Restoration of burrowing mayflies in the Laurentian Great Lakes: an example in western Lake Erie

USGS
science for a changing world

BURROWING MAYFLIES are aquatic insects that are classified in various ways, live in the mud, and are important because they are indicators of moderately productive water.

Order = Ephemeroptera

Suborder Furcatergalia

Infraorder = Palpotarsa (primitive burrowing mayflies)

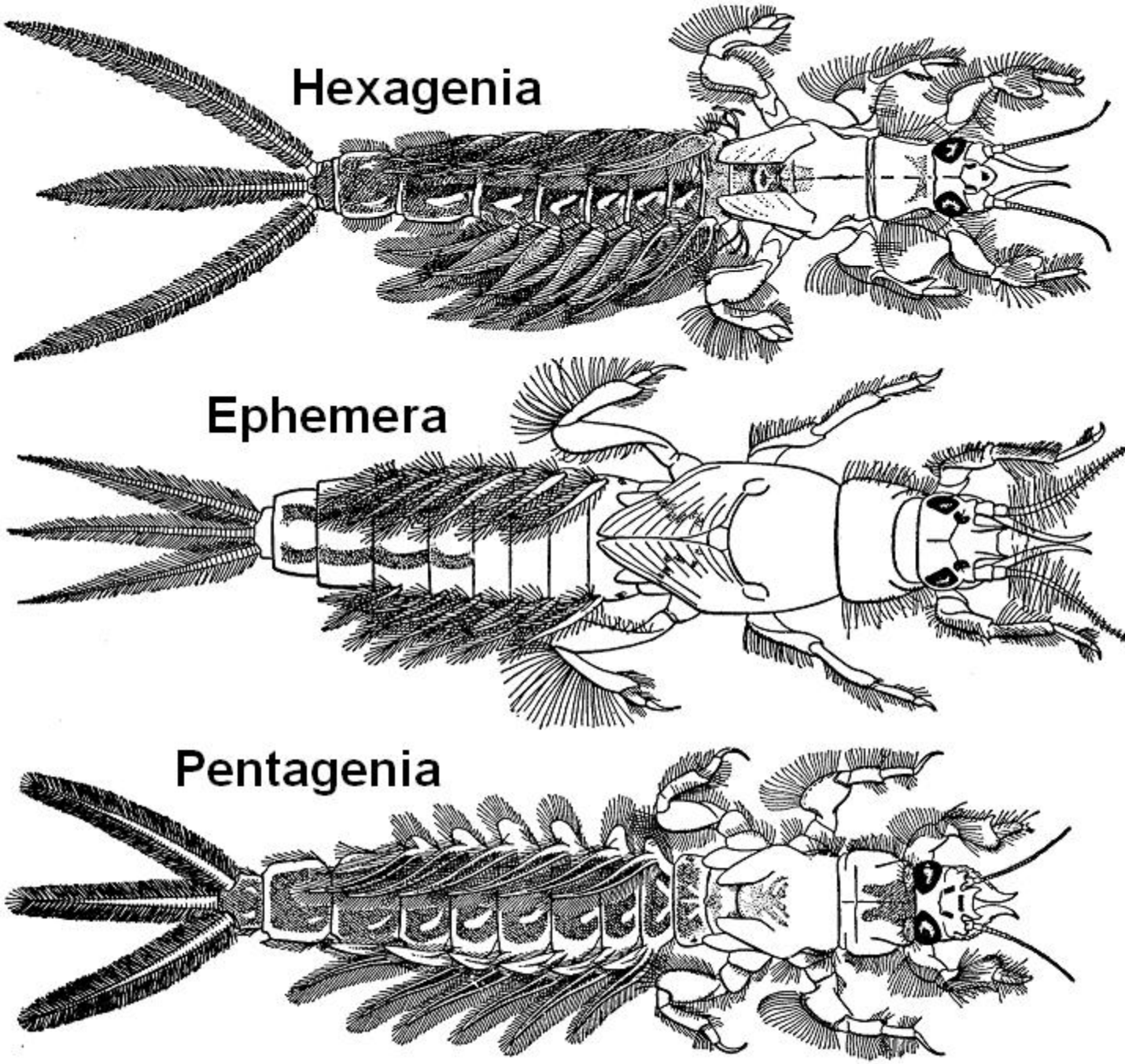
Infraorder = Scapphodonta (burrowing mayflies)

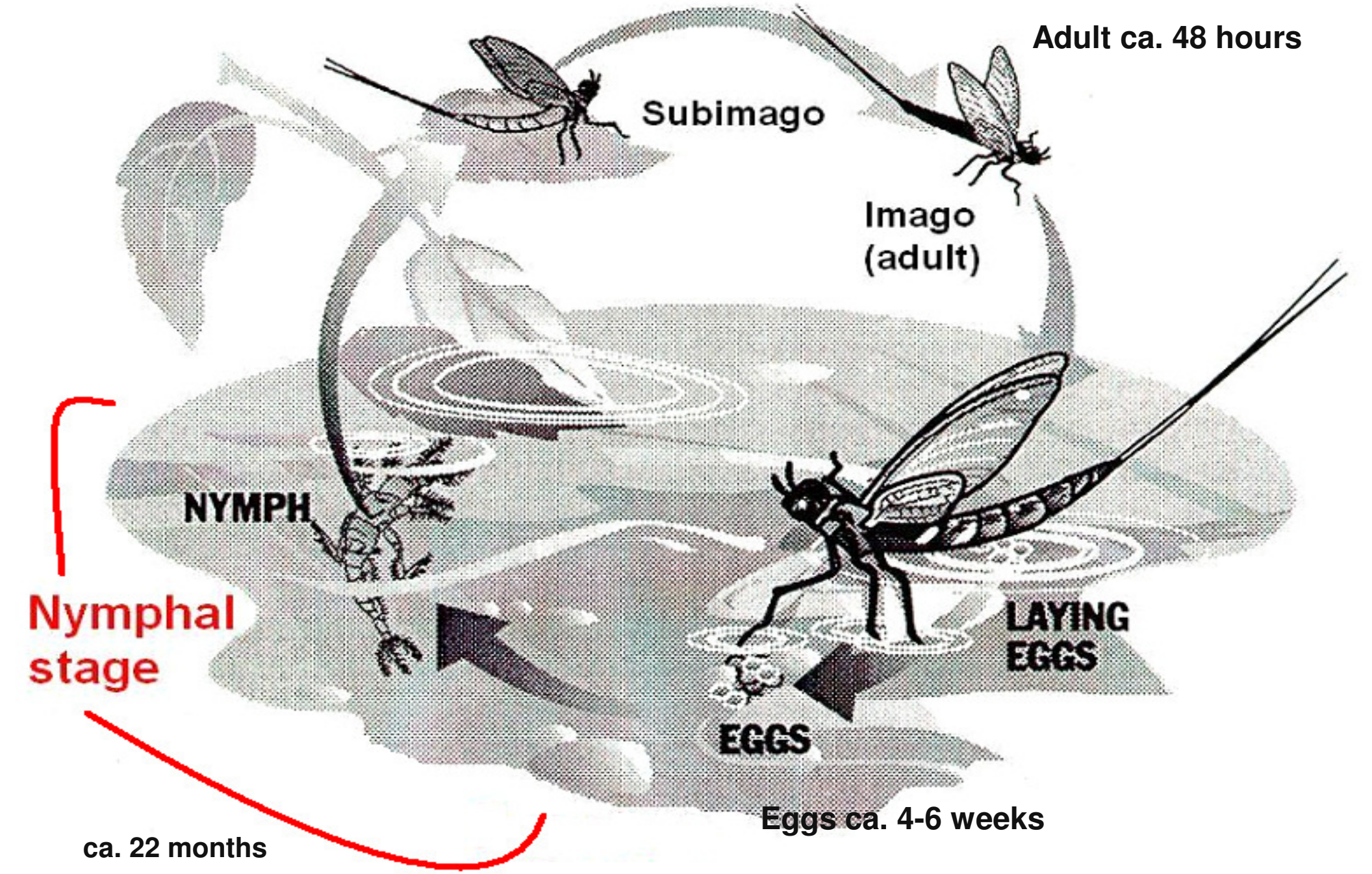
Family Potamanthidae

Family Polymitarcyidae

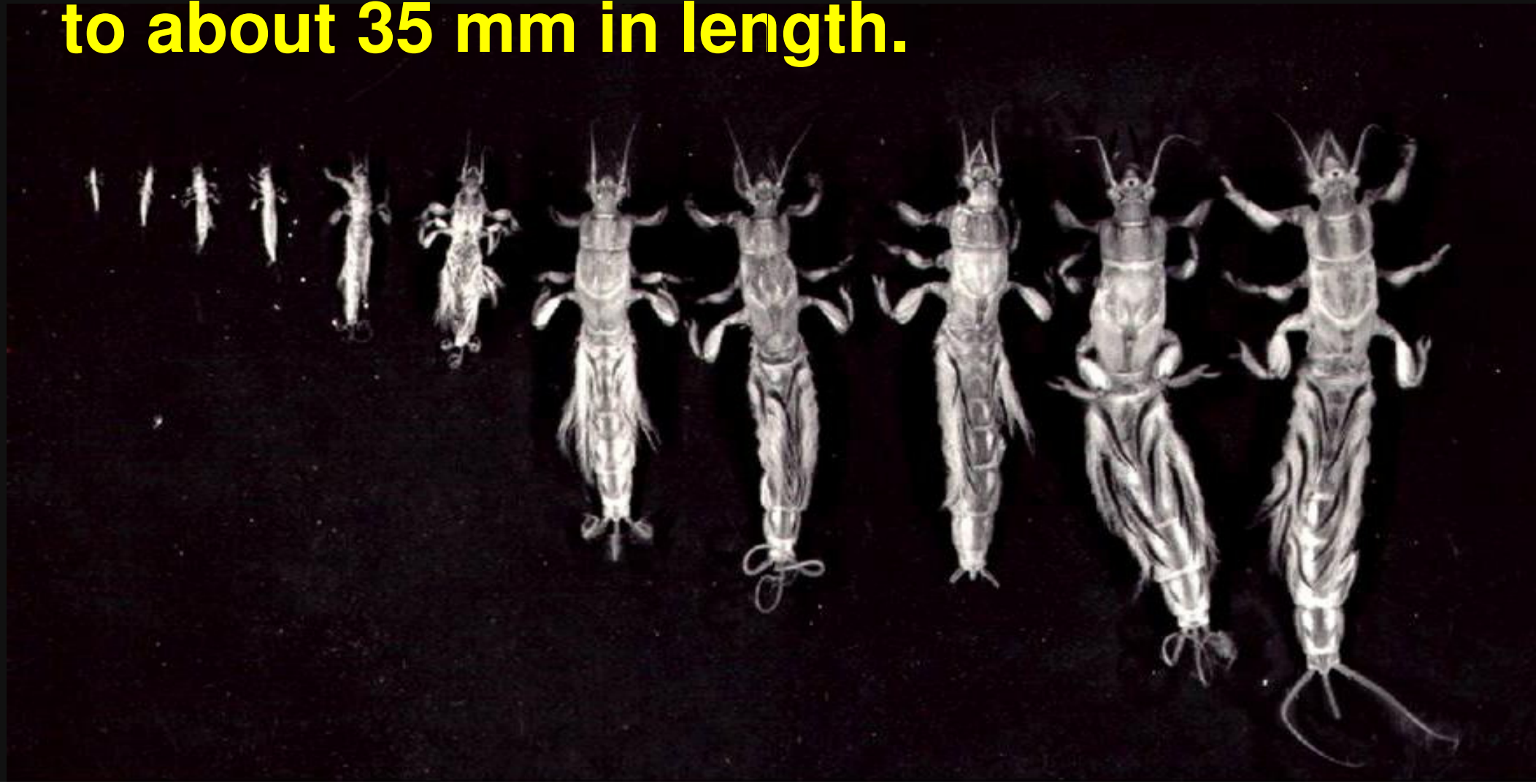
Family Ephemeridae

In the Great Lakes, there are three genera of burrowing mayflies. Today's discussion is about *Hexagenia*.



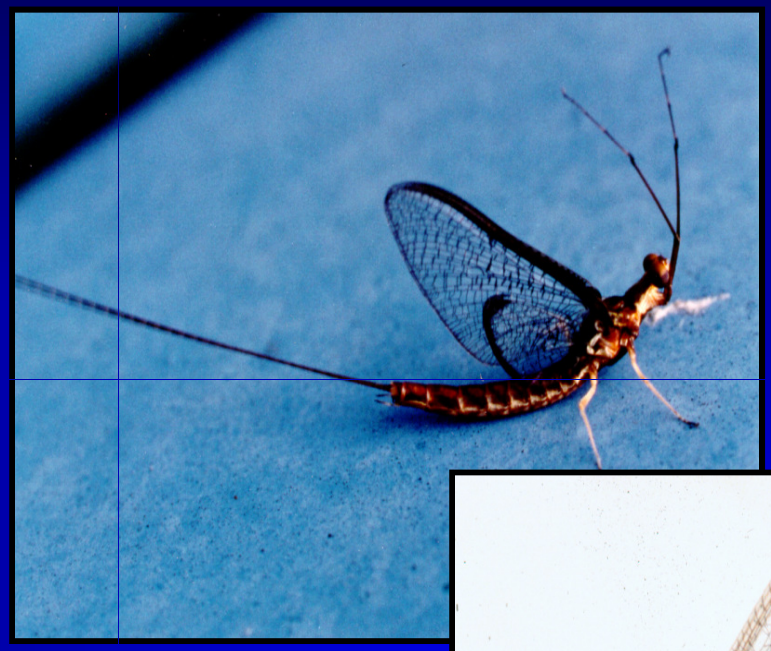

Adult ca. 48 hours
Subimago
Imago
(adult)
NYMPH
Nymphal
stage
LAYING
EGGS
EGGS
Eggs ca. 4-6 weeks
ca. 22 months

Hexagenia **nymphs in the Great Lakes grow to about 35 mm in length.**



Nymphs rise the water's surface, shed a skin, and fly to shore as sub-adults called subimagos.

Subimagoes shed their skins and transform into mature adults.



Male

Female

Adults mate in flight and females return to the water to deposit eggs.

