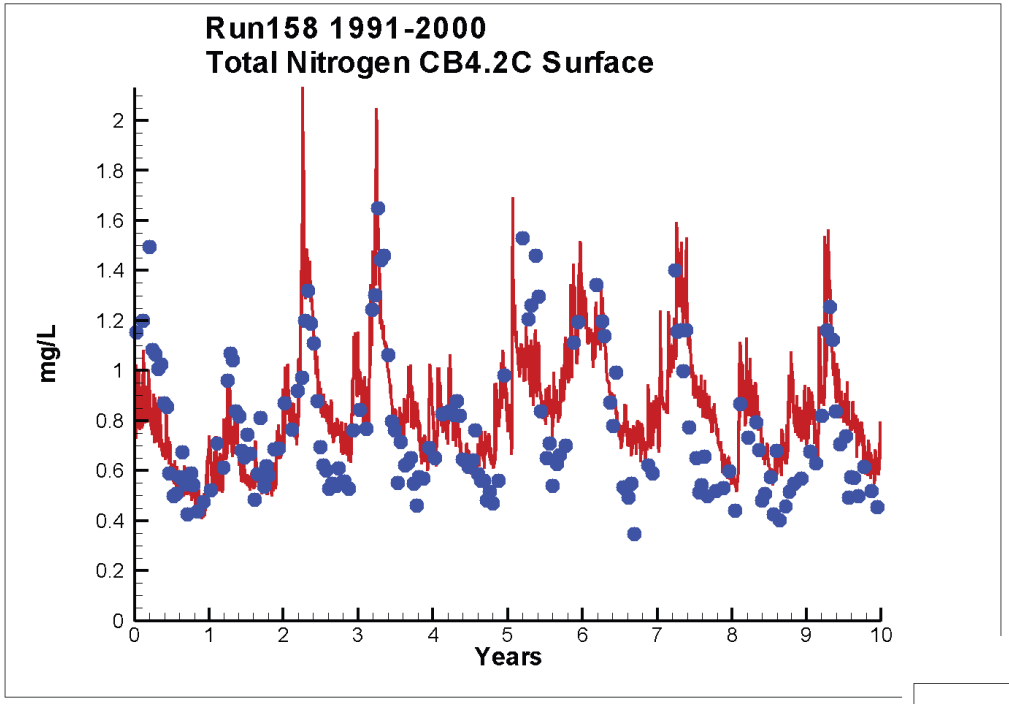

BALTIMORE
HOWARD
QUEEN ANNES
MONTGOMERY
LOUDOUN
ANNE ARUNDEL
KENT
DIST OF COLUMBIA
ARLINGTON
FAIRFAX CITY
FAIRFAX
ALEXANDRIA
PRINCE GEORGES
TALBOT
CAROLINE
MANASSAS PARK
PRINCE WILLIAM
CB4.2C
SUSSEX
CALVERT
CHARLES
DORCHESTER
STAFFORD
WICOMICO
ST MARYS
KING GEORGE
SPOTSYLVANIA
WORCESTER
WESTMORELAND
SOMERSET
ESSEX
RICHMOND
NORTHUMBERLAND
ET9.1
ACCOMACK
KING AND QUEEN
KING WILLIAM
HANOVER
LANCASTER