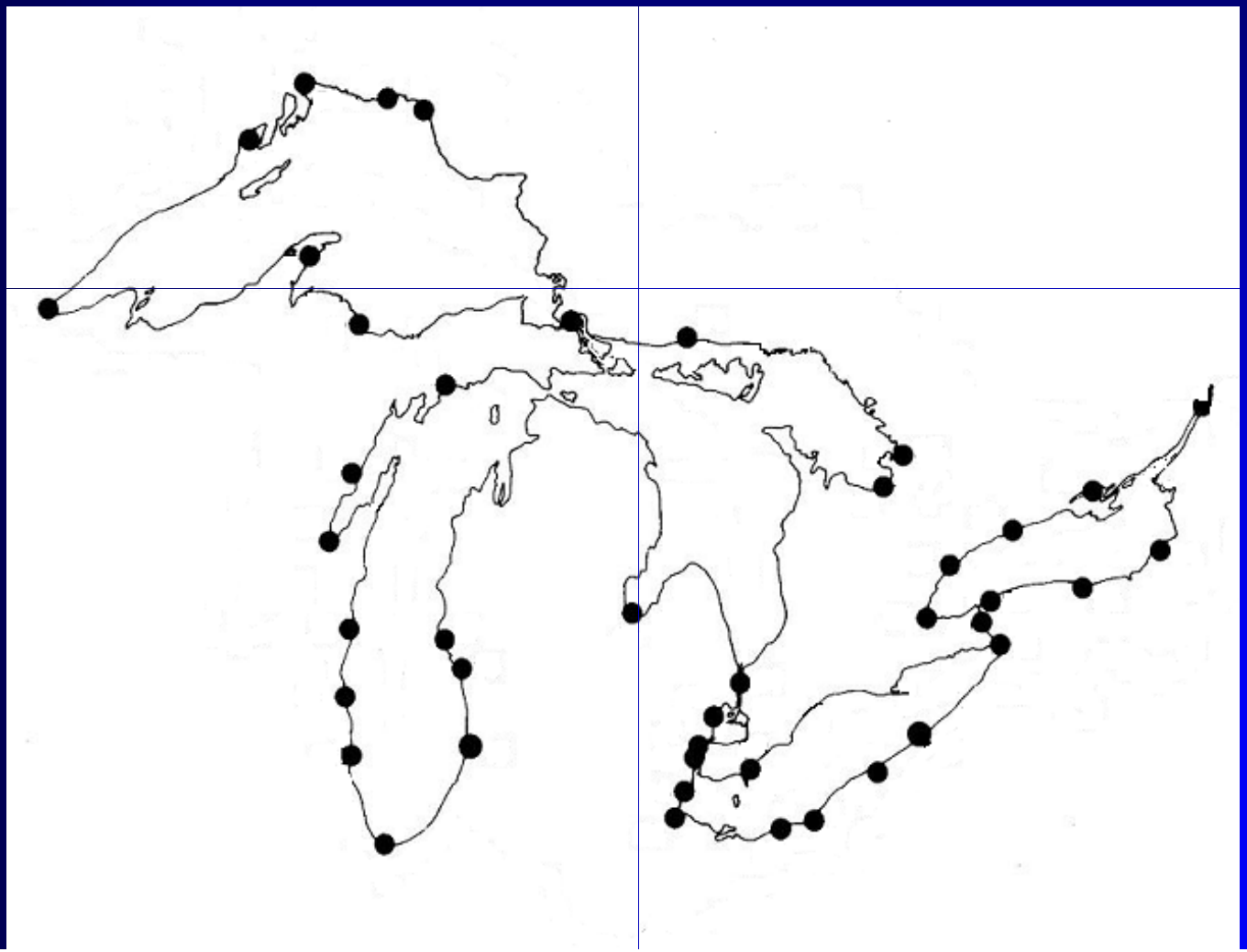
Burrowing mayflies are good organisms to assess some forms of habitat restoration because they respond to pollution abatement!

the Mississippi River

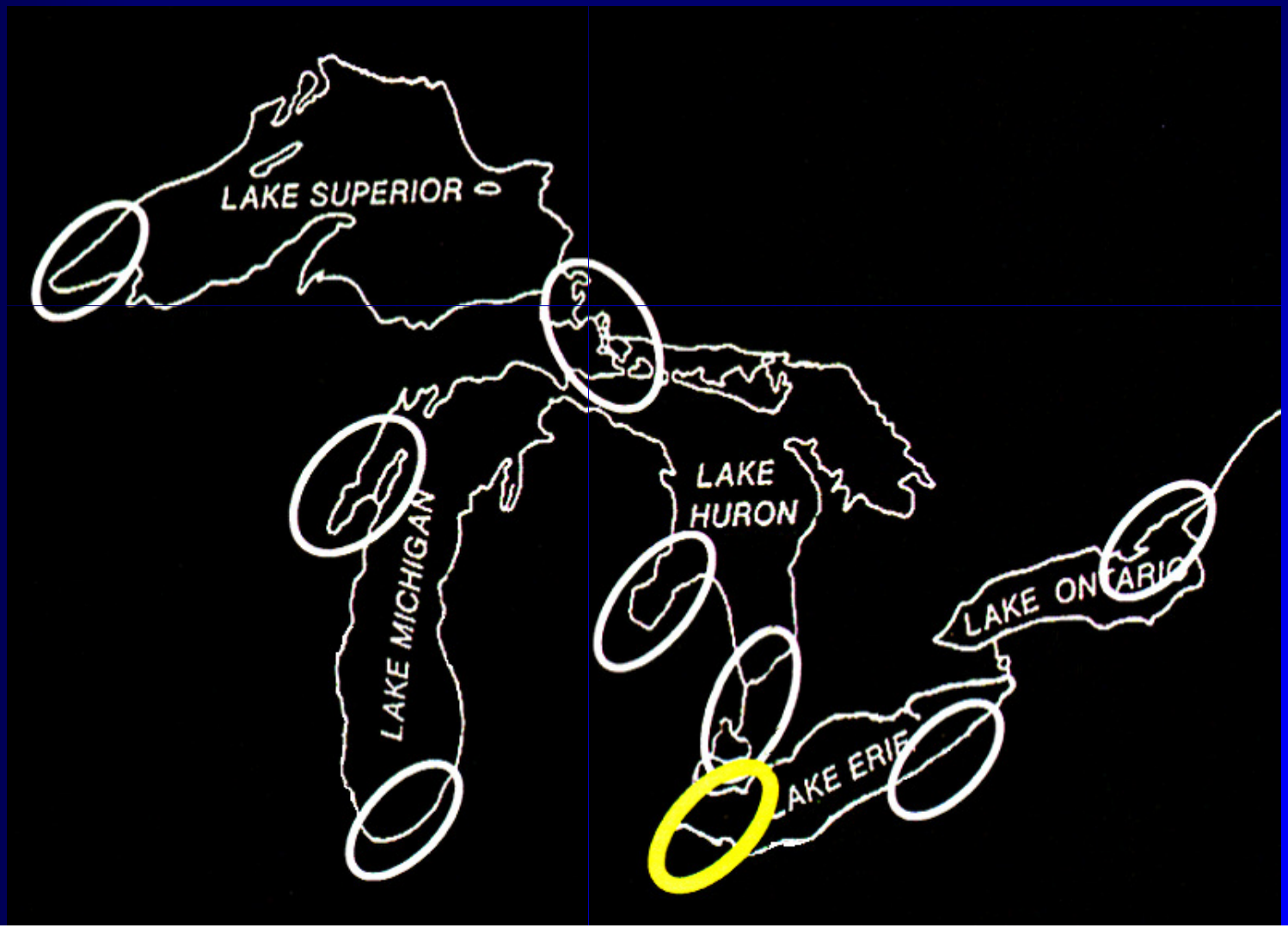
Hungary

The Netherlands

In the Great Lakes, we believe mayflies were common many years ago in most large bays and harbors (i.e., areas of concern) and….



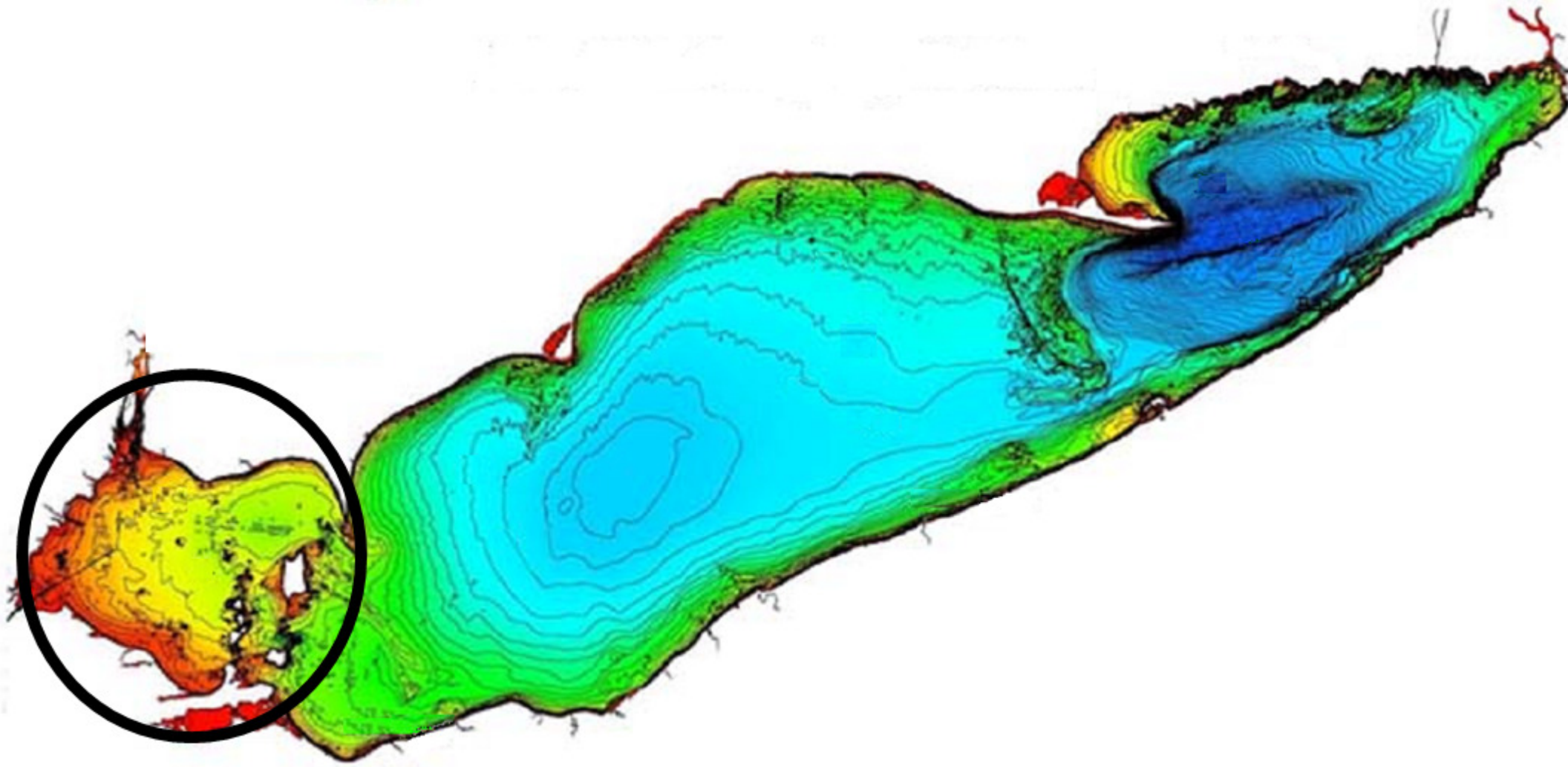
….in shallow water areas outside rivers and harbors.



Mayflies disappeared in many areas because of urban and industrial pollution associated primarily with World Wars I and II.

The Rouge River as it enters the Detroit River and western Lake Erie of the Great Lakes, circa 1950.

Our example today, is western Lake Erie where mayflies disappeared in the 1950s.

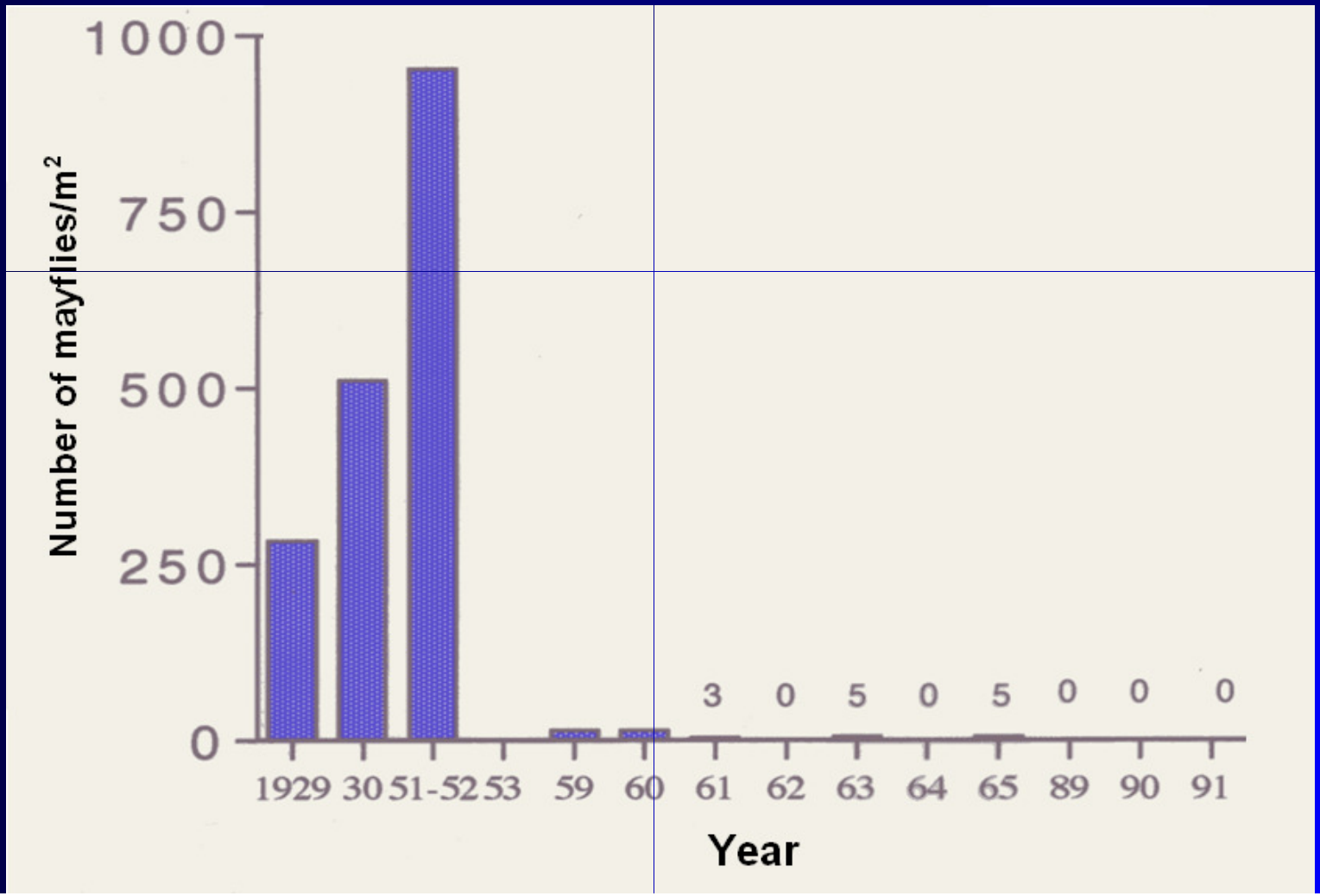


Phosphorus was the primary pollutant that led to the disappearance of mayflies because it caused excessive plant growth….

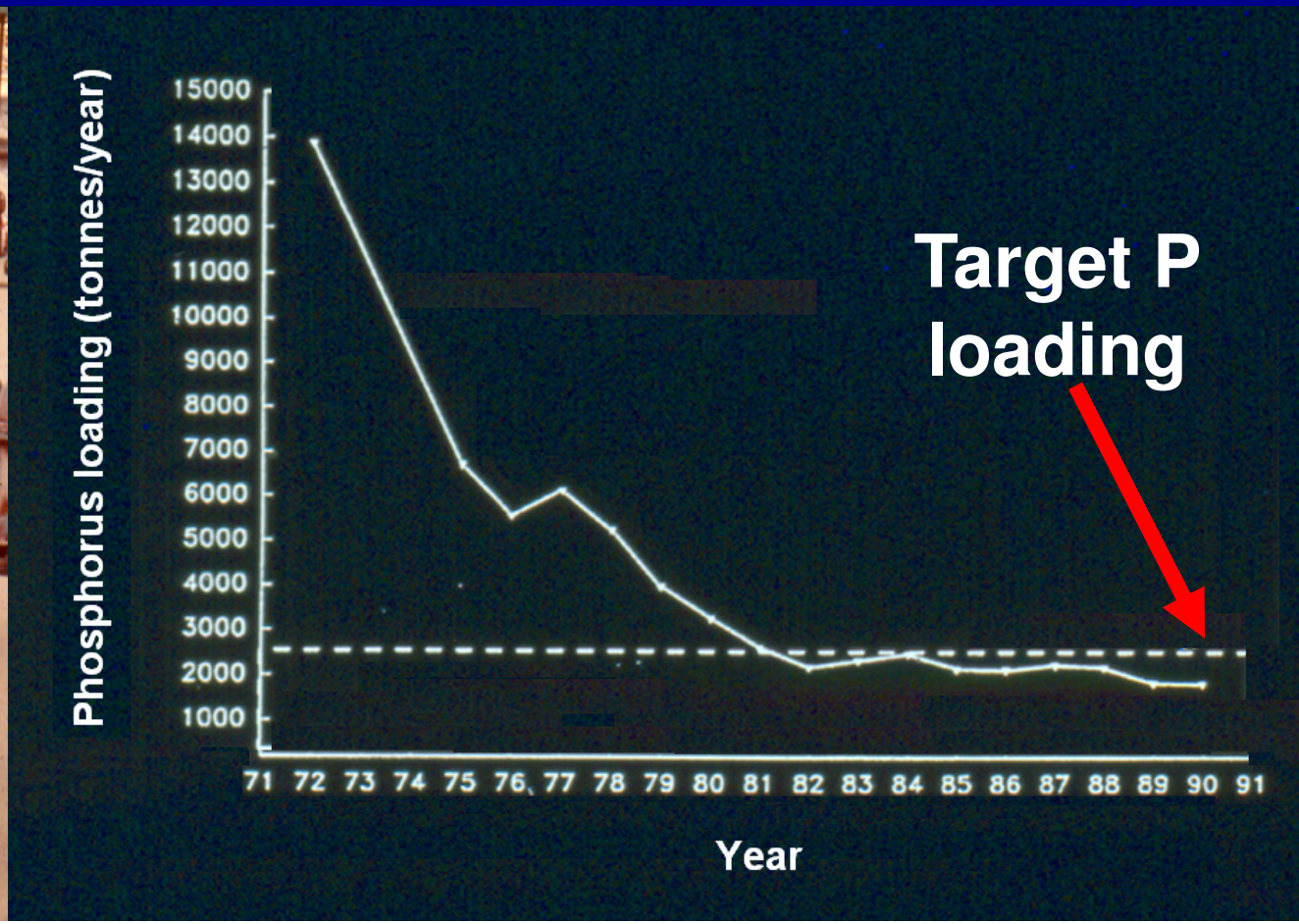
….which decomposed, used available oxygen, and killed aquatic life.

In the late-1950s, western Lake Erie was declared ‘dead’ by the national media.

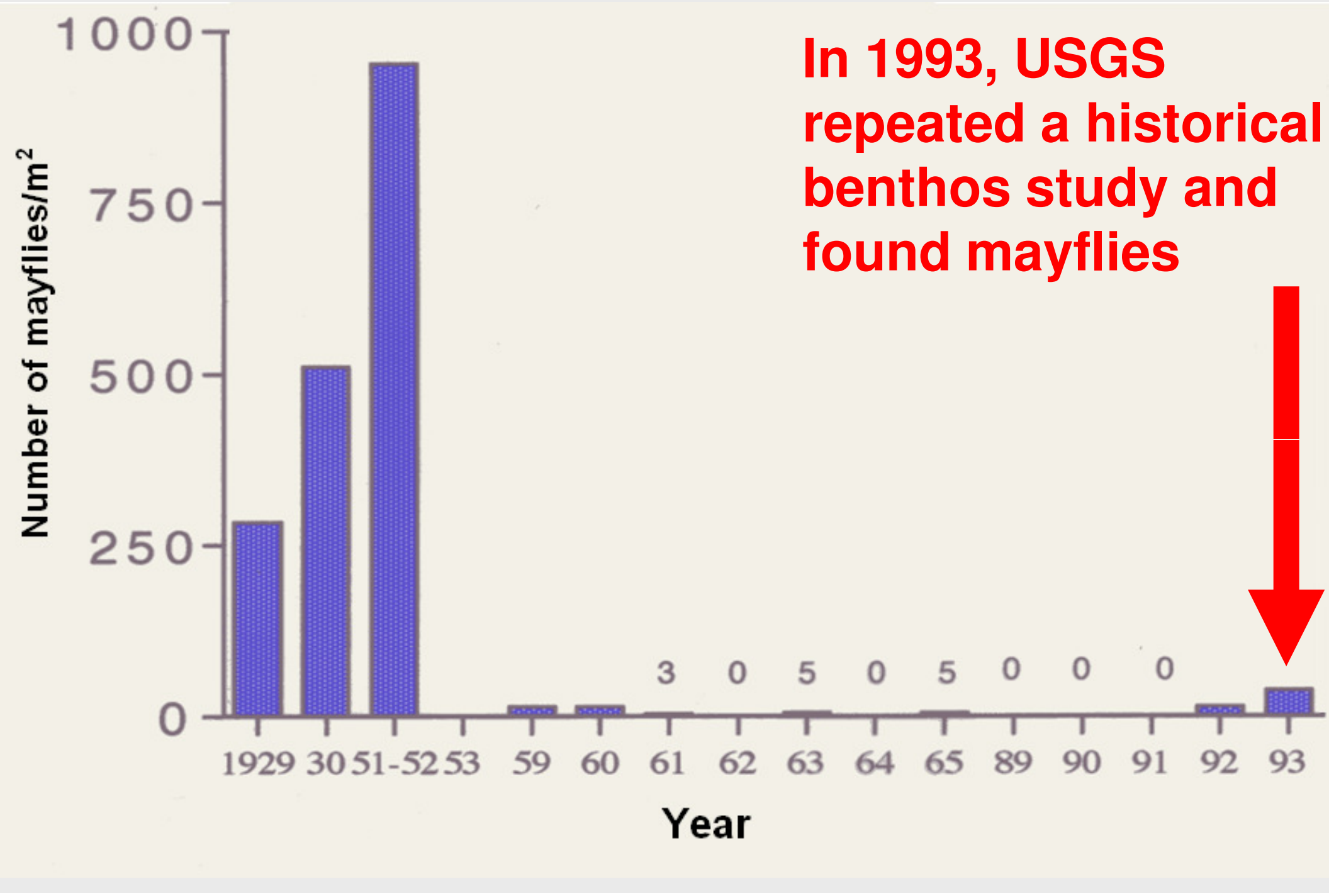
After a documented crash in abundance in 1951-52, mayflies were absent in western Lake Erie between 1953 and 1991.



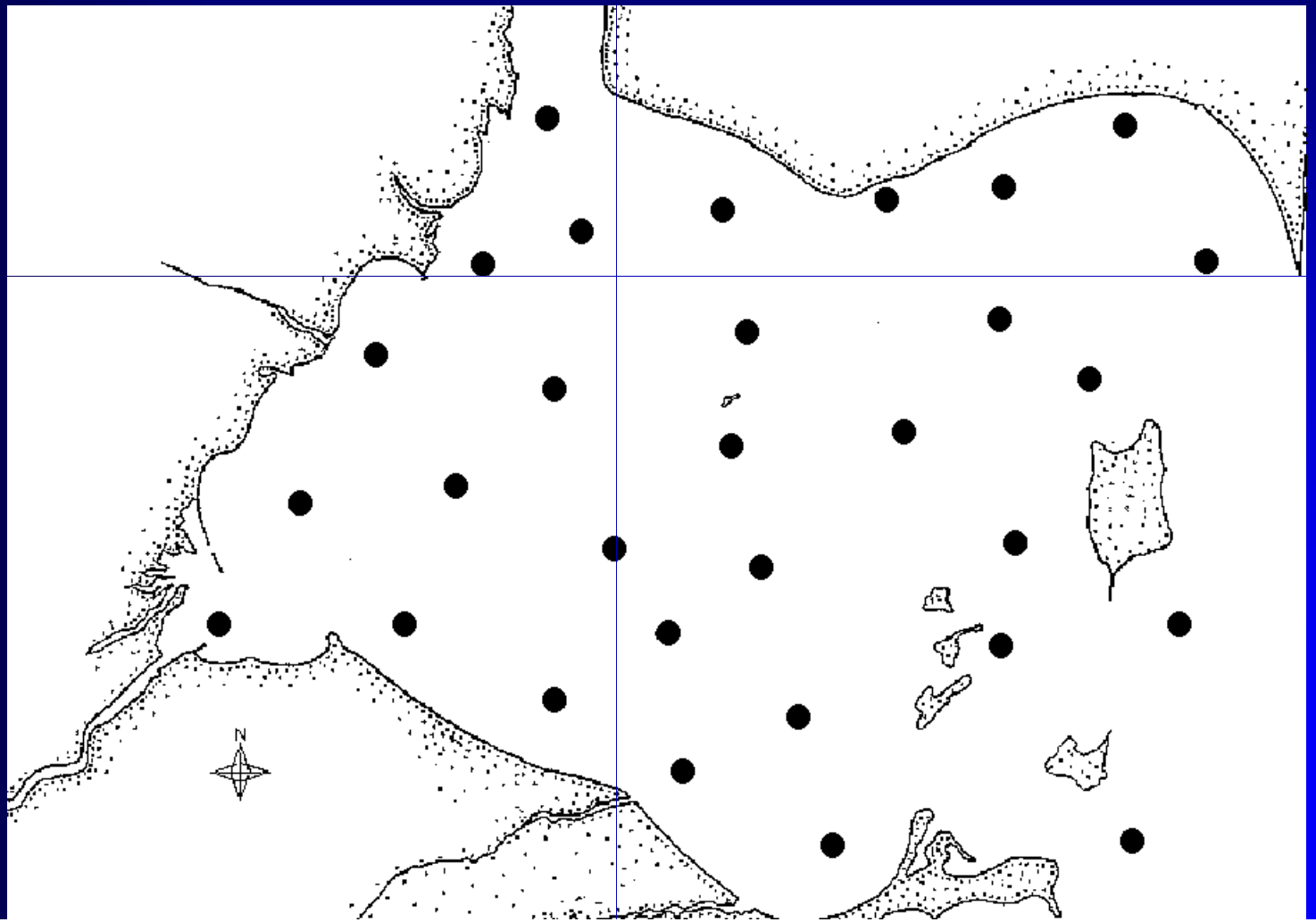
Pollution abatement began in the early-1970s. Nutrient addition models set a target loading for phosphorus of approximately 2500 tonnes/year.



In 1992, we found the first sign of mayfly restoration in Lake Erie-- mayflies on a Canadian ship in open waters.

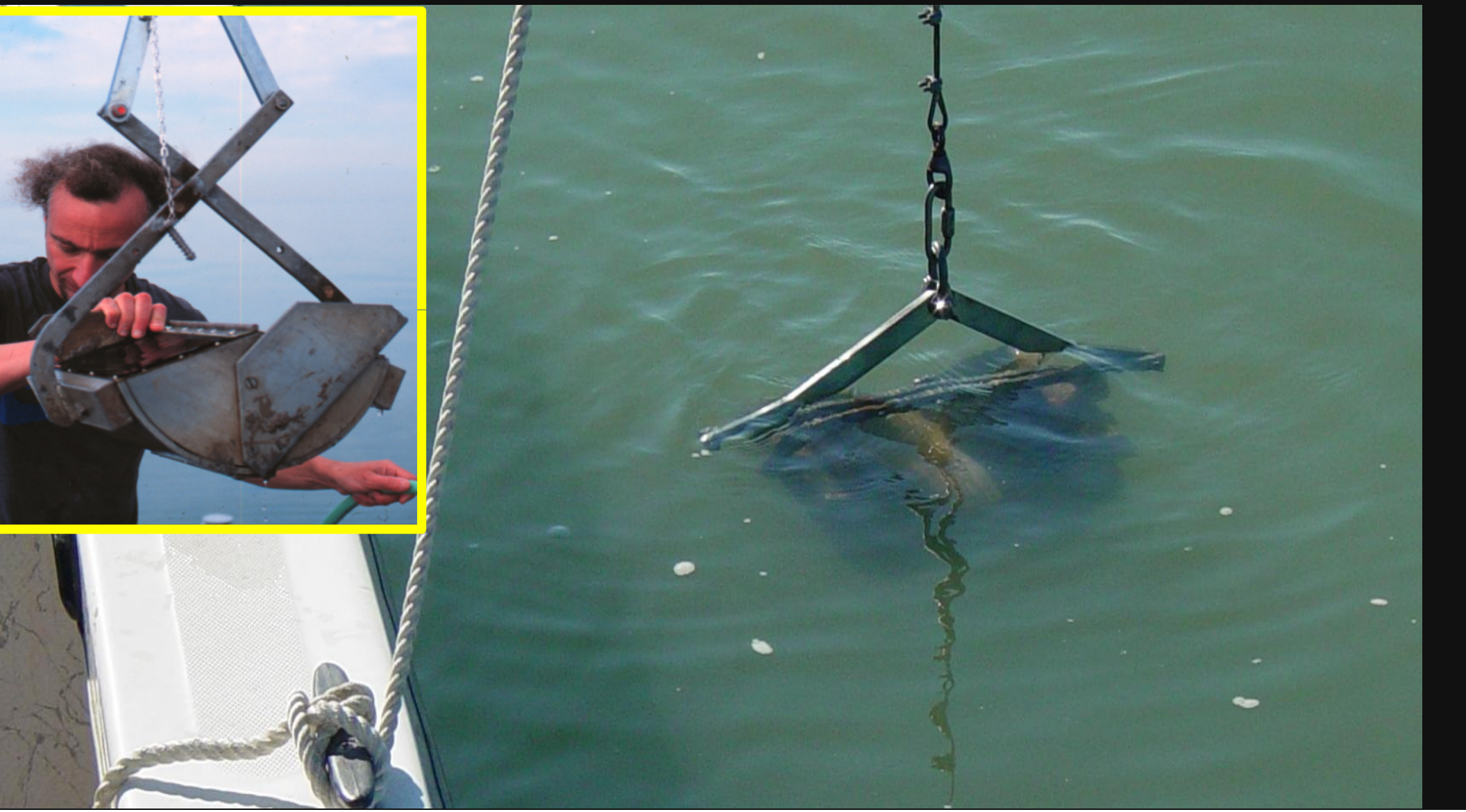

In 1993, USGS repeated a historical benthos study and found mayflies
Number of mayflies/m2
1000
750
500
250
0
3
0
5
0
5
0
0
0
1929
30
51-52
53
59
60
61
62
63
64
65
89
90
91
92
93
Year

Sporadic surveys for mayflies occurred between 1995 and 1999. USGS began systematic ‘surveys’ in 2000.