No Aquaculture

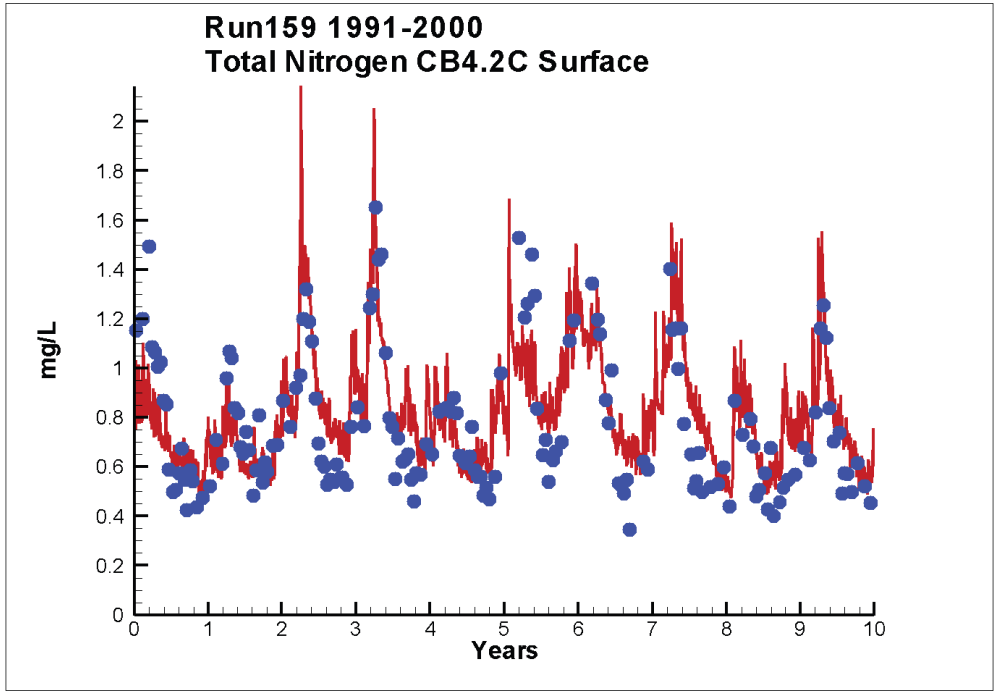
With Aquaculture

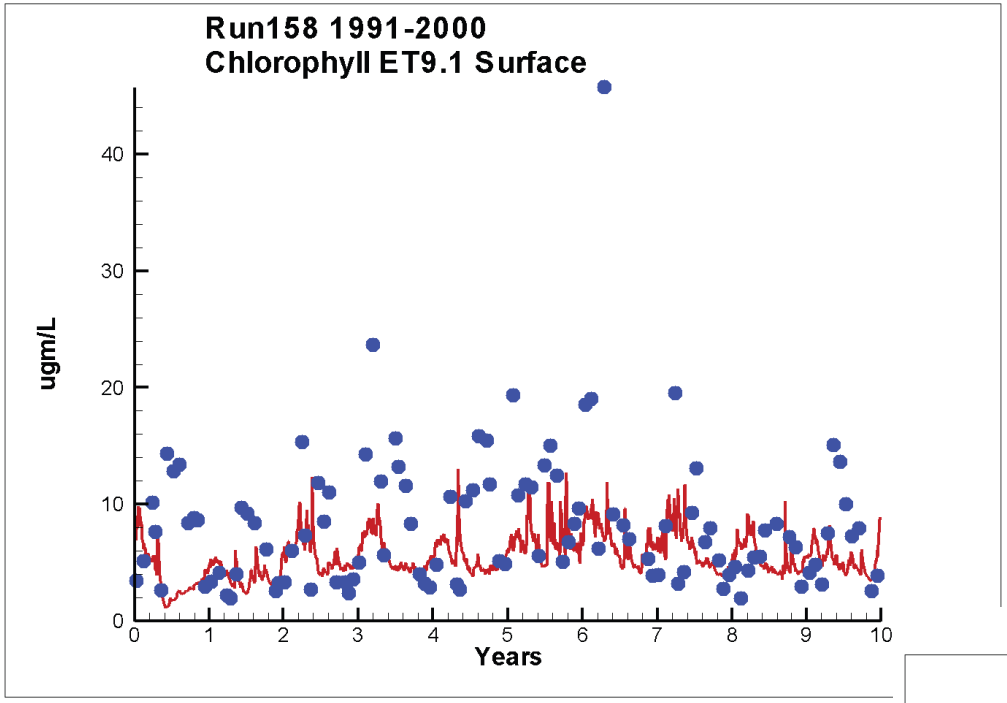




No Aquaculture

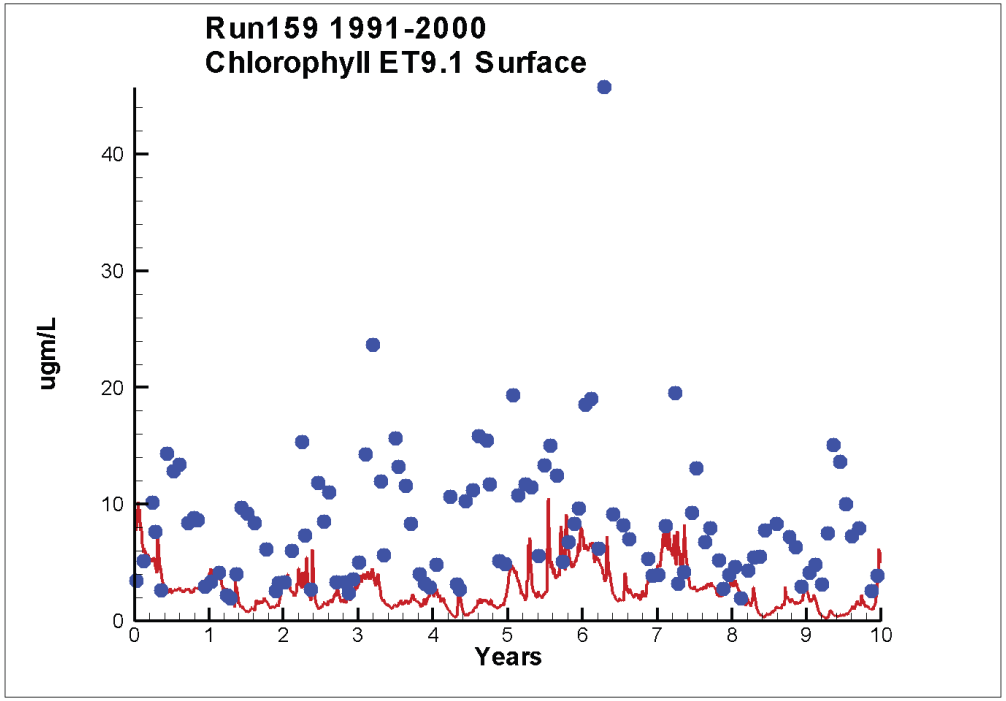
With Aquaculture

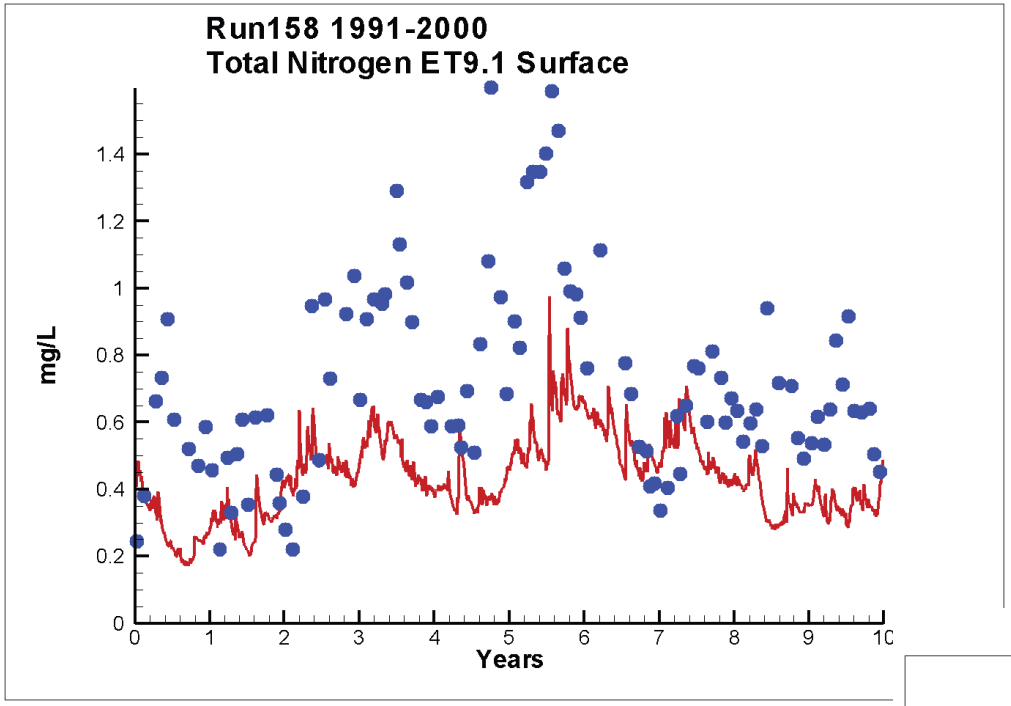




No Aquaculture

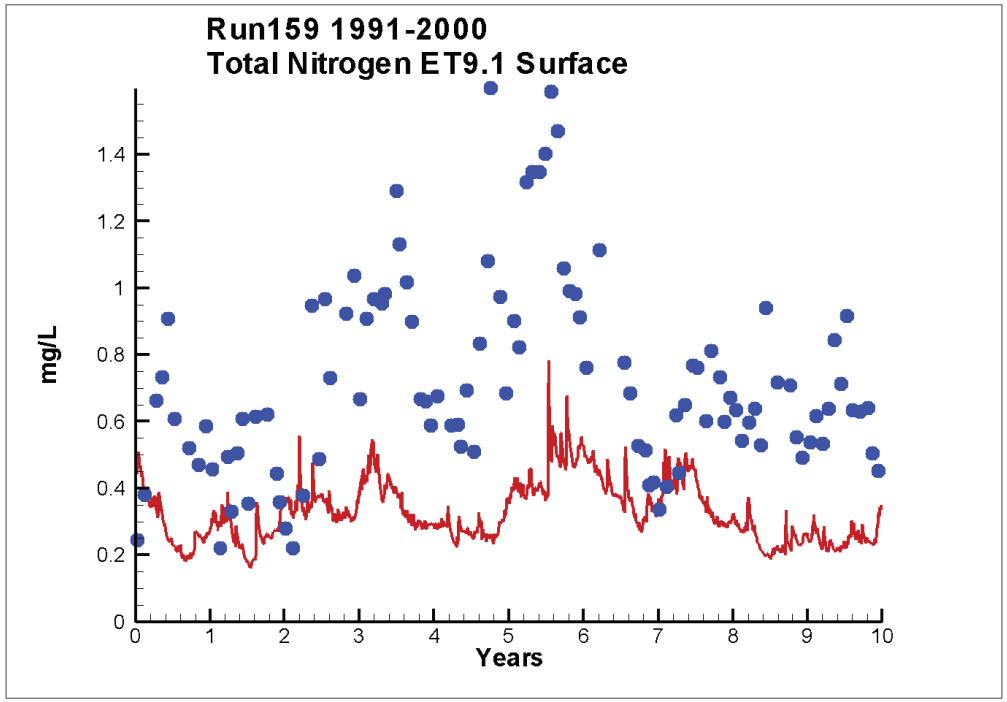
With Aquaculture





No Aquaculture

With Aquaculture



Problems with Aquaculture

- We have not yet completed a successful VA aquaculture run nor a ten-fold increase in MD aquaculture. Why not?
- Not all cells in our aquaculture regions will support aquaculture. Cells that support present levels will not support a ten-fold increase.
- With the reef population, we let the oysters self-locate. We allowed a ten-fold increase globally, not in each cell.
- We have to develop a similar process or another "work-around" for aquaculture. It will be difficult to exactly match reported biomass.