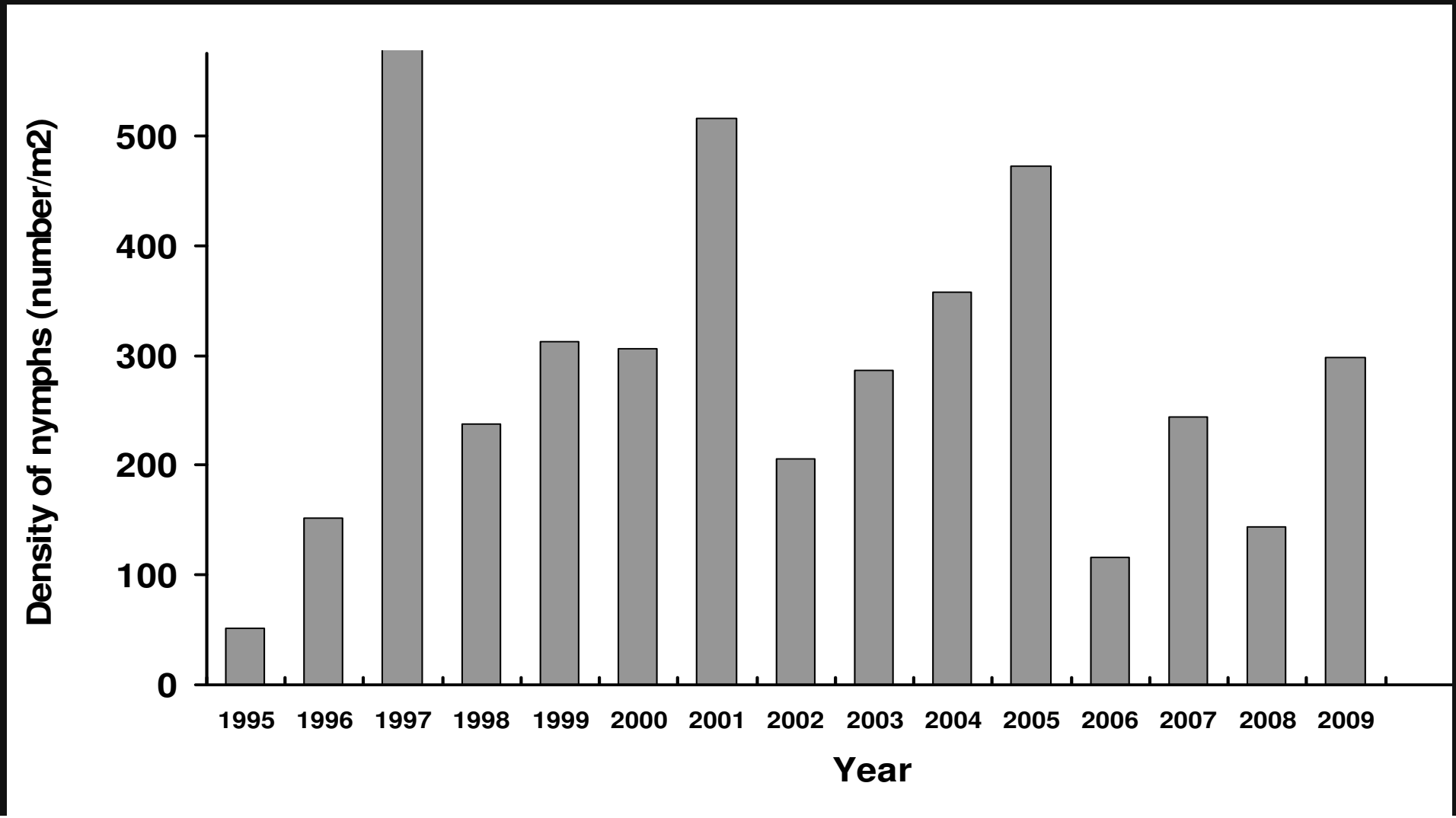


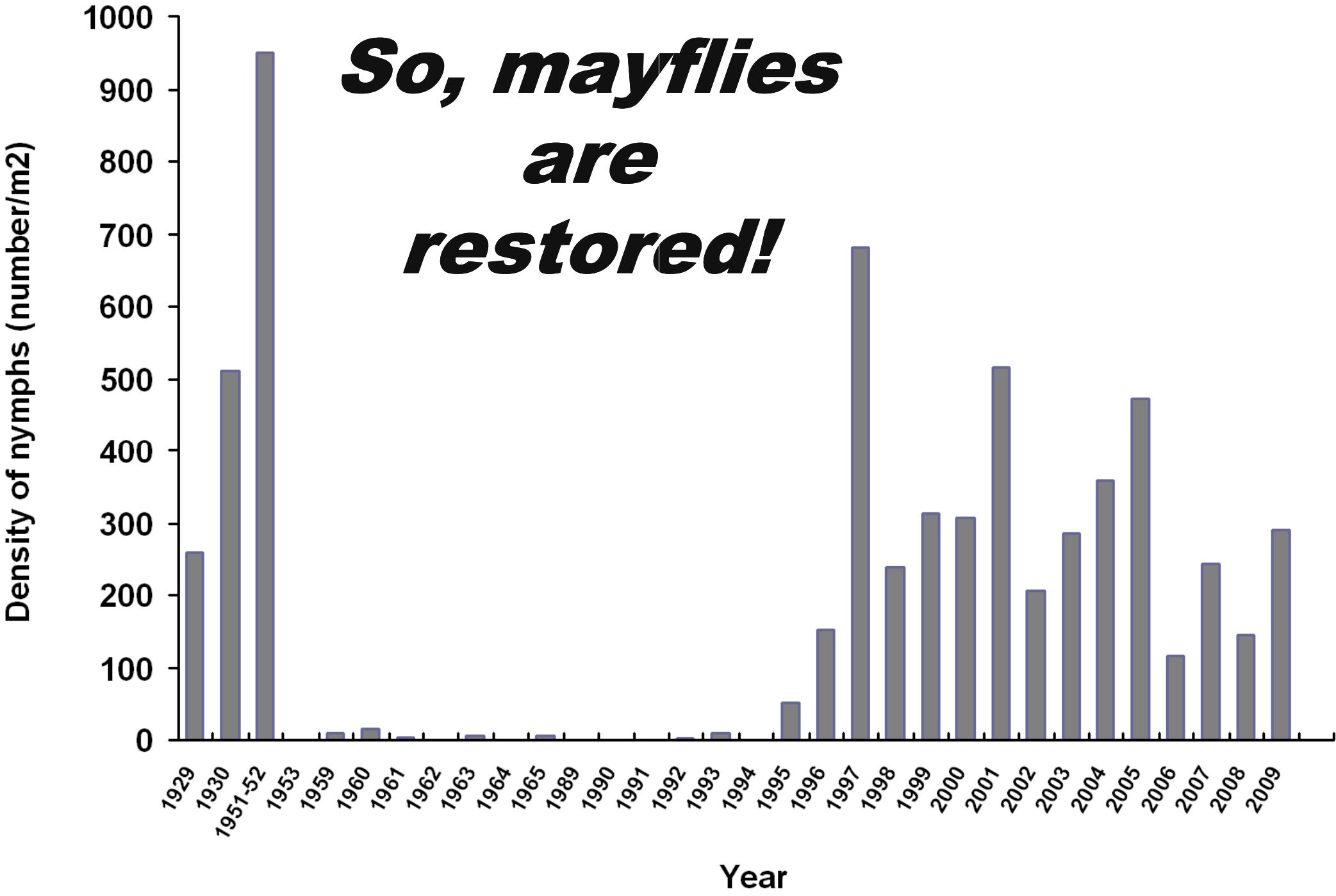
Surveys were conducted in early spring using small boats.

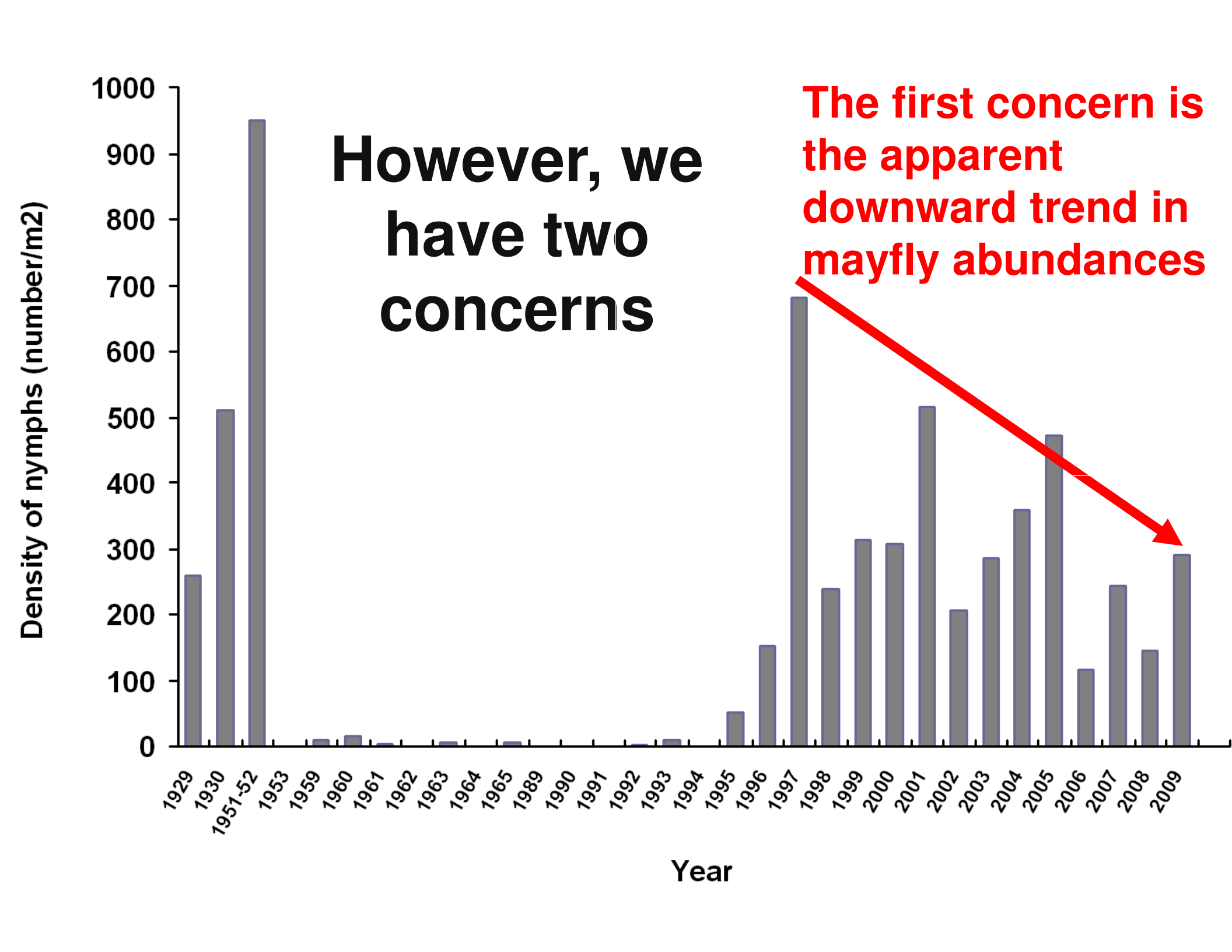
Mayflies were collected with a ‘standard’ Ponar dredge.

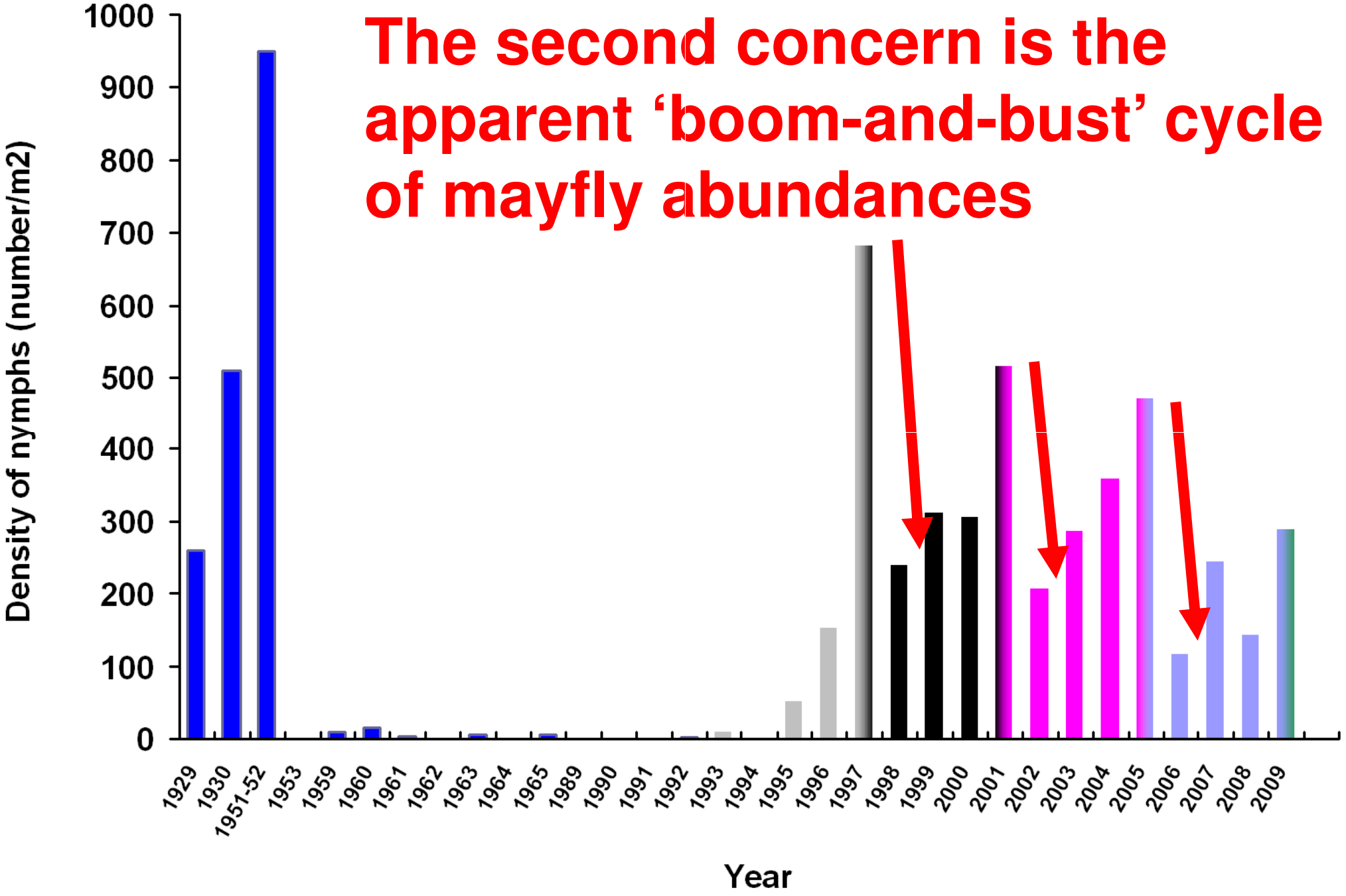


Results show mayflies were consistently found in western Lake Erie between 1995 and 2009.

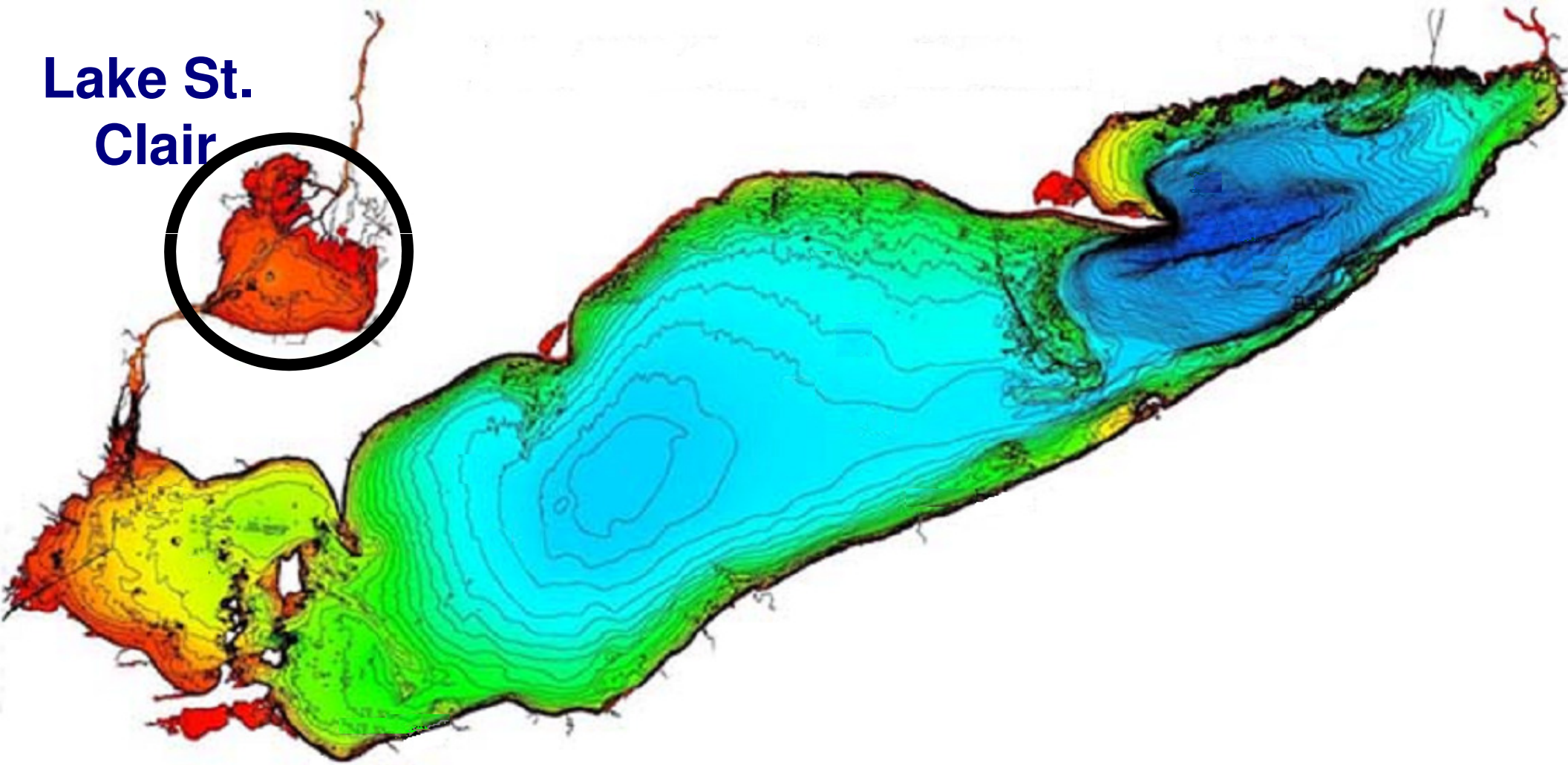



So, mayflies are restored!
Density of nymphs (number/m2)
1000
900
800
700
600
500
400
300
200
100
0
1929
1930
1951-52
1953
1959
1960
1961
1962
1963
1964
1965
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year


However, we have two concerns
The first concern is the apparent downward trend in mayfly abundances
Density of nymphs (number/m2)
1000
900
800
700
600
500
400
300
200
100
0
1929
1930
1951-52
1953
1959
1960
1961
1962
1963
1964
1965
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

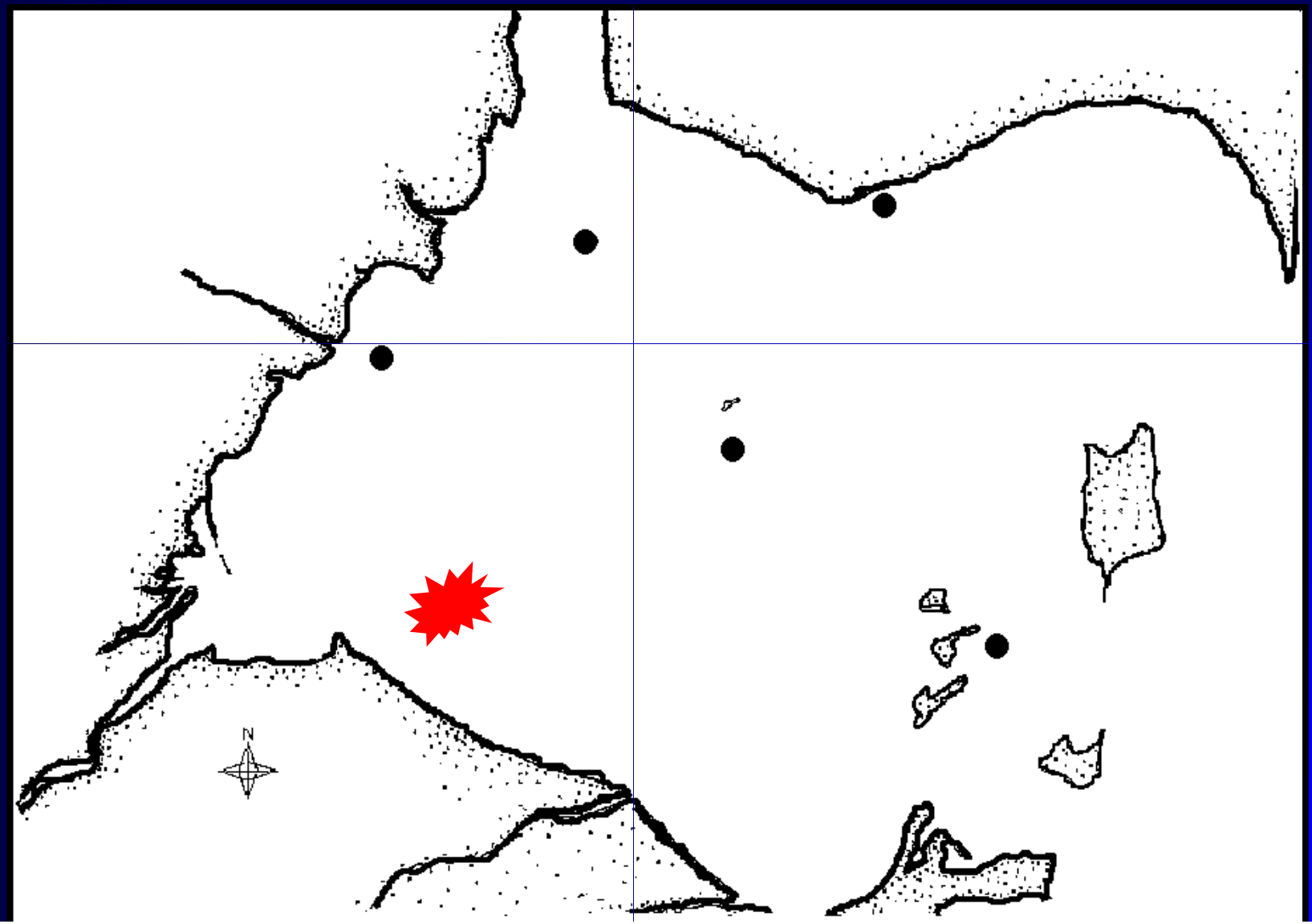

The second concern is the apparent 'boom-and-bust' cycle of mayfly abundances
Density of nymphs (number/m2)
1000
900
800
700
600
500
400
300
200
100
0
1929
1930
1951-52
1953
1959
1960
1961
1962
1963
1964
1965
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

We do not believe the boom-and-bust cycle in mayfly abundances is 'normal.' It does not occur in Lake St. Clair located upstream.



Field and Modeling Studies of Mayfly Abundance Crashes

We monitored mayflies at one site to look at specifics of mayfly abundance ‘crashes.’



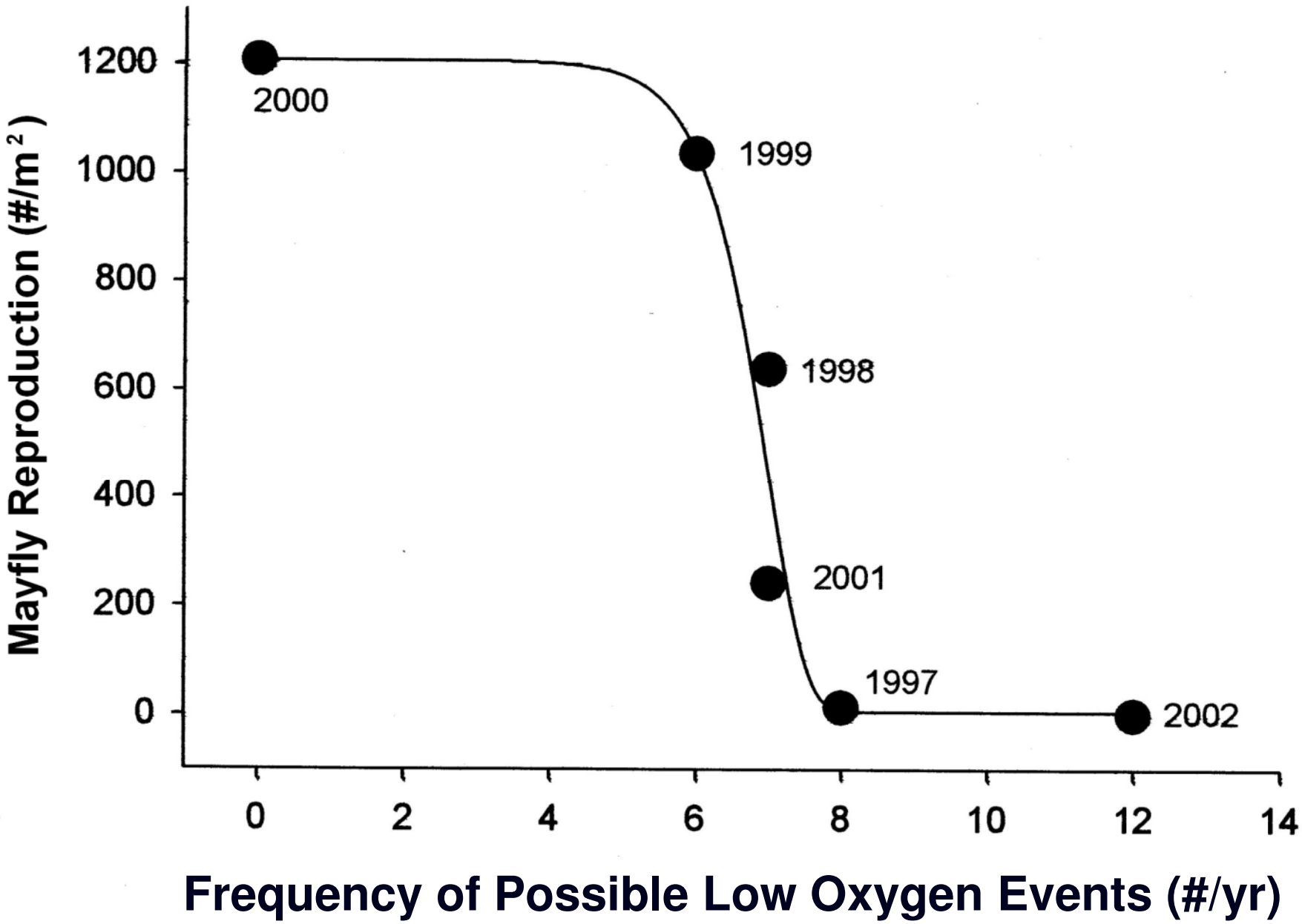
We found failed mayfly reproduction caused the ‘crashes’ in abundance.

2001 — **YOY**

Length (mm)	April	May	June	July	August	September	October
1							
2						73	
3		10				323	139
4	22	63				365	334
5	44	63	14			271	389
6	88	31	42			104	70
7	77	73	42	7		42	56
8	132	115	49	7		31	14
9	132	115	84	28			14
10	77	42	56	28			14
11	66	52	70	34			
12	77	94	98	83	13		
13	77	73	70	76	0		
14	55	63	91	76	20	10	14
15	44	21	56	110	34	10	14
16	55	42	84	89	101	10	28
17	11	21	42	48	81	63	42
18	11	21	35	48	94	83	70
19	11	31	35	7	94	73	70
20			7	7	54	21	70
21			7	7	47	31	14
22	11	21			13	52	70
23	33	42	7		13	10	28
24	11	21				21	14
25	0	0					
26	0	10					
27	11	0					
28		31				10	
29		10					
30		10					

2002 — **No YOY**

Length (mm)	May	June	July	August	September	October
1						
2						
3						
4	21					
5	72	41				
6	186	51	10			
7	238	102				
8	279	102				
9	197	174	10	7		
10	228	143	41			
11	155	82	20	7		
12	155	102	82	14	7	
13	134	113	123	49	14	14
14	52	164	184	62	28	7
15	72	133	174	90	56	21
16	31	72	154	83	49	35
17	52	41	133	146	83	35
18	31	41	82	132	104	70
19	31	41	51	132	97	126
20	10	20	41	62	49	70
21	72	10		42	97	56
22		10	10	42	83	112
23				49	56	91
24	10			14	21	56
25	31			7	21	14
26	10					14
27	21	20			7	14
28	10	10				
29					7	
30						


Mayfly Reproduction (#/m²)
1200
1000
800
600
400
200
0
2000
1999
1998
2001
1997
2002
0
2
4
6
8
10
12
14
Frequency of Possible Low Oxygen Events (#/yr)

These field and modeling studies indicate low oxygen limits mayfly restoration in western Lake Erie.

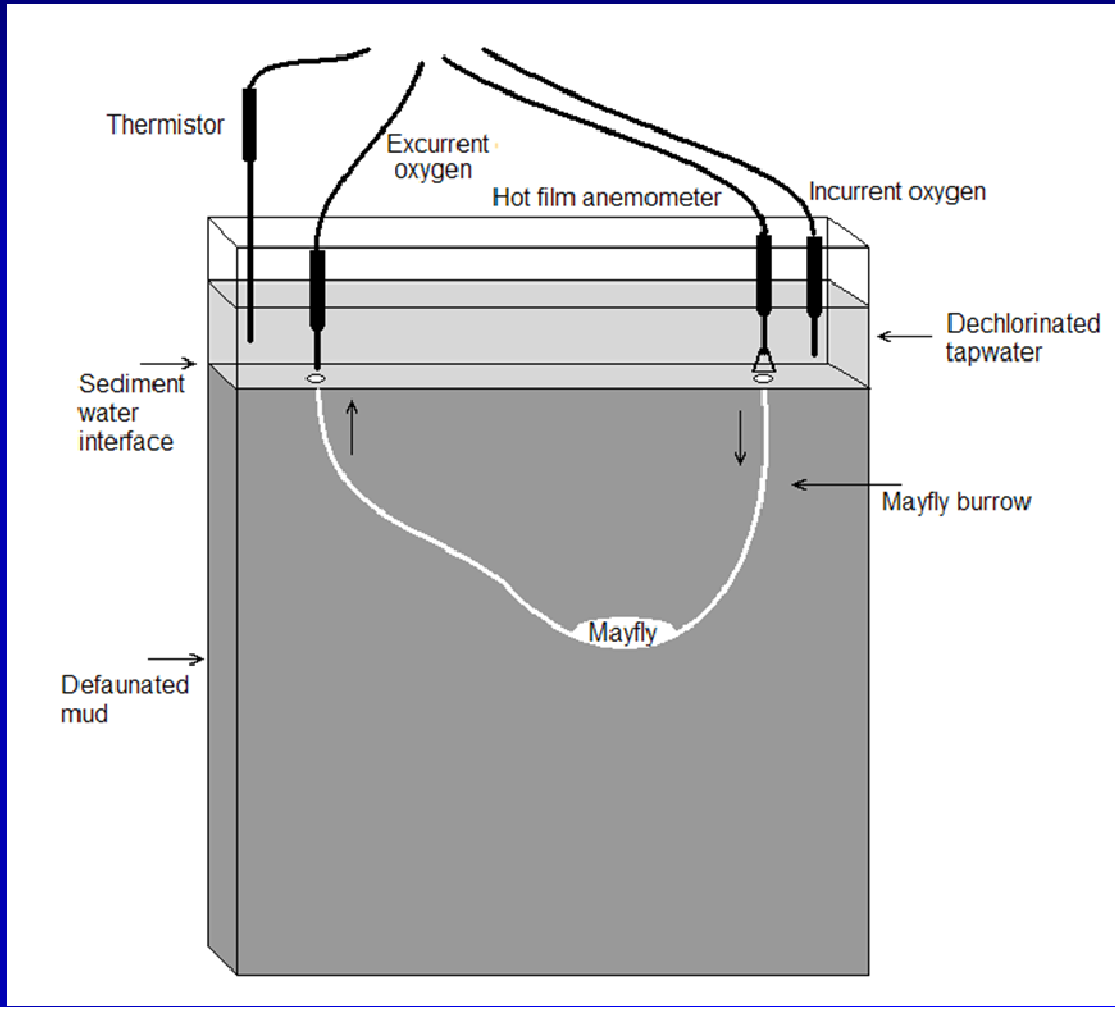
So, what is causing low dissolved oxygen?

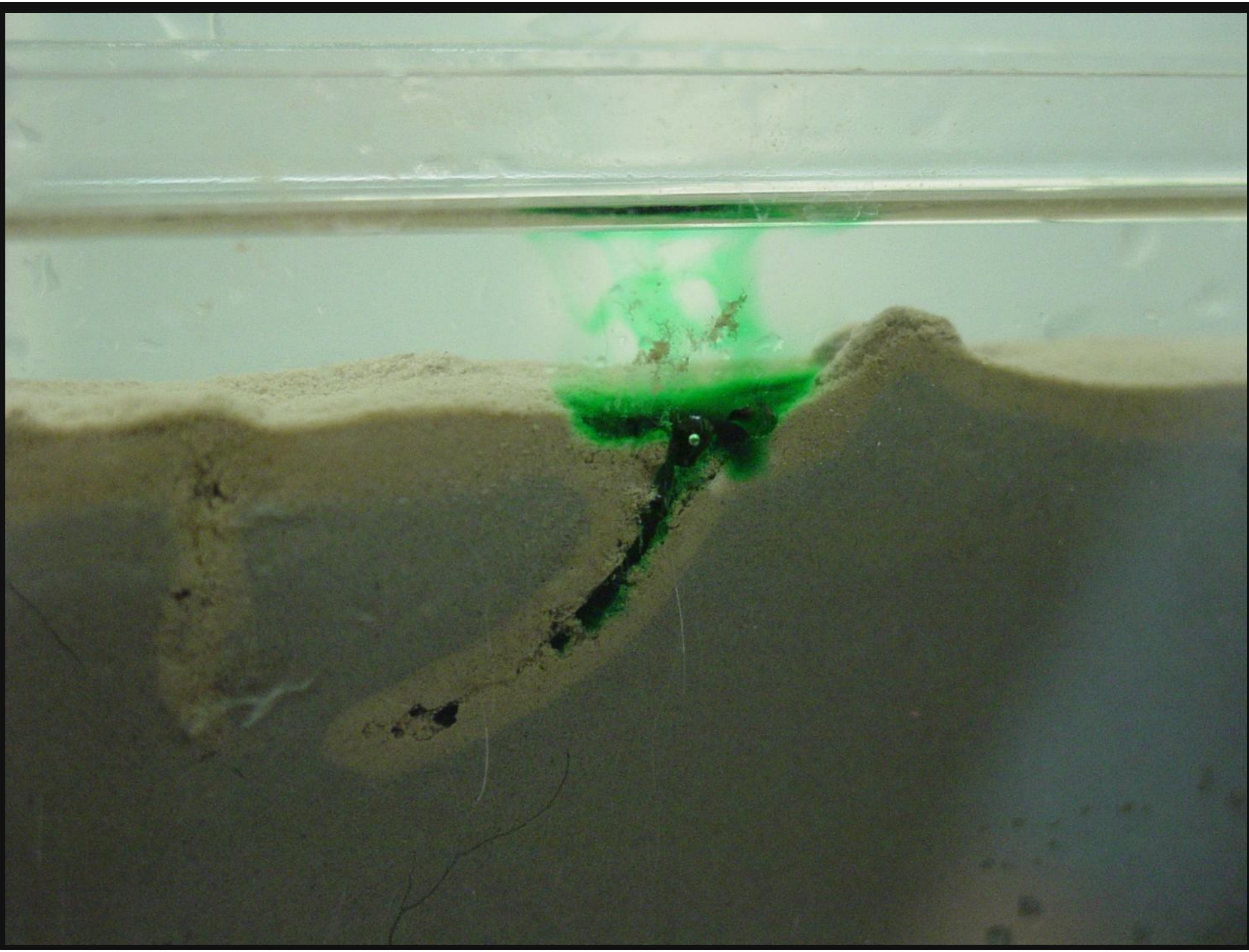
- **-- residual or increasing pollution?**
- **-- self-regulation by mayflies?**
- **-- competition for oxygen with other benthos and bacteria?**

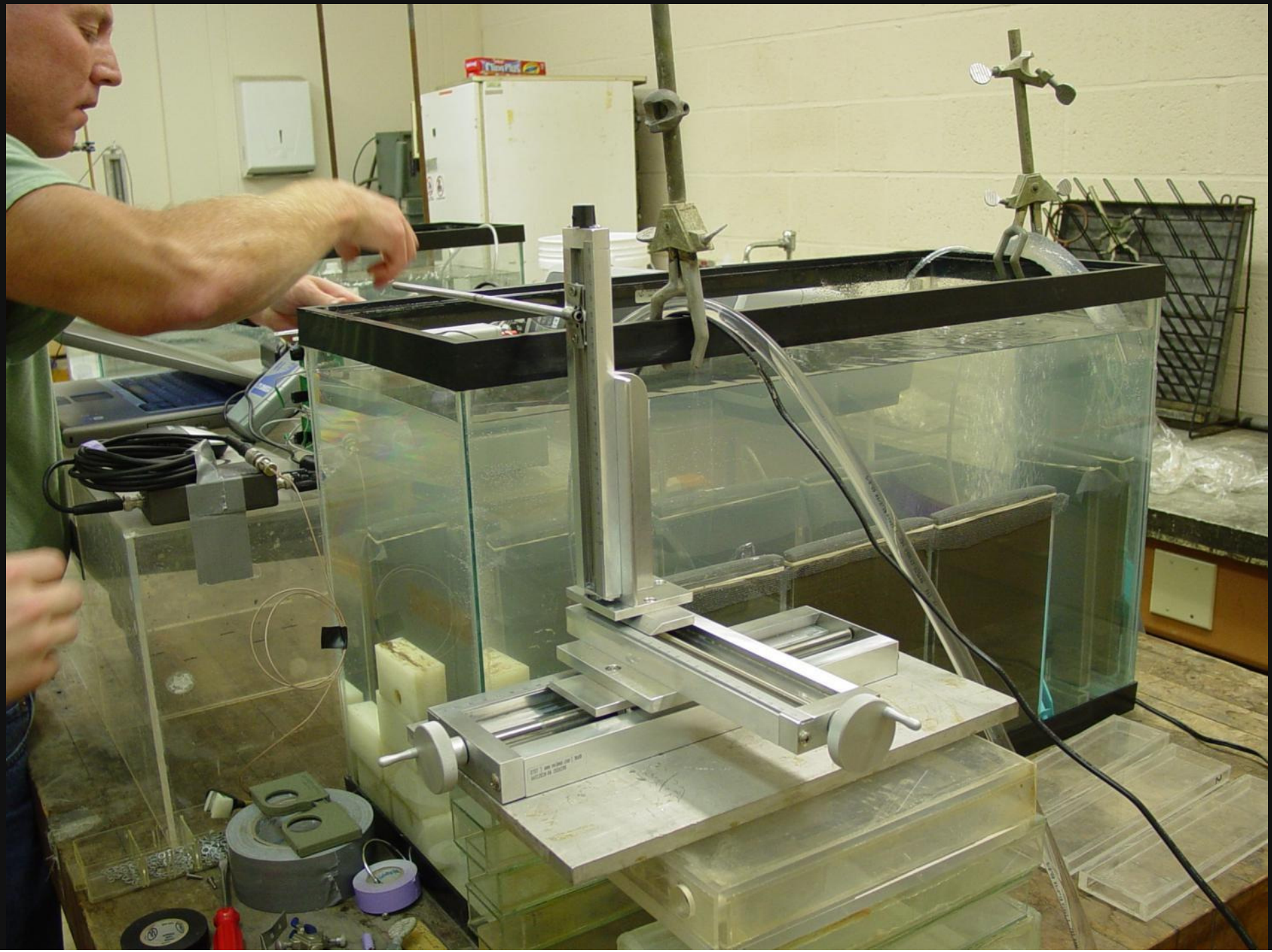
Laboratory, Field, and Modeling Studies Of Mayfly Self-regulation

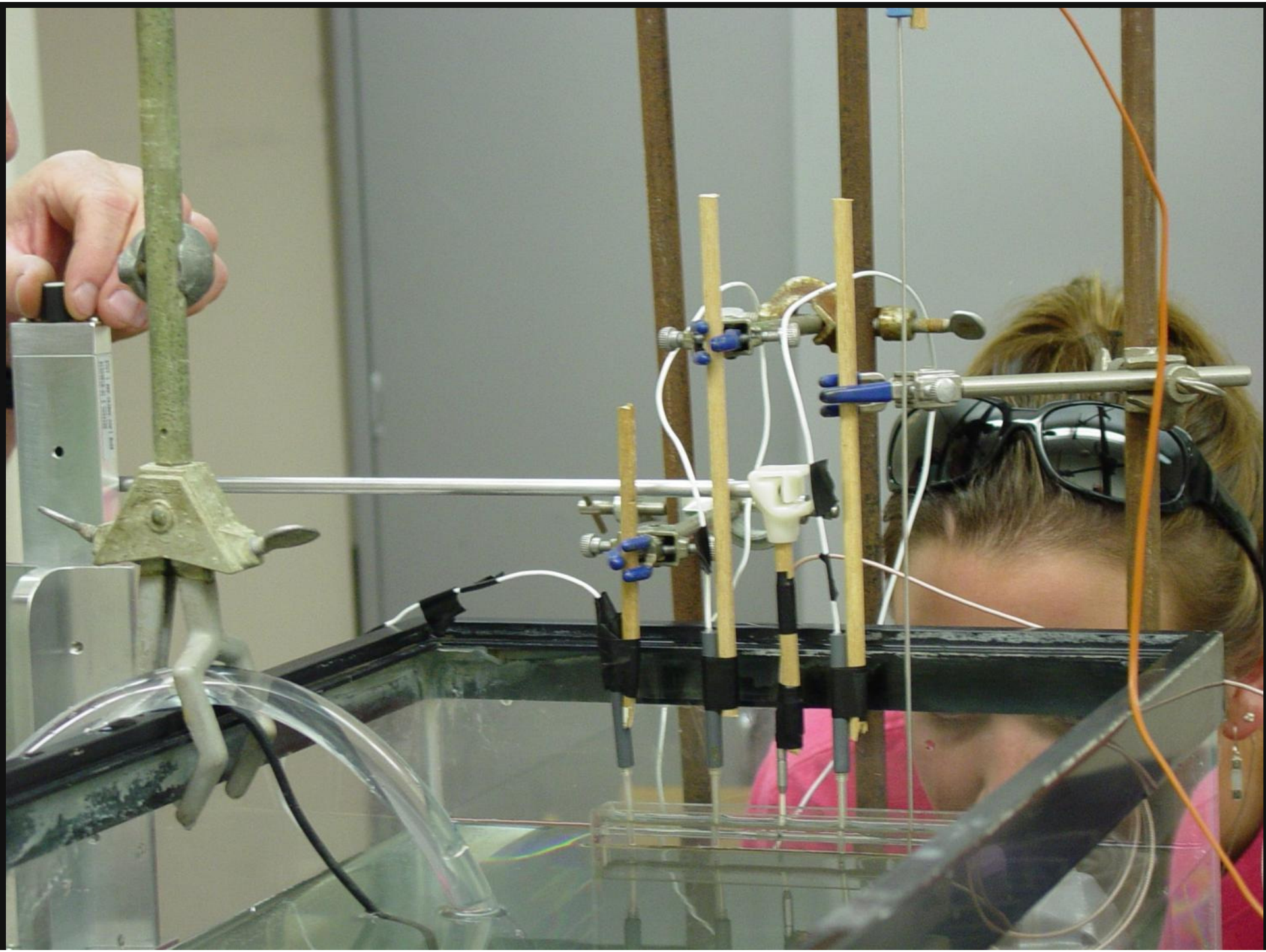
Laboratory studies are only beginning.

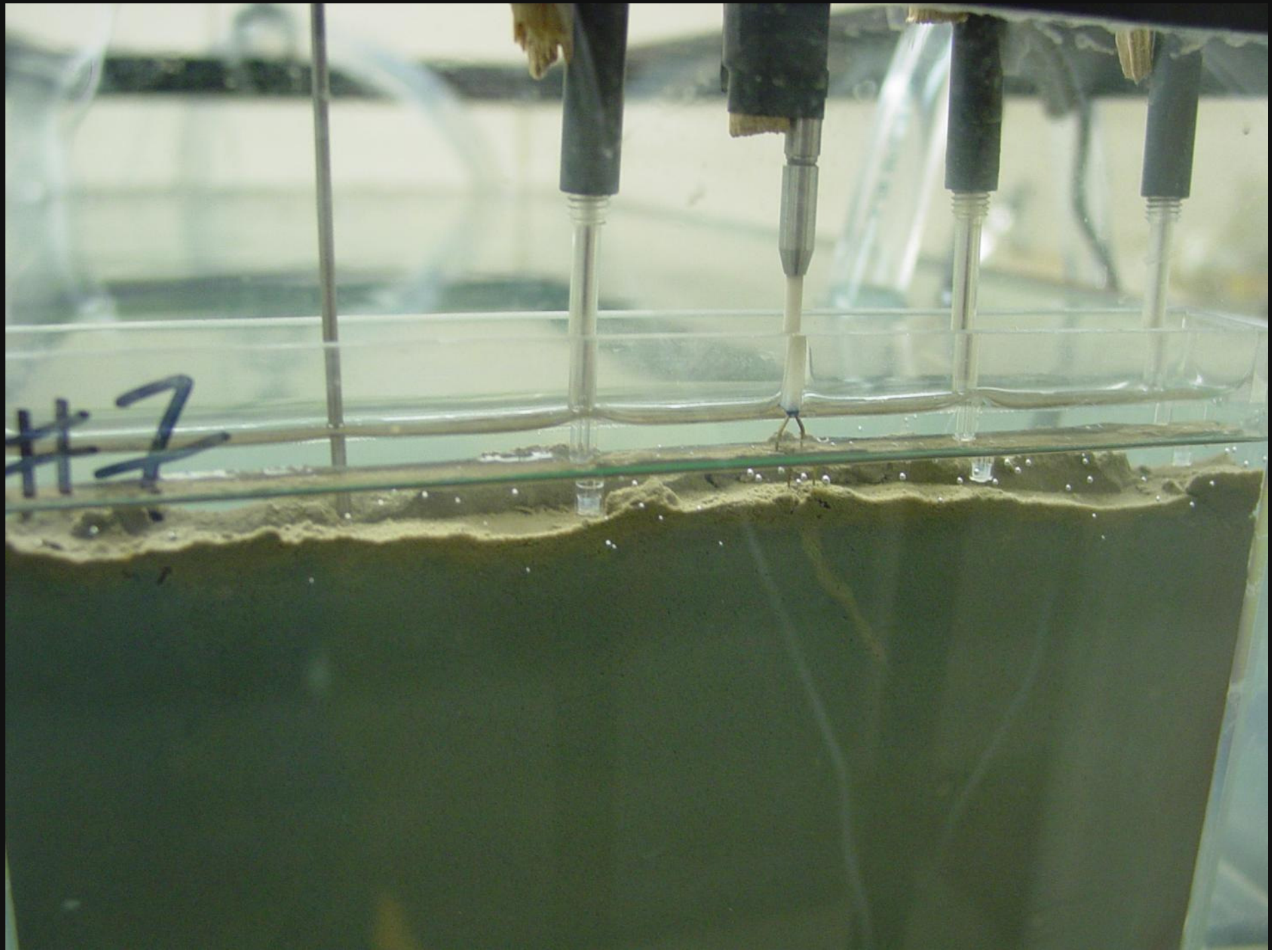
- DePauw University, Greencastle, IN
- Niagara University, Niagara, NY
- Case Western Reserve University, Cleveland, OH

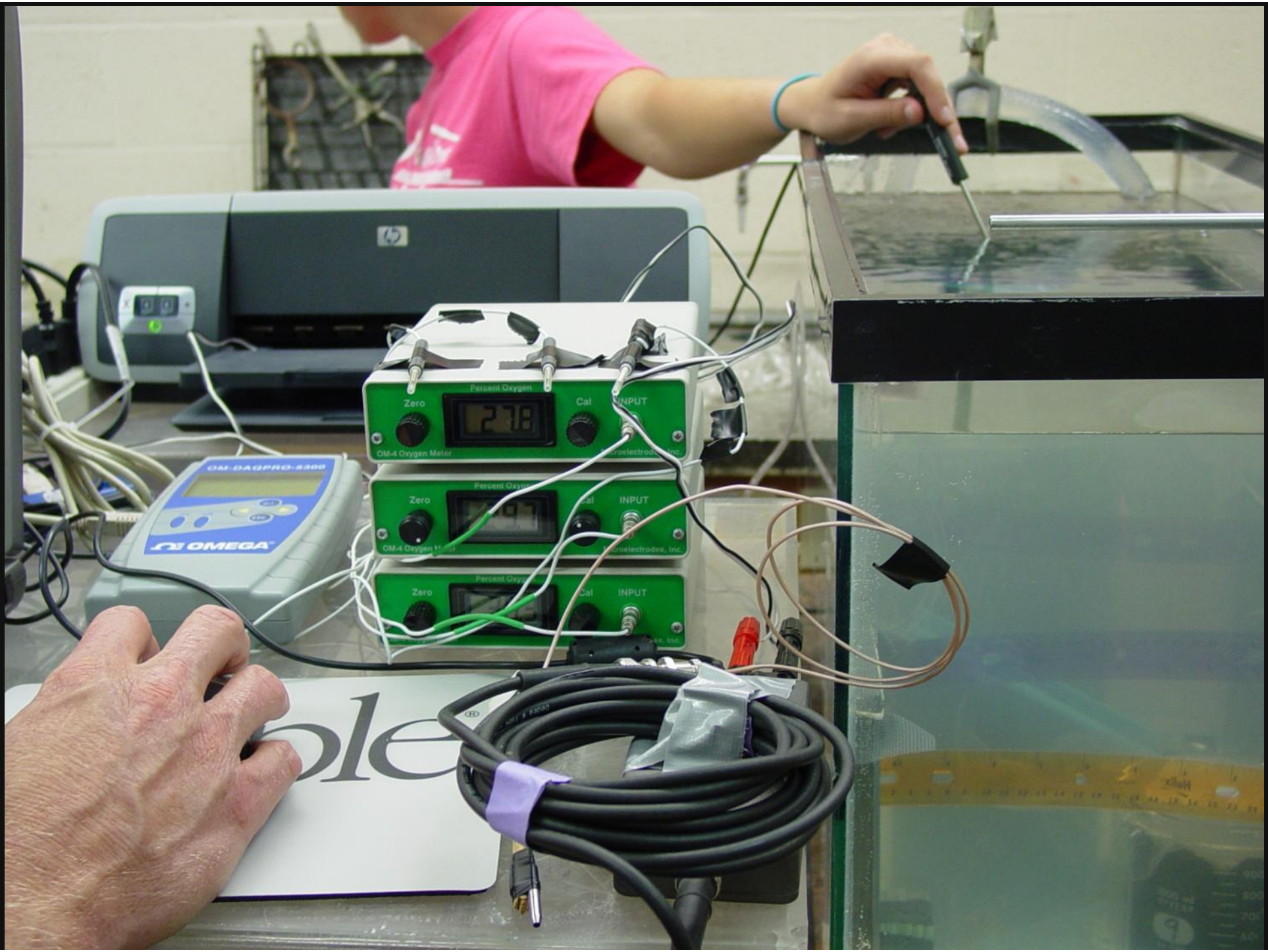


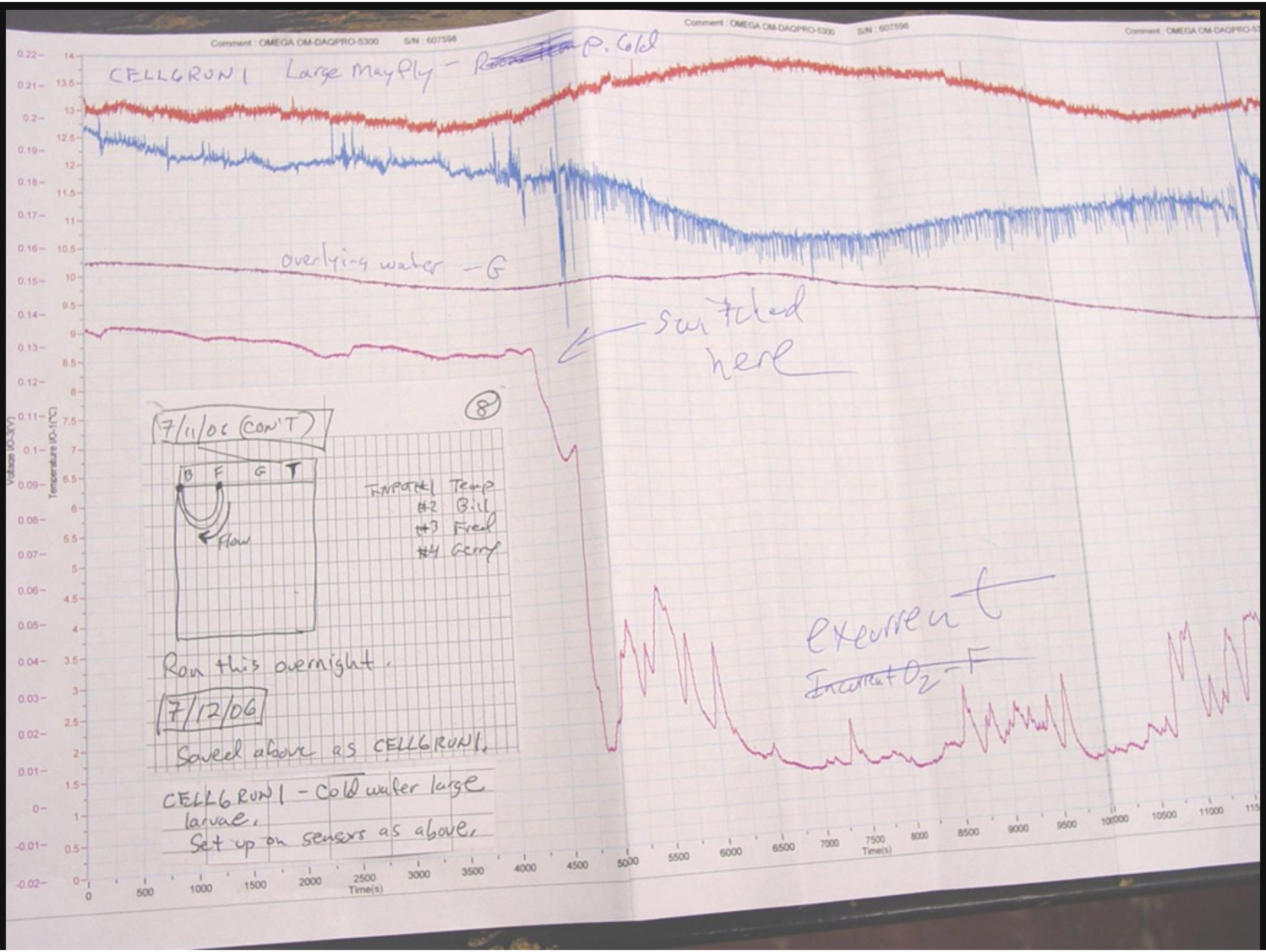




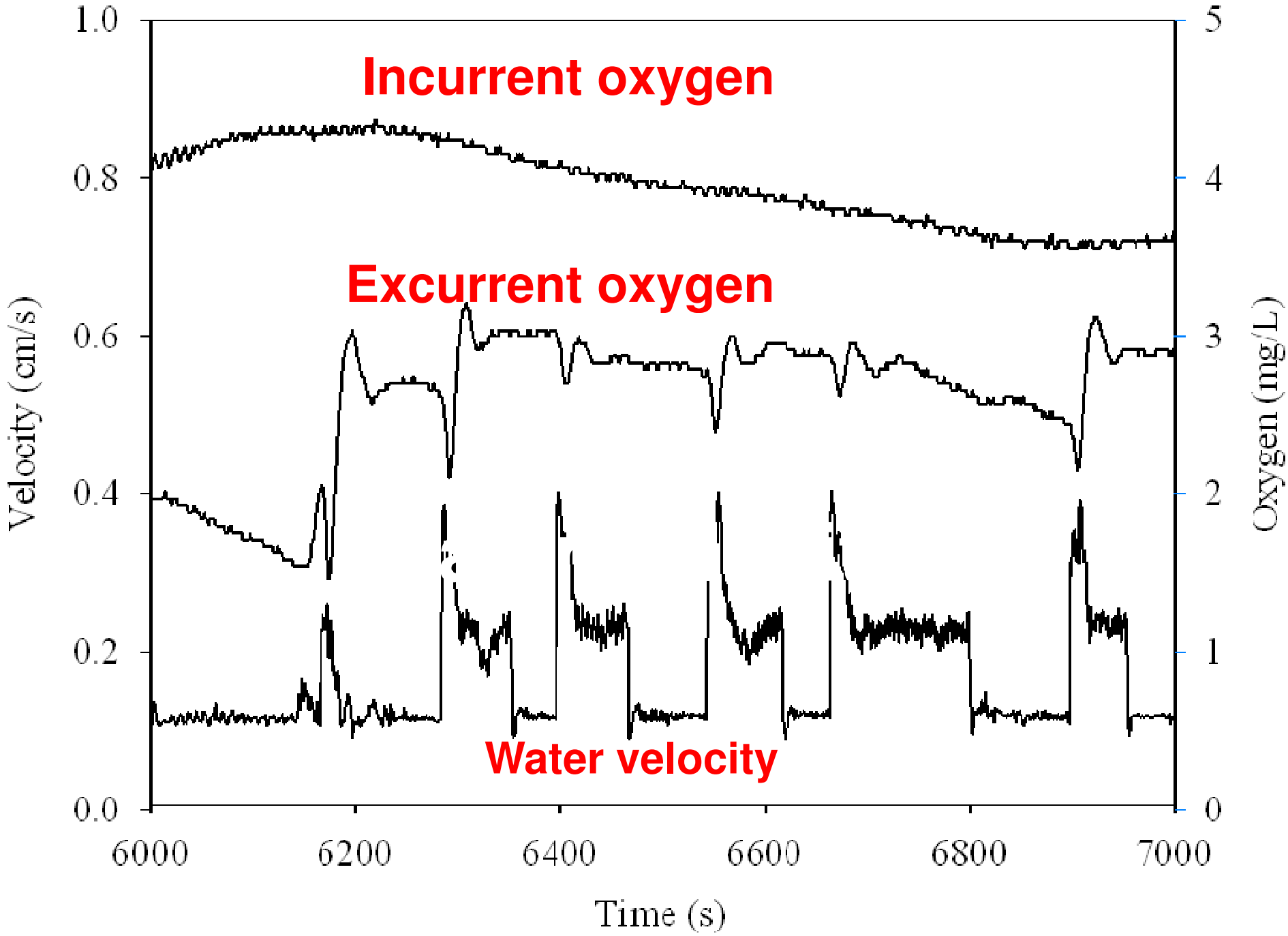


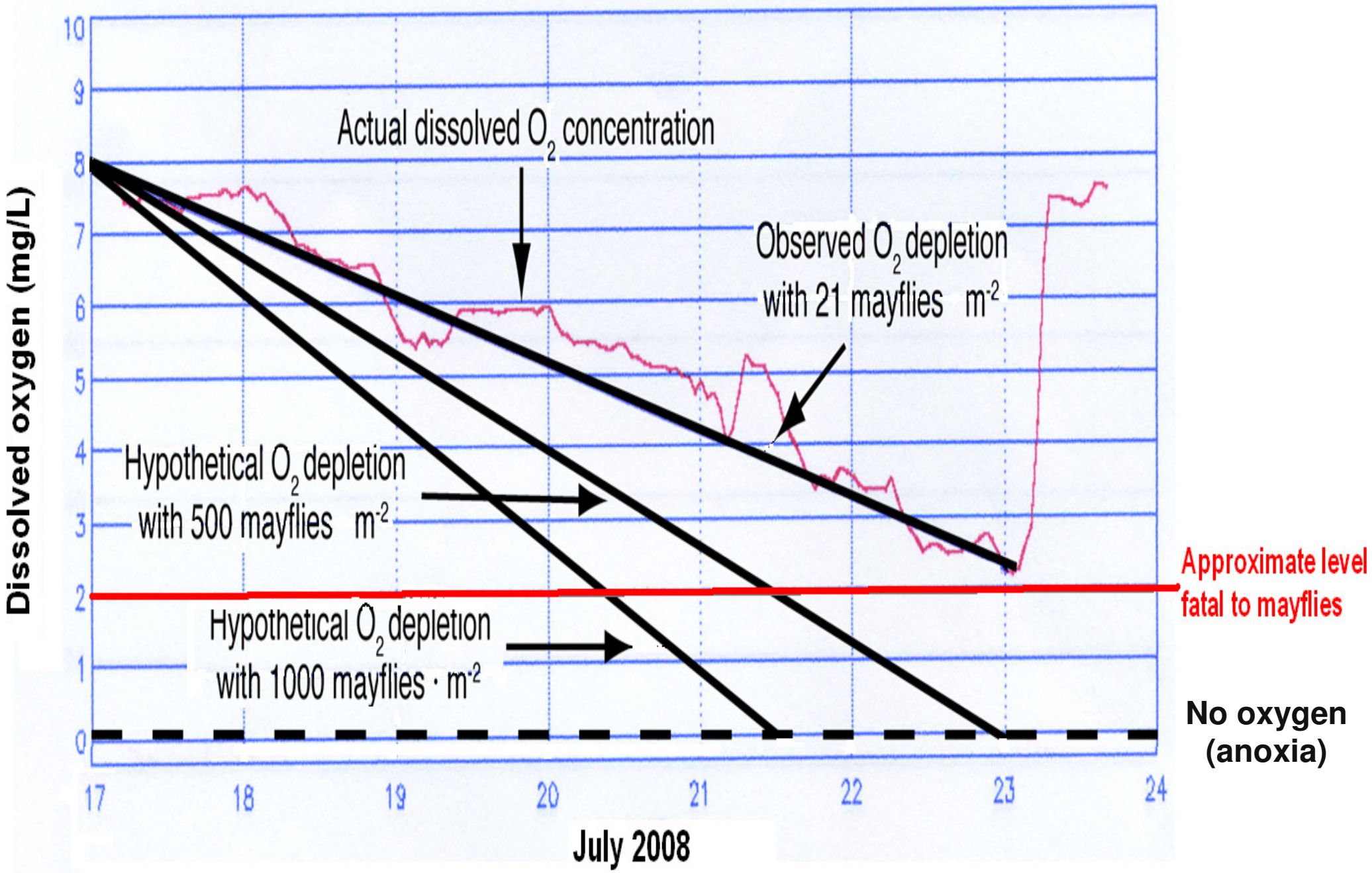

#7


Percent Oxygen
Zero
Cal
INPUT
OM-4 Oxygen Meter
OMEGA


Comment : OMEGA OM-DAQPRO-5300 S/N : 607598
CELL6RUN1 Large Mayfly – ~~Room Temp~~ C. Cold
overlying water – G
switched here
experiment
~~Incurrent O2 – F~~
Voltage I/O-3(V)
Temperature I/O-1(°C)
Time(s)
7/11/06 (CON'T)
8
B F G T
Flow
THERMAL Temp
#2 Bill
#3 Fred
#4 Gerry
Run this overnight.
7/12/06
Saved above as CELL6RUN1.
CELL6RUN1 – Cold water large larvae.
Set up on sensors as above.


THE ATMOSPHERE


Incurrent oxygen
Excurrent oxygen
Water velocity
Velocity (cm/s)
Oxygen (mg/L)
Time (s)
1.0
0.8
0.6
0.4
0.2
0.0
5
4
3
2
1
0
6000
6200
6400
6600
6800
7000


Dissolved oxygen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
17
18
19
20
21
22
23
24
July 2008
Actual dissolved O_2 concentration
Observed O_2 depletion with 21 mayflies m^{-2}
Hypothetical O_2 depletion with 500 mayflies m^{-2}
Hypothetical O_2 depletion with 1000 mayflies · m^{-2}
Approximate level fatal to mayflies
No oxygen (anoxia)

In summary, we believe that in western Lake Erie...

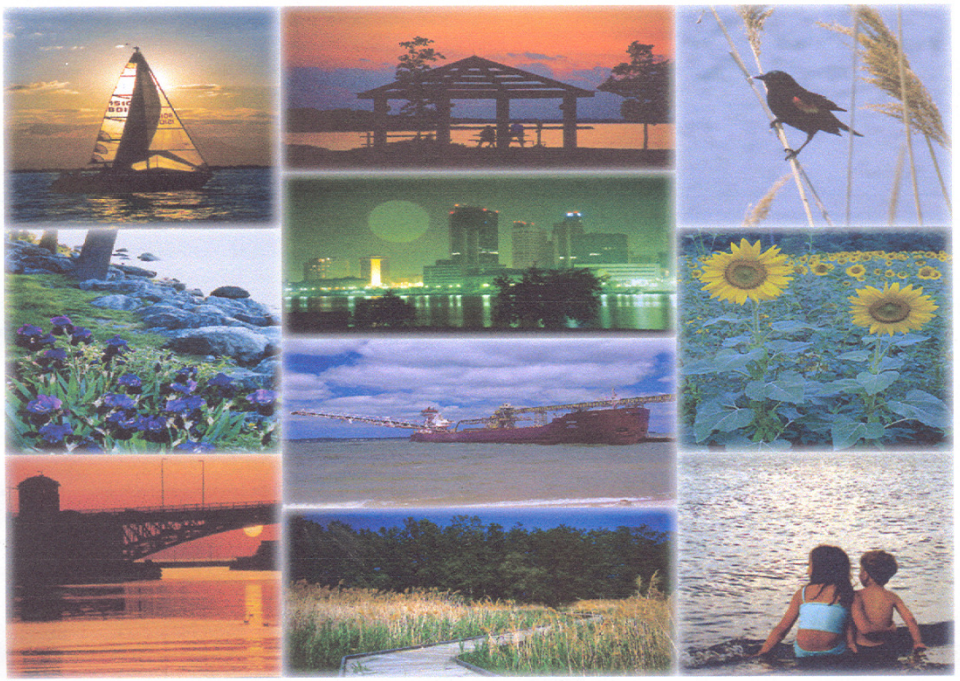
- the return of mayflies is good news! Restoration is happening!,

- stability of mayfly populations is being negatively affected by low dissolved oxygen,

- at high densities, respiration by mayflies contributes to low oxygen which supports the hypothesis of 'self-regulation.'

So, how is mayfly abundance data being used?

Management agencies are setting target goals for lake-wide restoration plans.

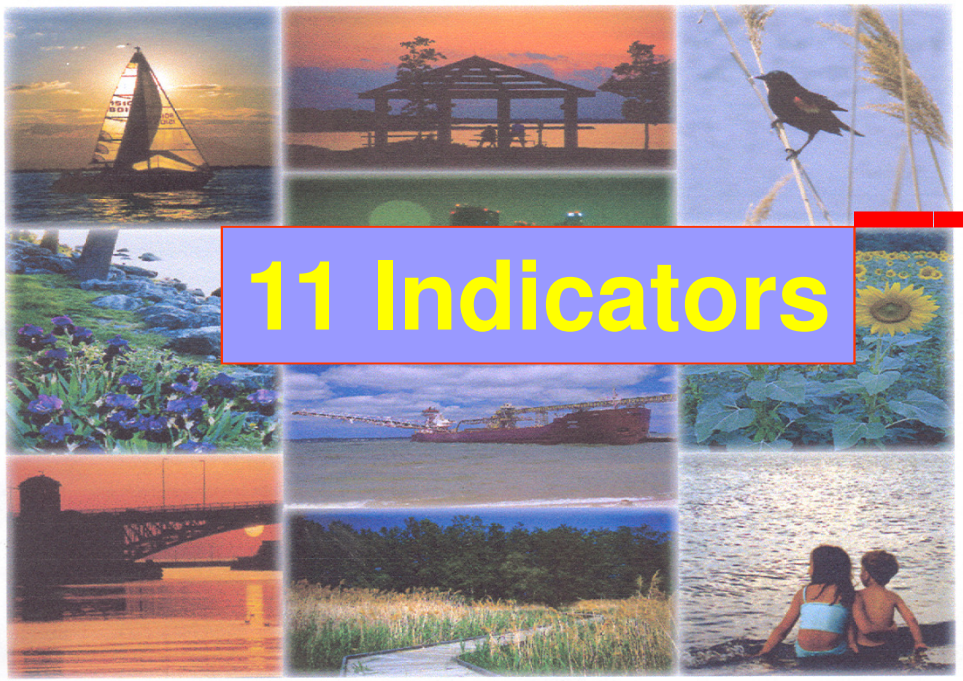


State of the Lake Report

2004

Lake Erie Quality Index

Ohio Lake Erie Commission



State of the Lake Report

2004

Lake Erie Quality Index

Ohio Lake Erie Commission

Biological Indicator

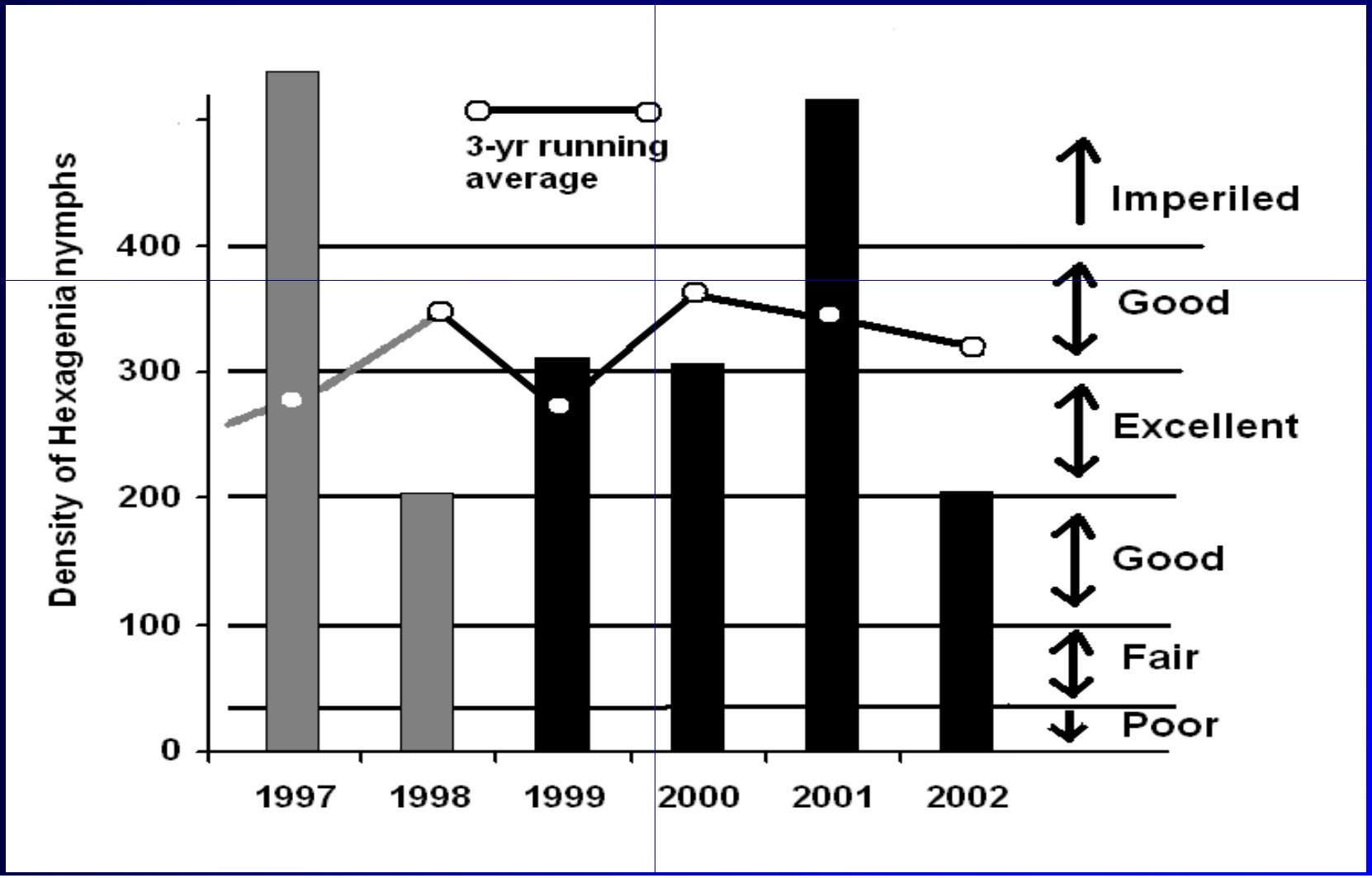
↓

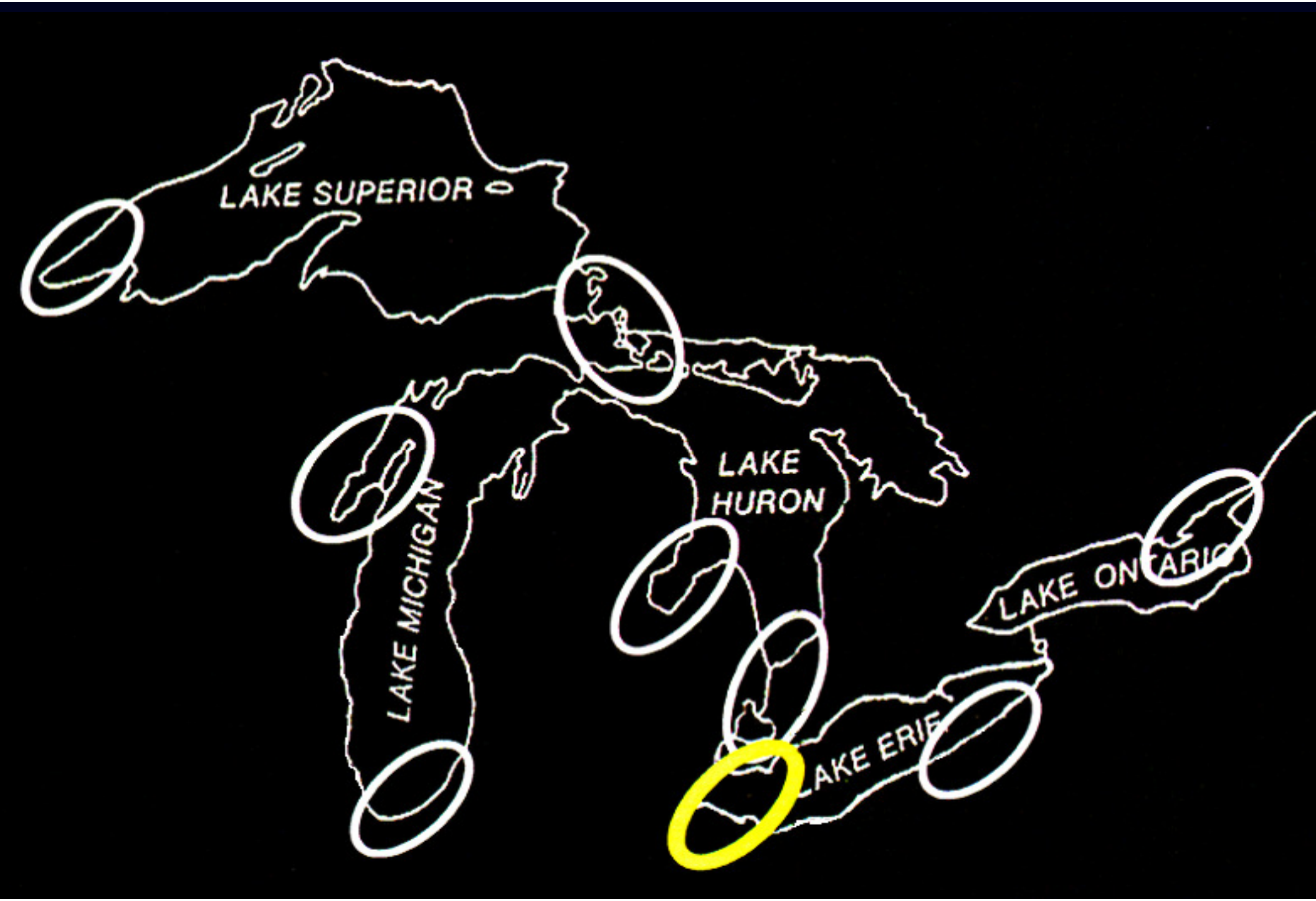
Key Metrics

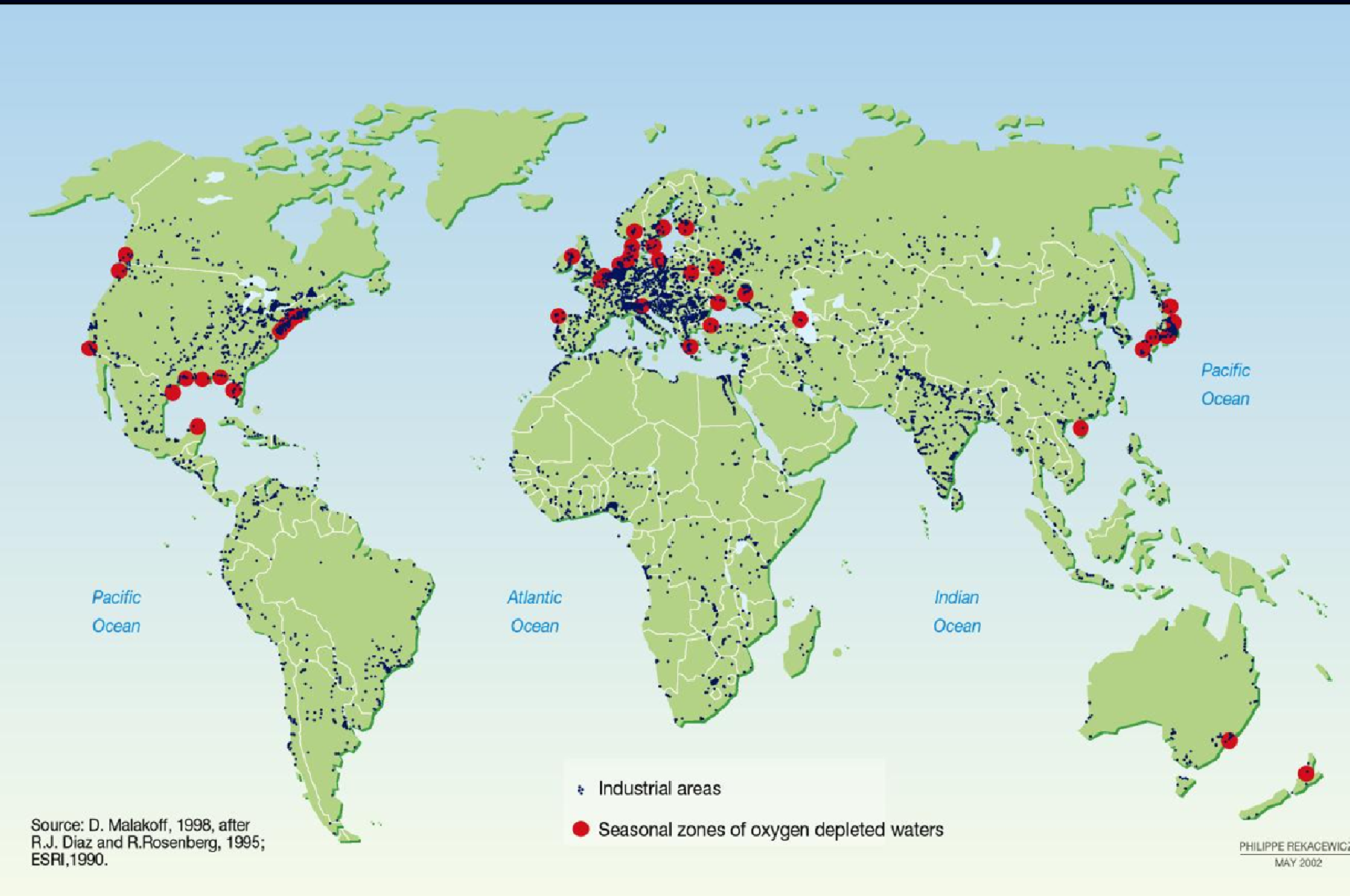
↓

Burrowing mayfly 'abundance'

Once determined for Lake Erie, we believe target goals for mayflies will be useful elsewhere including…




LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO


Pacific
Ocean
Atlantic
Ocean
Indian
Ocean
Pacific
Ocean
Industrial areas
Seasonal zones of oxygen depleted waters
Source: D. Malakoff, 1998, after
R.J. Diaz and R.Rosenberg, 1995;
ESRI,1990.
PHILIPPE REKACEWICZ
MAY 2002